Program Book

UltrafastX

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and 3rd Youth Forum on Ultrafast Science

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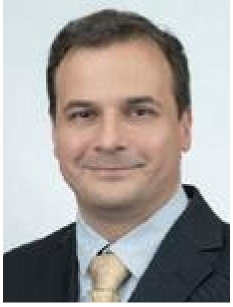
Ultrafast electron probing of plasmons and plasmon probing of electrons

Péter Dombi
Wigner Research Centre for Physics and ELI-ALPS

I will review recent research results that we achieved in the fields of ultrafast plasmonics as well as probing of the dynamics of plasmonic photoelectrons and hot electrons in various media. We recently demonstrated nonadiabatic tunneling of photoelectrons from plasmonic nanoparticles for Keldysh-gamma values between 1.3 and 2.2 [1]. With the help of ultrashort plasmonic wavepackets, we could also probe interband and intraband transitions in gold and establish hot electron population dynamics with unprecedented interface selectivity [2]. In addition, we also demonstrated that hot electron probing is possible with ellipsometry in a 46 nm thin surface layer [3]. Finally, I will also present a very recently developed optical chip device with which we could perform 3D carrier-envelope phase scanning and phase sculpting of focused femtosecond laser beams [4].



Péter Dombi acquired his MSc in Physics at the University of Szeged in Hungary in 2001 and his PhD at the Vienna University of Technology in Austria in 2005. He is currently research group leader at the Wigner Research Centre for Physics in Budapest and the founding head of the Ultrafast Science and Applications Division of the ELI-ALPS laser facility. With his research background in ultrafast science and laser physics, he has demonstrated several breakthrough results in carrier-envelope phase-controlled interactions, ultrafast plasmonics and femtosecond oscillator technology. He has authored or co-authored 82 peer-reviewed journal papers including several ones in Nano Lett., Nature Comm., Optica, Phys. Rev. Lett. etc. He has been supervising 11 PhD students, 6 of whom with completed degrees. He has been acting as PI in several national and international research grants and project networks.

Development and application of ultrafast light sources at SECIUF

Zhiyi Wei[1,2,3], Hao Teng[1], Shiyaqng Zhong[1] and Bingbing Wang[1]

1Beijing National Research Center for Condensed Matter Physics, and Institute of Physics, Chinese Academy of Sciences

2University of Chinese Academy of Sciences

3Songshan Lake Materials Laboratory

An ultrafast light facility with femtosecond laser, attosecond laser, ultrafast X-ray and diffraction electrons was established at Beijing in recent year, which is one of three major parts of the Synergetic Extreme Condition User Facility (SECUF). Integrated with equipments such as eTOF, ARPES, PEEM, STM and COLTRIMS etc, it supplies an advanced platform to study the fundamental dynamics processes in physics, chemistry, biology, and material sciences with ultrafast temporal resolutions on the molecule and atomic scale. Few laser pulses with 10mJ energy and ultrahigh peak power up to 1PW were realized. In particular, to explore electron motion, isolated attosecond pulse (IAPs) with pulse duration shorter than 87as are generated. The characterization of the temporal profile was analyzed by using Frequency Resolved Optical Gating for complete reconstruction of attosecond bursts technique (FROG-CRAB). In this prestation, we will introduce the main functions and specifications of the facility, which has been opened for international scholars for carry out the applied research, some new progresses and results will also reported.

Zhiyi Wei obtained Ph.D in 1991 at Xi' an Institute of Optics and Precision Mechanics. He joined in the Institute of Physics, Chinese Academy of Sciences since 1997 and was prompted as full professor in 1999. His research focus on the ultrafast laser technologies. Up to now, he published more than 400 peer review papers, reported more than 80 invited talks at international conferences. For his contributions, he won the National Science Fund for Outstanding Young Scholars in 2002 and elected as Optica Fellow in 2017 and Chinese Optical Society (COS) fellow in 2020 respectively.

Strong-field ultrafast optics and precision measurement of transient processes

Peixiang Lu[1,2*]

1Wuhan National Laboratory for Optoelectronics and School of Physics, Huazhong University of Science and Technology
2Optics Valley Laboratory

The emergence of ultrafast lasers have provided powerful tools for studying the dynamics of matter under extreme conditions, with significant applications in physics, chemistry, biology, and other fields. At the end of the last century, with the development of femtosecond ultrafast laser technology, femtosecond time-resolved ultrafast detection techniques revealed the nature of processes such as chemical reactions at the atomic and molecular levels. This opened up a series of new interdisciplinary frontiers, with femtosecond chemistry as a representative example. However, for the even faster timescales of atomic and molecular internal electron dynamics (attosecond scale), traditional femtosecond detection techniques are no longer sufficient. Achieving such high resolution has always been an important topic in the field of ultrafast science. The generation of attosecond pulse sources will provide powerful tools for attosecond time-resolved ultrafast dynamic detection. We will introduce the generation and manipulation methods of attosecond pulses based on high harmonic generation, as well as our application research on ultrafast process detection based on attosecond sources. In addition, we will also introduce our works of achieving high spatial-temporal precision measurement of ultrafast processes in atoms, molecules and solid materials using intense ultrafast laser fields. This includes a focus on the application of techniques such as high harmonic spectroscopy, strong-field photoelectron holography, and other ultrafast spectroscopic technologies.

TBD

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Amplification of a single-cycle pulse

Eiji J. Takahashi
Extreme Laser Science Laboratory

We propose a novel scheme called advanced dual-chirped optical parametric amplification that employs two kinds of nonlinear crystals to overcome the bottleneck of pulse energy scalability for single-cycle mid-infrared laser pulses.

Eiji J. Takahashi is currently a team leader of Ultrafast Coherent Soft X-ray Photonics Research Team, RAP, RIKEN, and is a chief scientist of Extreme Laser Science Laboratory, CPR, RIKEN. His research interests include high-intensity laser-matter interactions, attosecond science, and high-power laser technology.

Generation and Control of Sub-cycle Optical Vortex Pulses

Yu-Chieh Lin, Yasuo Nabekawa, Katsumi Midorikawa
RIKEN Center for Advanced Photonics

Intense few-cycle optical vortex (OV) sources are highly promising in strong-field applications such as high order-harmonic generation, filamentation, and supercontinuum. The generation of such laser pulses is owing to the progress of the ultrafast amplifier technologies combined with achromatic methods for OV generation. Here, we report on the realization of a carrier-envelope phase (CEP) controllable, over-octave bandwidth OV source with a wavelength range of 0.9-2.4 μm and a pulse duration of 4.7 fs, corresponding to 0.9 cycles at the carrier wavelength of 1.54 μm. We employ this light source to demonstrate the arbitrary CEP control for the manipulation of the spatiotemporal properties of sub-cycle OV pulses.

Katsumi Midorikawa received Ph. D degree from the Graduate School of Engineering, Keio University, Japan, in 1983. He joined Laser Science Research Group in RIKEN in 1983 and became a Chief Scientist of Laser Technology Laboratory in 1997. He is currently Director of RIKEN Center for Advanced Photonics and a leader of Attosecond Science Research Team. His research interests include ultrafast intense lasers, nonlinear optics and their applications to ultrafast phenomena, laser microprocessing, and multiphoton spectroscopy. He recently focuses his research on attosecond pulse generation and metrology. He is a Fellow of IEEE, Optical Society of America, American Physical Society, Japan Society of Applied Physics, and the Laser Society of Japan. He also received the Chang Jiang Scholar Award in 2007.

Strong field quantum optics probed in attoseconds

Zengxiu Zhao
National University of Defense Technology

Strong field excitation/ionization has been long considered the other extreme of light-matter interaction, in contrast to resonant excitation by weak continuous light used in quantum optics. In this talk, I will focus on the bridging of the two extremes and demonstrate that their interplay plays a critical role in strong field quantum optics due to the multiple dimensional freedom of ultrafast dynamics such as electronic, vibration, rotation and spin-orbit coupling. I will briefly introduce our recent achievement on the generation of isolated attosecond pulse with 51 as duration and then emphasize on the attosecond probing of the ionic population dynamics, the evolution of quantum coherence and the resulted coherent emission with all of which involves of the quantum optics behaviors of atoms and molecules in strong laser fields.

Professor Zengxiu Zhao obtained Ph. D degree from Kansas State University, US, in 2005. After postdoctoral study in the University of Ottawa from, he joined the faculty of NUDT. He was appointed as full professor in December, 2008. Dr. Zhao has published more than 100 refereed papers (including 10 publications in Physical Review Letters) which have been cited more than 2500 times.

High harmonic generation driven by quantum light

Oren Cohen
Department of physics

I will present theoretical and experimental investigations on high harmonic generation and ultrafast electronic motion driven by quantum light [1-3]. Topics include: i) Generalization of the pondermotive potential and electronic Volkov state to quantum light ii) quantum strong field approximation iii) Generation of squeezed high-order harmonics iii) and iv) photon correlation force.

TBD

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Ultrafast dynamics of microcavity exciton-polariton condensation at room temperature

Hui Li1, Fei Chen2, Hang Zhou2, Junhui Cao3, Song Luo2, Zheng Sun1, Zhe Zhang2, Ziqiu Shao3, Beier Zhou4, Hongxing Dong4, Alexey Kavokin3, Tim Byrnes5, Zhanghai Chen2, and Jian Wu1

1State Key Laboratory of Precision Spectroscopy, East China Normal University
2Department of Physics, College of Physical Science and Technology
3School of Science, Westlake University
4Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences
5Division of Arts and Sciences, New York University Shanghai

In semiconductor microcavities, the strong coupling between photons and excitons can form quasi-particles exhibiting part-light part-matter characteristics, named exciton polaritons (EPs). These quasiparticles are bosons and can achieve Bose-Einstein condensation (BEC) at high temperature due to their small effective mass (~10-4 me). On the other hand, the excitonic components provide EPs with large nonlinearity. EPs have shown variety of intriguing properties and broad application prospects in the fields of information processing and quantum communication. In material systems such as ZnO and perovskites, EPs can form condensation even at room temperature, providing novel platform for practical applications. However, the ultrafast dynamics of EP condensation at ambient condition is still largely unexplored. To address this problem, we have developed a femtosecond angle-resolved spectroscopic imaging technique, which enables multidimensional, time-resolved measurements of photoluminescence with femtosecond resolution. We have systematically investigated the ultrafast dynamics of macroscopic quantum states of EP condensates, revealed the formation, relaxation and parametric scattering dynamics of the condensates under non-resonant excitation [1-3] and observed the bosonic cascading dynamics in EPs [4]. Further, we proposed a novel physical mechanism to achieve ultrafast switching in room-temperature BEC with ultra-high extinction ratio based on manipulating the parametric process of the photonic part in EPs [5]. Our work allows for revealing the novel mechanisms of room-temperature condensates and engineering of the fundamental process in condensation dynamics, which will be beneficial towards basic studies and potential applications of polariton systems.

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Advanced attosecond sources for material science

Oliviero Cannelli
ATTO-CFEL, DESY

In the past two decades, high-harmonic generation (HHG) enabled the development of attosecond extreme ultraviolet (EUV) and soft X-ray (soft-X) table top sources. Despite uninterrupted progresses in the field, preserving high HHG brightness while extending the photon energy cutoff (Ecutoff) towards higher photon energies remains an open challenge.
In this respect, conventional strategies use longer laser driver wavelengths, exploiting the λ2 dependence of the ponderomotive potential at the expense of the HHG photon flux. More recent schemes harnessed higher driving field intensities, entering in the so-called nonadiabatic regime. Under these conditions, a dense plasma is generated within the generation medium, causing a strong reshaping of the driving laser field and significant changes in the phase matching conditions that ensure coherent build up of the HHG field within the generation medium.
In this talk, I will present the development of an innovative glass cell able to confine high gas pressures (up to 5 bars) in short propagation lengths, demonstrating significant Ecutoff spectral extension with respect to conventional phase matching conditions. Specifically, we reached photon energies up to 200 eV using 800 nm laser driver in Neon, generating HHG spectra 6-8 times more intense than with 1500 nm light in Argon. These results promise great opportunities for table top ultrafast investigations, which will complement experiments so-far only possible in large scale facilities. The unprecedented temporal resolution of HHG sources in the XUV and soft-X range will enable studying the early dynamics of optoelectronic functional materials with element- and site-selectivity, with crucial implications for material science.

Oliviero Cannelli received his Ph.D. in Physics from Ecole Polytechnique Fédérale de Lausanne (EPFL) in 2021 under the supervision of Prof. Majed Chergui and Prof. Giulia Fulvia Mancini. He was Postdoctoral Researcher in LACUS (EPFL) until 2023, when he joined the ATTO group of Prof. Francesca Calegari in DESY, Hamburg, with a fellowship from the Swiss National Science Foundation. During his studies, he was granted bachelor (2011) and master (2014) scholarships upon national competitions in Italy, while in 2022 he received the best PhD thesis award in the STEM field prize from the SAIS (Switzerland). In 2023 he was awarded a Marie Skłodowska-Curie Postdoctoral Fellowship. He is co-author of 19 publications on peer-reviewed international journals and he has an h-index of 10. The main focus of his research is harnessing cutting-edge ultrafast X-ray sources, including both tabletop setups and large-scale facilities (synchrotron and free electron lasers), for the development of new investigation techniques, among which helical dichroism and temperature-jump methods in the X-ray domain, simultaneous ultrafast X-ray emission spectroscopy and X-ray diffraction, femtosecond impulsive stimulated resonant inelastic X-ray scattering, core-level transient grating spectroscopy.

Femtosecond Fieldoscopy

Hanieh Fattahi
Max Planck Institute for the Science of Light

Femtosecond Fieldoscopy is a novel metrology for detecting the electric field of light with high detection sensitivity, dynamic range, upto petahertz detection bandwidth, and high spatial resolution. These criteria offer unprecedented prospects in label-free sensing. In this talk, I present our recent results on the development of the ultrashort source required for Femtosecond Fieldoscopy, highly sensitive detection of water molecules in the gas and liquid phase, and a roadmap toward high-resolution spectro-microscopy.

Hanieh Fattahi received her PhD in Physics at Ludwig Maximilians university of Munich in 2015. She is the recipient of the Minerva fast-track scholarship of the Max Planck Society in 2016 and was elected as a member of "Schiemann Kolleg" in 2017. She has been a visiting scientist of the Chemistry department of Harvard University and Oxford University.
Since 2020, she is leading her independent research group at the Max Planck Institute for the Science of Light in Erlangen. She is also the fellow of the Max Planck center for Extreme and Quantum Photonics in Ottawa, and the Max Planck School of Photonics.
Her research focus is on i) the development of mid-infrared and near-infrared few-cycle sources, ii) the development of highly sensitive light detection metrologies, and iii) Mid-infrared, overtones, and stimulated Raman field-resolved spectro-microscopy

Attosecond Electron motion Imaging and Controlling

Dandan Hui
Xi' an Institute of Optics and Precision Mechanics

Most of the macroscopic changes involve local rearrangement of the atoms and electron density in the microcosm, which defines the fundamental mechanisms of the change. The electron wave packet dynamics in semiconductor nanostructures, molecular orbitals and the inner shells of atoms vary from tens of femtosecond to a few attoseconds. Attosecond science capitalizes on the extreme nonlinearity of strong light fields, to obtain attosecond temporal resolution and give access to the electron motion dynamics of matter in real-time. The talk will discuss the electronic response in dielectric following the strong laser field to demonstrate all-optical light field metrology with attosecond resolution and the electron motion control using synthesized light waveforms. Also, an attosecond electron imaging technique, promising orders of magnitude faster than the highest reported imaging resolution, will be discussed. It would provide more insights into the electron motion of neutral matter in real time and space and would have long-anticipated attosecond science applications in quantum physics, chemistry, and biology.

Dandan Hui is a researcher scientist at Xi' an Institute of Optics and Precision Mechanics, Chinese Academy of science, with an extensive background in attosecond electron diffraction, imaging and spectroscopy, attosecond optical pulse synthesis, and Electron optical design. She obtained her Ph.D. from University of Chinese Academy of Sciences in 2019. During her Ph.D., she studied at Argonne National Lab as a visiting scholar for two years on ultrafast electron microscope and linear accelerators. Then she worked at the University of Arizona from 2019 to 2022 focusing on attosecond electron microscopy. Dandan' s main research is to generate isolated attosecond electron pulses and achieve attosecond temporal resolution in electron microscopy, or "Attomicroscopy", with the ultimate goal of imaging electron motion in real time and space. She has synthesized and characterized isolated attosecond (half cycle) optical pulses and demonstrated electron motion imaging and control in neutral materials, which paves the way for establishing the long-anticipated ultrafast optical switches and extending the frontiers of the modern electronics and information processing technologies into petahertz realm. Her work is published in Nature Photonics, Science Advances, APL Photonics, Faraday Discussion etc.

High-flux, attosecond, extreme-ultraviolet sources for studies of ultrafast processes in solid- and gas-phase targets

Balázs Major

Extreme Light Infrastructure Attosecond Light Pulse Source (ELI ALPS) and University of Szeged

With the advancement of laser technology, connected secondary sources are also continuously being developed. High-harmonic generation (HHG) is a reliable, lab-scale source of coherent, extreme-ultraviolet (XUV) radiation with the possibility to produce attosecond pulses. With the increase of photon flux, repetition-rate or spectral coverage/tuning range, applicability of these experimental tools is extending to several fields related to ultrafast, dynamical processes in all types of matter. The High-Repetition-rate laser-driven Gas-based High-order Harmonic Generation (HR GHHG) beamlines of the Extreme Light Infrastructure Attosecond Light Pulse Source (ELI ALPS) started operating in the past years. The two beamlines – the HR GHHG Gas and the HR GHHG Condensed – now provide 100-kHz-repetition-rate, high-flux, XUV radiation. The beamline for condensed phase targets is combined with a time-compensated XUV monochromator, and cutting-edge experimental end stations are also attached to both beamlines for studying solid- and gas-phase targets. In this talk I will present recent advances in the development of attosecond sources based on HHG for different application purposes, with a focus on some recent progress and latest experiments for the two unique attosecond sources of ELI ALPS.

Balazs Major is senior research fellow at the Extreme Light Infrastructure Attosecond Light Pulse Source (ELI ALPS), leading the high repetition-rate attosources (HRAtto) group, and is assistant professor at University of Szeged. He obtained his PhD at the same university in 2017. After PhD, he joined the team of ELI ALPS, and visited several attosecond physics research groups as guest researcher, for example at Lund University, the Max Born Institute (Berlin) or Institut Lumiere Matiere (Lyon). Since early 2020 he has been leading the development, operation and research activity of two attosecond beamlines at ELI ALPS. He is a reviewer for several photonics journals, member of conference program committees, and from 2022 he chairs the Short Wavelength Sources and Attosecond/High Field Physics Technical Group of Optica for a three-year term. In 2021 he was selected as one of the Emerging Leaders of AMO Physics by the Editorial Board of IOP Journal of Physics B.

High power femtosecond solid-state lasers for driving high repetition rate HHG

Jiangfeng Zhu
Xidian University

High power femtosecond lasers have been extensively studied for driving high-order harmonic generation (HHG) and single attosecond pulse generation. Driven by the cutting-edge applications, next generation femtosecond lasers are featured by high average power and high repetition rate. Thin-disk laser, slab laser and fiber amplifier have the potential for generating femtosecond lasers with hundreds to thousands watt of average power and kHz to MHz repetition rate. But each scheme has its limitations such as long pulse duration, massive nonlinear effect, very complex setup, etc. Considering the efficiency and flexibility for high repetition rate HHG, we proposed high power high repetition rate femtosecond Yb bulk all-solid-state amplifier which has the advantages of compact and simple setup, high laser efficiency, very short pulse duration and good beam quality. At present, the regenerative amplifier can produce average power as high as 65 W, single pulse energy of 6.5 mJ, the shortest pulse duration of 132 fs and tunable repetition rate from 1 kHz to 1 MHz without readjusting the cavity parameters. 50 W/ sub-100 fs pulses directly from the regenerative amplifier and 100 W /200 fs power amplification are designed and in research progress.

Prof. Dr. Zhu received the Ph.D. degree in ultrafast optics from the Institute of Physics, Chinese Academy of Sciences, Beijing, China, in 2008. He was with the Department of Applied Physics, Hokkaido University, Sapporo, Japan, from 2008 to 2011, as a Post-Doctoral Fellow. Since 2011, he has been with the School of Optoelectronic Engineering, Xidian University, Xi’an, China. His research interests include novel ultrafast laser technology, nonlinear frequency conversion, and their applications. He has authored and co-authored more than 100 peer-reviewed papers; more than 50 contributed and invited talks at international conferences.

Controlling laser-dressed Fano line shape using attosecond extreme-ultraviolet pulse with a spectral minimum

Cheng Jin
School of Physics, Nanjing University of Science and Technology

Taking advantage of the Cooper minimum in the photo-recombination cross-section of atoms and molecules, the minimum structure can be created in their high-order harmonic generation (HHG) spectra with a phase jump, which can be used to synthesize a shaped extreme-ultraviolet (XUV) pulse with a split temporal profile. In this talk, we first show that minima are presented in the HHG spectra of aligned CO2 molecules, and resulted temporal profiles can be adjusted either by changing the degree of alignment or by varying the pump-probe angle. Using isolated shaped XUV pulses, we then study attosecond transient absorption (ATA) spectra of helium 2s2p autoionizing state which is coupled to the 2s2 dark state by a time-delayed infrared (IR) laser. We find the asymmetric Fano line shape can be tuned into symmetric Lorentzian. This is due to the significant decrease of population of 2s2p state during the pump process caused by the shaped XUV pulse.

Cheng Jin is currently a full professor at Nanjing University of Science and Technology. He received the Ph.D. degree in physics from Kansas State University, USA in 2012, and from 2012 to 2015, he worked as postdoctoral researcher in the J. R. Macdonald Laboratory at Kansas State University. He has been awarded as "Jiangsu Specially-Appointed Professor" and "Thousand Youth Talents Plan". He has chaired and participated in a number of National Natural Science Foundation of China. He has published over 80 journal articles and authored two books. His main contribution in the strong-field physics and attosecond science includes the development of macroscopic propagation model for high harmonics and the waveform synthesis method for improving harmonic efficiency. His other research interests involve the generation of isolated attosecond pulse, high harmonic generation in a hollow waveguide, macroscopic scaling of high harmonics, the generation of vortex high harmonics, and high harmonic generation in solids.

Polarization Conversion from a Radial Polarized vector laser beam to structured high order harmonics in Monolayer Transition Metal Dichalcogenide

Peng Ye[1,2,3,4]*, David Gauthier[1], Marie Froidevaux[2], Sergey Babenkov[1], Xu Liu[1], Vijay Sunuganty[1], Hamed Merdji[1,2], Willem Boutu[1]

1LIDYL, CEA, CNRS, Université Paris-Saclay

2LOA, ENSTA ParisTech, CNRS, Ecole Polytechnique

3Institute of Physics, Chinese Academy of Sciences

4Songshan Lake Material Lab

We employ a radial vector laser beam to induce the generation of high-order harmonics in a monolayer of molybdenum disulfide crystal. This cylindrical vector beam allows measuring the local response in a single measurement. Molybdenum disulfide (MoS2) functions as a polarization converter, effectively converting a radially polarized fundamental laser beam into a spatially structured polarized harmonic beam. Our findings indicate that the intensity of the 4th harmonic exhibits not only the crystal symmetry but the nature of the elements.

Objective + Methods + Results and Discussions + Conclusions

High order harmoncis generation (HHG) in gas medium was discovered more than 30 years ago [1], and HHG in bulk crystal was discovered 10 years ago [2]. From bulk crystal to monolayer, the symmetry is further broken down. Liu et al. found that both even and odd harmonics can be generated from monolayer MoS2 crystal. The intensity of the harmonics change with a period of 60 degrees by rotating the laser polarization with respect to the crystal [3]. Recently, Kobayashi et al. found that the harmonic emission from a monolayer crystal depends not only on the symmetry but also on the material nature [4].

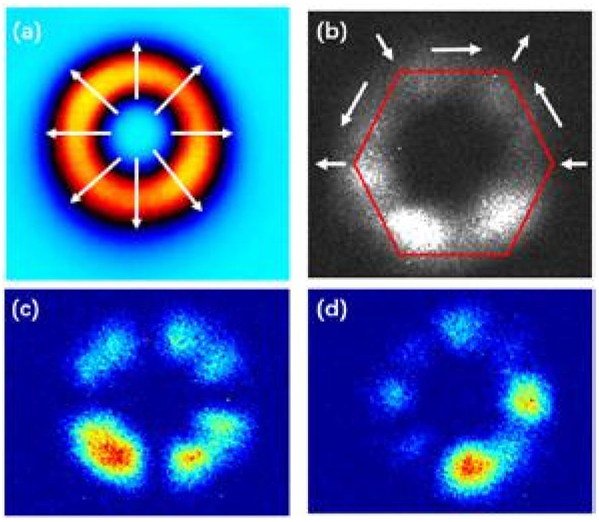


Figure 1. (a) Spatial profile of the fundamental laser at focus. The white arrows show the polarization of the radial vector laser beam. (b) Spatial profile of the 4th harmonic without a polarizer. The white arrows show the expected polarization. (c) and (d) show the spatial profiles of the 4th harmonic with a polarizer in vertical and horizontal directions, respectively.

To spatially structure the harmonic emission with respect to the laser polarization, we used a radial vector beam (1800 nm, 40 fs, 100 kHz). Figure 1 (a) shows the locally varying polarization state at the focus of the laser irradiating a MoS2 monolayer crystal in the strong field regime. From a single acquisition, one can observe all the non-perturbative polarization responses of the sample. As an example, we show the near-field spatial profile of the 4th harmonic in Figure 1 (b). In Fig.1 (c)[(d)], a polarizer with the vertical[horizontal] transmission direction was put in front of the camera. One can see the 8 maximum around a circle. The white arrows in Fig. 1(b) show the polarization variation of H4.

Our approach, utilizing a radial vector beam, enables simultaneous access to all the polarization responses exhibited by the sample, while also transform the radial vector fundamental beam into a high harmonic generation (HHG) beam with spatially structured polarization state.

Generation of 51 as Isolated Attosecond Pulses with Double Optical Gating

Fan Xiao, Jiacan Wang, Li Wang, Wenkai Tao, Jianhua Wu, Zhigang Zheng, Xiaowei Wang, Zengxiu Zhao

Department of Physics, National University of Defense Technology

In conclusion, by setting the gate width to be 2.67 fs, we generate 51 as IAPs in the energy range of 55-143 eV using CEP unstabilized 5.3 fs NIR laser pulses with the help of DOG gating technique. This work is beneficial to generation of ultra-short isolated attosecond pulse, pump-probe experiments of researching ultrafast electron dynamics, generation of below threshold harmonic and so on.

With the development of spectroscopy and need for ultra-fast time measurement in experiment, the isolated attosecond pulse has been proved to be a powerful tool for the detection of ultra-fast electron dynamics. The study of isolated attosecond pulse source is of vital importance for the development of attosecond science. Recently, few-cycle middle infrared pulses are more popular than few-cycle 800 nm near infrared pulses, because a higher cutoff and wider spectrum can be generated. However, few-cycle near infrared pulses have unique advantages, such as higher conversion efficiency and optical gating techniques are mature.

Direct sampling of ultrashort laser pulses

P. Huang[1], H. Cao[1,2], H. Yuan[1,2], Y. Fu[1,2]
1- Center for Attosecond Science and Technology, Chinese Academy of Sciences
2- University of Chinese Academy of Sciences

We propose and demonstrate an all-optical pulse sampling technique based on the third order process with perturbations (TOP-Sampling), which provides a simple and robust manner to characterize ultrashort laser pulse without employing retrieval algorithm and can be potentially applied for electric field measurement. The TOP-sampling method reduces the required intensity by more than one order compared with other all-optical sampling technologies, and it’s suitable for ultrashort pulse characterization even to the single cycle from deep-UV to far-infrared range.

Temporal characterization of ultra-short pulses is essential for the investigations of microscopic particle dynamics and generating attosecond pulses. Among various pulse characterization techniques, the methods through reconstructing the temporal profile based on measured information in the spectral domain, such as FROG, SPIDER, and D-Scan, are widely used among the ultrafast optics community. In comparison, the temporal sampling methods, which are capable to provide an ultrafast temporal “gate”, are proved to be suitable for measuring ultra-broad band laser pulses. Further-more, the temporal sampling methods are sensitive to the absolute phase of the pulses, so they can be used to measure the full electric field of pulses. For example, temporal sampling methods such as atto-second streak camera, NPS and TIPTOE, are all based on sub-femtosecond gate formed by photoionization or photoemission, which has been successfully employed to characterize ultrashort laser pulses in broad spectral ranges. Recently, the development of several all-optical sampling methods provides relatively simpler means for direct characterization of ultra-short pulses in time do-main.

In our approach [1,2], a two-orders weaker perturbation pulse perturbs the signal pulse from third order process, which is generated by another strong fundamental pulse. The modulation of the signal pulse energy directly represents the temporal pro-file of the signal pulse. We have successfully utilized third harmonic generation (THG) in ambient air and transient grating process (TGP) to characterized few-cycle and multi-cycle from visible to infrared pulses, which is consistent with the results verified by widely employed frequency re-solved optical gating (FROG) method.

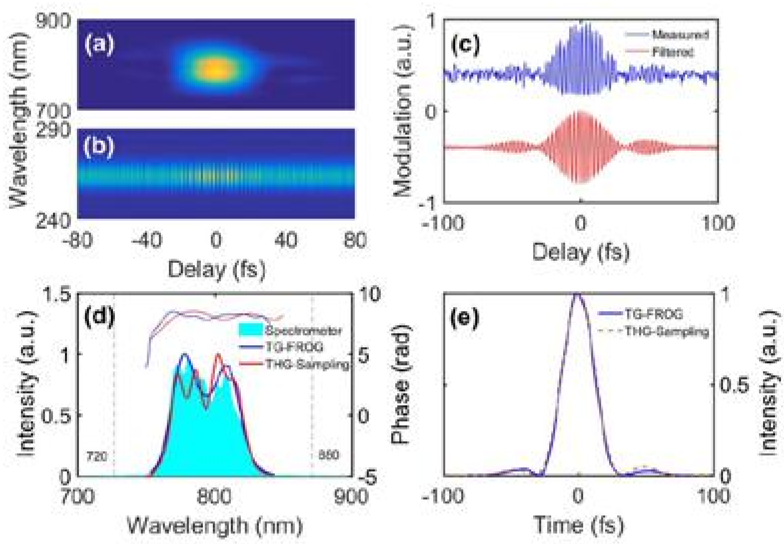


Figure 1. Comparison between TOP-Sampling and TG-FROG measurement. (a) Measured TG-FROG traces; (b) Measured delay-dependent TOG spectrum; (c) TOG intensity modulation before (blue line) and after (red line) filtering; (d) Spectrum measured by spectrometer (cyan area), spectral intensity (lower lines) and phase (upper lines) by TOG Sampling (red lines) and TG-FROG (blue lines; (e) The pulse envelope obtained by TG-FROG (blue line) and THG-Sampling (red dotted line).

High harmonic generation in solids: particle and wave perspectives

Liang Li[1*]
1Wuhan National Laboratory for Optoelectronics and School of Physics, Huazhong University of Science and Technology

The last three decades have seen the breakthrough of ultrafast science due to the generation of high-order harmonics and attosecond pulse by using a near-infrared femtosecond laser. Just after the observation of high harmonic generation (HHG), the plateau structure of the spectra, which can not be explained by traditional perturbation theory, has attracted lots of interests, and the pioneer studies eventually led to great achievements: “three-step” recollision model. An analytic model called strong field approximation (SFA) was established following the idea of “three-step” recollision. The “three-step” recollision model provides an intuitive basis for understanding the electron dynamics underlying the strong-field processes, e.g., HHG, above threshold ionization (ATI) and nonsequential double ionization (NSDI), which has stimulated advanced attosecond spectroscopy methods, e.g., high harmonic spectroscopy (HHS) and laser-induced electron diffraction (LIED), for imaging and steering the electron dynamics in attosecond timescale.

Recently, HHG has also been observed in solids, which makes it possible to extend the successful attosecond science to condensed-matter phase. To achieve this goal, an accurate understanding of the physical mechanisms underlying the solid HHG is essential. Here, we focus on the semiclassical perspectives of solid HHG which aims to decode the phase information of coherent electron dynamics and lies at the heart of HHS. We revisit the recollision picture for high-harmonic generation in solids, and show a perspective for the recently proposed Huygens-Fresnel picture.The differences and unifications between particle-like recollision picture and wave-like Huygens-Fresnel picture are clarified, and the advantages and drawbacks of the different methods are compared. The important role of the wave-like behavior of electron motion in HHG from solids has been demonstrated. Our work paves the way to realize the subfemtosecond imaging of matter using HHS in solids, and stimulates a novel paradigm for ultrafast electrodynamic processes in strong fields.

High contrast sub-10 fs pulses from cross-polarized wave generation in multiple thin BaF2 plates

Xianzhi Wang [1], Zhaohua Wang [1,2,3], Jiajun Li [1,2], Jiawen Li[1,2], Zhiyi Wei[1,2,3]

1Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences
2University of Chinese Academy of Sciences, Beijing
3 Songshan Lake Materials Laboratory

Recently, few-cycle pulses with relativistic intensities have been achievable with the development of optical parametric chirped pulse amplification (OPCPA) technology and nonlinear pulse compression, which have opened new opportunities in ultrafast science like generating relativistic high-order harmonics and intense isolated attosecond pulses from solid surfaces. For lasers at relativistic intensities and above, the temporal contrast is one of the most important parameters to avoid the undesirable effect from the pre-pules and pedestal before the interaction between the main pulse and the target. Thusly, broadband and high-contrast seed pulses are essential for few-cycle relativistic lasers.

However, with the demand for shorter pulse duration, obtaining high-contrast few-cycle seed pulses mostly requires two separate nonlinear steps for contrast improvement and pulse compression, except for nonlinear elliptical polarization rotation (NER) in hollow-core fiber and thin fused silica plates with spatial filter. Here we present high contrast sub-10 fs pulses generation by cross-polarized wave generation in multiple thin BaF2 plates, with a spectrum spanning from 570 to 960nm at the -20 dB intensity level.

The setup of proof-of-principle experiment is shown in Fig. 1, which was performed on a home-built Ti:sapphire laser with energy of 1.5 mJ and pulse duration of 38 fs at 1 kHz. There were a pair of thin film polarizers and half waveplate to attenuate the pulse energy, and an aperture to reduce the beam diameter. Then, the pulse with energy of 430 μJ was focused on the BaF2 plates by a lens (f = 2 m) and collimated by a concave mirror afterwards. At the focus position, the beam diameter is 720 μm at 1/e2 intensity, which implies a peak intensity of 2.8×1012 W/cm2. Three [011]-orientated BaF2 plates with thickness of 0.2 mm were placed after the focus, and the distance was kept close but not to form filaments in the crystal. After collimation, the cleaned pulse was filtered out by a Glan–Taylor prism and sent into diagnostic devices.

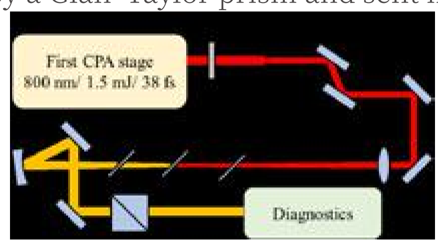


Fig. 1. Experimental setup.

The filtered spectra were as shown in Fig. 2(b), which covers 570 to 960nm at the -20 dB intensity level after three plates, supporting a transform limited pulse of 6 fs. Due to the limited bandwidth of chirped mirrors, some short wavelength part was lost after compression. The compressed pulse duration was 9.7 fs, with the driving pulse duration of 37.5 fs, implying a compression ratio of 3.9, which exceeded the spectrum broadening factor of regular XPW by far. The output energy after filtering was 112 μJ, corresponding to an efficiency of 26 %. Moreover, the temporal contrast was improved by 4 orders of magnitude before -200 ps.

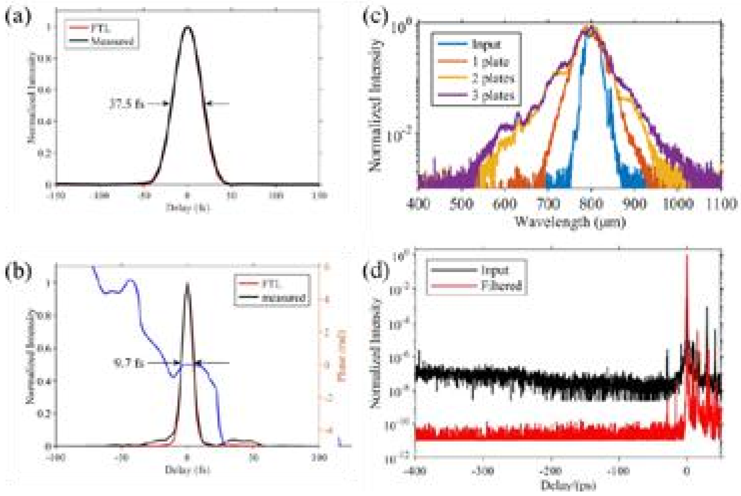


Fig. 2. Output parameters.

This method combines the temporal contrast improvement with pulse compression, which makes it very suitable to be integrated into ultra-intense laser facilities with few-cycle pulse duration.

Electro-optic 3D snapshot of laser driven kilo-ampere electron bunches

Kai Huang[1,3]*, Zhan Jin[2,3], Nobuhiko Nakanii[1,3], Tomonao Hosokai[2,3], Masaki Kando[1,3]
1 Kansai Institute for Photon Science (KPSI), National Institutes for Quantum Science and Technology (QST)
2 SANKEN, Osaka University
3 Laser Accelerator R&D, Innovative Light Sources Division

The realization of a compact X-ray free-electron laser for pump-probe applications is a popular topic in the research of laser wakefield acceleration. The 3D charge density is closely related with the 6D brightness that primarily determines the lasing process in the undulator. However, this parameter has not been experimentally measured in previous studies. We report on an electro-optic 3D snapshot of a laser wakefield electron bunch at a position outside the plasma. The 3D shape of the electron bunch was detected by simultaneously performing optic transition radiation (TR) imaging and electro-optic (EO) sampling. Detailed 3D structures were reconstructed using a genetic algorithm. The numerical investigation of the imaging of poly-chromatic transition radiation and EO spatial decoding have been carried out in details. This research is an application of the electrooptic sampling technique in the detection of transition radiation at femtosecond time scale. The experimental and numerical methodology could be used in studies of accelerators, high-power lasers, and terahertz optics.

O-FIB and beyond: Pursuing super-resolution in fs laser 3D manufacturing

Hong-Bo Sun
Tsinghua University

Femtosecond laser manufacturing is unique in three-dimensional (3D) prototyping capability, and it also may be utilized for producing fine structures from hard-processing transparent materials due to the high-field feature of a femtosecond laser. A natural question is how nanoscale fabrication accuracy may be achieved since the light- solid matter interactions are generally violent. Here we report several new findings that we prove valid to minimize interaction volume, including optical far-field induced near-field breakdown (O-FIB) effect, surface plasmon polariton imprinting effect, and combinative usage of multi-photon and threshold effect. As a result, we improve the fabrication spatial resolution of transparent solid materials from the conventional optical-diffraction limit (hundreds of nanometers) to a new limit, quantum limit, which is material dependent (several nanometers).

Hong-Bo Sun, received the B.S. and the Ph.D degrees in electronics from Jilin University, Changchun, China, in 1992 and 1996, respectively. He worked as a postdoctoral researcher in Satellite Venture Business Laboratory, the University of Tokushima, Japan, from 1996 to 2000, and then as an assistant professor in Department of Applied Physics, Osaka University, Japan. In 2004, he was promoted as a full professor (Changjiang Scholar) in Jilin University, and since 2017 he has been working in Tsinghua University, China. His research interests have been focused on laser precision manufacturing. He has published over 500 papers, which have been cited for over 30000 times, and H factor is 88, according to ISI search report. He is currently the executive editor-in-chief (EEIC) of Light: Science and Applications and Deputy editor-in-chief of PhotoniX (Both from Nature Publishing Group). He is IEEE, OSA and SPIE fellow.

Laser plasma accelerator and radiation-induced cancer vaccine

X. Q. Yan et al.
Peking University

Radiation pressure acceleration (RPA) has been proposed and extensively studied, which shows circularly polarized (CP) laser pulses can accelerate mono-energetic ion bunches in a phase-stable-acceleration (PSA) way from ultrathin foils. For appropriate parameters, CP pulses may accelerate foils as a whole with most of the transferred energy carried by ions. It is found that self-organizing proton beam can be stably accelerated to hundreds MeV in the interaction of a CP laser with a solid target at ~1022W/cm2. Recently proton beam with energies less than 10 MeV, <1% energy spread, several to tens of pC charge can be stably produced and transported in Compact LAser Plasma Accelerator (CLAPA I) at Peking University, while CLAPA II- medical laser proton accelerator (100~200MeV) is under construction in Huairou Science City in Beijing. The CLAPA beam line is an object–image point analysing system, which ensures the transmission efficiency and energy selection accuracy for proton beams with initial large divergence angle and energy spread. Primary application experiments based on laser-accelerated proton beam have also been carried out in CLAPA I, such as FLASH therapy. Presently mouse cells were FLASH irradiated (~10^9 Gy/s) at the dose of 10–40 Gy with ultra-fast laser-generated proton beam. It is found that tumor cells after radiation as vaccination in mice have an inhibitory effects on the growth of distant non-irradiated tumors, proving that this method may activate autologous anti-tumor immunity through immune system.

Yan Xueqing, distinguished professor of Boya, Peking University. He received a bachelor's degree in Engineering Physics from Tsinghua University in 1999 and a doctor's degree in particle physics and nuclear physics from Peking University in 2004. At present, he is the deputy Dean of the school of physics of Peking University, the director of Huairou laser acceleration innovation center.

In 2008, he won the German Humboldt Fellowship, in 2010, he won the National Natural Science outstanding youth fund, In 2018, he was selected into the Beijing outstanding young scientists program. In 2019, he was an outstanding lecturer at the University of California (UCI) and the Hogil Kim accelerator award in 2019 at the International Accelerator Conference. In 2020, he won the He Liang He Li science and technology progress award.

Attosecond soliton molecule dynamics and modulations

Minglie Hu
Tianjin University

The interactions of optical solitons in passively mode-locked lasers result in abundant bound states that reflect intriguing nonlinear attractor behaviors in complex dissipative systems. By adopting a balanced optical cross-correlation method with a 5zs/$\sqrt{\text{Hz}}$ temporal resolution, we derive an upper estimate of 60 as intramolecular timing jitter, which is integrated from 100 Hz to the Nyquist frequency (60 MHz). To the best of our knowledge, this is the first evidence for attosecond timing jitter within robust bound solitons in dissipative systems. Furthermore, we experimentally demonstrate the synchronization of the internal vibrations of soliton molecules through the optical injection of a master oscillator signal. Direct observation of the synchronization process is enabled by balanced optical cross-correlation detection, a technique allowing real-time detection of intramolecular separation with sub-femtosecond temporal resolution. By retrieving these universal synchronization features, the role of the soliton molecule as a nonlinear dynamical system of chief importance is further highlighted.

TBD

Minglie Hu received the B.Sc. degree in electrical engineering from the School of Precision Instruments and Optoelectronics Engineering, and the Ph.D. degree in optical engineering from Tianjin University in 2000 and 2005, respectively. He is currently a Professor at School of Precision Instruments and Optoelectronics Engineering, Tianjin University. His current research interests include mode-locking laser oscillators and amplifiers, fiber lasers, nonlinear and linear propagation in photonic crystal fibers, and THz photonics.

Three-dimensional spatiotemporal optical wave packets and phase singularities

Andy Chong
Pusan National University

The propagation of optical waves is mainly understood as separate processes of the beam (spatial) and the pulse (temporal) propagation. However, the propagation of spatiotemporal three-dimensional (3D) wave packets with unique spatial and temporal wave combinations can exhibit noble phenomena. In this talk, noble optical waves such as Airy, Bessel, and combined spatiotemporal optical waves are to be discussed. Unique phase structures such as the spatio-temporal optical vortex and the toroidal vortex will also be discussed.

Dr. Andy Chong is an associate professor of the Physics Department at the Pusan National University. He received his B.S. degrees in Physics and Mechanical Engineering from the University of Texas at Austin in 1996. After working for several industrial companies such as Corning Inc. and Samsung, he came back to academia for graduate studies. He received M.S. and Ph.D. in Applied Physics from Cornell University in 2008 for his fiber laser/amplifier works. He started the faculty position at the University of Dayton in 2011. He recently moved to the Pusan National University in 2022. His research interest is in ultrafast optics, especially in lasers, optical amplifiers, and noble three-dimensional optical wave packets.

Generation of high-energy few-cycle laser pulses via OPCPA in the midwave and longwave infrared spectral region and their applications

Uwe Griebner, Martin Bock, Lorenz von Grafenstein, Pia Fuertjes, Azize Koc, Michael Woerner, and Thomas Elsaesser
Max Born Institute

Compact optical parametric chirped pulse amplifier (OPCPA) systems generating record peak power levels around 5 µm and 11 µm wavelength are presented. Operating at 1 kHz repetition rate, the 2-µm pumped OPCPAs deliver idler pulses with 3 mJ, 80 fs at 5 µm and 65 µJ, 185 fs at 11 µm wavelength. The 5-µm OPCPA serves as driver for hard X-ray generation whereas nonlinear transmission of water is demonstrated using the 11-µm OPCPA.

Uwe Griebner received the Ph.D. degree in physics from the Technical University of Berlin, Germany in 1996. His Ph.D. research was on fiber bundle lasers with high average power. Since 1992 he has been with the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy in Berlin, Germany, working on diode-pumped solid-state lasers, fiber lasers, waveguide lasers, semiconductor lasers, ultrafast lasers and amplifiers, and digital holography. He is currently focused on high-energy few-cycle pulse generation in the midwave and longwave infrared spectral range via optical parametric amplification.

The Progress and Perspective of direct-liquid-cooled Yb:YAG thin disk laser Technology

Huabao Cao
Center for Attosecond Science and Technology
Xi’an Institute of Optics and Fine Mechanics of CAS

The amplification of high average power 1030 nm laser pulses with direct-liquid-cooled Yb:YAG thin disk laser head was experimentally demonstrated for the first time. The wavefront was measured and it showed that the wavefront distortion was small for the laser head containing two Yb:YAG thin disk while pumped with 1200 W. In our preliminary experiment, near 100 W average power was achieved with a ring regenerative amplifier based on that laser head. The results showed that the thermal issue was greatly suppressed with this approach and laser beam of fundamental mode was obtained. With optimization of the laser head and the regenerative amplifier, more than 200 W is expected in the upcoming experiment.

Huabao Cao, Research Fellow in Xi’an Institute of Optics and Fine Mechanics. He graduated from Wuhan University with bachelor degree of Physics in 2007 and received his PhD of optical engineering from Shanghai Institute of Optics and Precision Mechanics, Chinese Academy of Sciences in 2012. From August 2012 to April 2014, he worked in the Laser Technology Engineering Department of the Laser Fusion Research Center of the Chinese Academy of Physic. From May 2014 to January 2020, he worked in the ELI-ALPS located in Hungary, where he concentrated on the development of high repetition, ultra-short light sources, providing driving sources for research fields such as attosecond pulses generation. He joined the Xi’an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences in February 2020. His main research interest is high average power near-infrared/mid-infrared femtosecond laser technology.

Energy Transfer from Two-Color Femtosecond Laser Pulses to Semiconductors

Mizuki Tani, Kakeru Sasaki, Eiyu Gushiken, Daiju Horii, Hiroki Katow, Yasushi Shinohara, Kenichi L. Ishikawa
The University of Tokyo

The interaction of ultrashort intense laser pulses with semiconductor and dielectric materials has been taking significant attention from various viewpoints such as high-harmonic generation and laser material processing with suppressed heat-affected zone. In this talk, we will present our recent theoretical investigation on the optical energy absorption of crystalline silicon subject to dual-color and/or multi-pulse (two or three) femtosecond laser pulses, using the time-dependent density functional theory (TDDFT).

Kenichi L. Ishikawa received the B.Eng. and M.Eng degrees in nuclear engineering from The University of Tokyo (Japan) in 1992 and 1995, respectively, and the Ph.D. (Dr. rer. nat.) degree in physics from RWTH Aachen University (Germany) in 1998. He is currently a Professor at Department of Nuclear Engineering and Management, Graduate School of Engineering, as well as Research Institute for Photon Science and Laser Technology, The University of Tokyo. He is concurrently Guest Professor at Osaka University since 2019. He was a Postdoctoral Researcher at CEA-Saclay from 1998 to 2000, a Special Postdoctoral Researcher at RIKEN from 2000 to 2002, an Associate Professor at The University of Tokyo from 2002 to 2008, a Senior Researcher at RIKEN from 2008 to 2009, and a Project Associate Professor at The University of Tokyo from 2009 to 2014.

Generation of high-quality electron beams from a laser wakefield accelerator and its application to coherent, ultrashort X-rays

Masaki Kando
Kansai Institute for Photon Science (KPSI),
National Institutes for Quantum Science and Technology (QST)

When an intense, short-pulse laser, whose length is comparable to the plasma wavelength, is focused on to underdense plasma, a plasma electron oscillation (Langumuir wave, or plasma wave) is excited behind the laser pulse. This plasma wave is called laser wake and its static electric field is called laser wakefield. The phase velocity of the wakefield can be determined by the plasma density, and it can trap and accelerate initially energetic electrons to high energy. This acceleration process is called laser-plasma acceleration, or laser wakefield acceleration (LWFA). LWFA is currently studied actively in the world because it can provide compact, high-quality electron beams compared to conventional linear accelerators. We aim to realize a compact, X-ray free-electron laser (FEL) based on LWFA with the support of the JST MIRAI program (Creating new values that meet social and industrial needs by science and technology). As a milestone goal, we pursue to demonstrate lasing in a self-amplified spontaneous emission (SASE) regime in the extreme ultraviolet wavelength. Here, we show our recent electron beam parameters achieved in our laser electron platform LAPLACIAN in RIKEN SPring-8 Center and the latest experimental results.

Masaki Kando received the B. S. degree in Physics from Kyoto University in 1993 and Dr. of Science in Physics and Cosmology from Kyoto University in 1998. He worked at Science and Technology Agency and Japan Atomic Energy Research Institute as a postdoc during 1998-2001. He joined Kansai Institute, Japan Atomic Energy Research Institute in 2001 as a research staff. After several reorganizations of the institute, now he is a deputy director general of Kansai Institute for Photon Science, National Institutes for Quantum Science and Technology, and a visiting professor at SANKEN, Osaka University. His research interest has concentrated on the interaction of high peak power lasers with matter, especially in laser acceleration, novel radiation sources, beam physics, and high field science.

Subrelativistic laser driven attosecond electron pulse generation and coherent surface plasmon polariton amplification

Ye Tian
Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

High power surface polaritons can be used to construct on-chip information transmission, spectral detection, and compact radiation sources. In this work, we introduce the use of femtosecond laser to generate the interaction between electrons and surface plasmon (SPP), and realize the “amplification” of SPP energy. By measuring the “establishment” of SPP coherent amplification, we explain the stimulated amplification mechanism in the interaction between free electrons and SPP. The time width of the free electron is decisive to the coherence of the radiation. For example, attosecond electron pulse generation or density concentration is an important basis for realizing short-wave radiation. This work introduces the study of attosecond electron pulse generation and dynamics on solid surface under relativistic laser field. High contrast femtosecond laser pulse incident on the surface of the mirror can directly feedback its attosecond dynamic characteristics under the action of light field from the electronic image. Direct detection of attosecond dynamics of free electron pulse train is realized. The light field at this intensity detects electron dynamics at an instantaneous scanning speed of about 60μrad/as.

Ye Tian is Professor of Chinese Academy of Sciences, Shanghai Institute of Optics and Fine Mechanics. His main area of research is the ultraintense ultrafast laser interaction with plasmas, electron bunch, currently with the goal to advance table-top electron acceleration and light sources from the THz to the X-ray.

Ultrafast Research Activities in APRI

Do-Kyeong Ko
Advanced Photonics Research Institute (APRI)
Gwangju Institute of Science and Technology (GIST)

Since the Advanced Photonic Research Institute (APRI), a research institute of the Gwangju Institute of Science and Technology (GIST), was established in 2001, APRI have achieved many outstanding research outputs in the ultrafast laser science and applications including ultra-high-performance, ultrahigh-intensity laser development, proton generation, electron generation, THz photonics and spectroscopy, and others. APRI have 4.2 PW ultrafast laser research facility and have been conducted various researches, such as nonlinear spectroscopy, nano-optics, optical fiber, optical materials/devices, bio-photonics, and quantum optics. In this talk, the recent research activities and achievements of APRI will be introduced.

DO-KYEONG KO received the Ph. D. degree in Physics from Seoul National University in 1992. From 1992 to 2003 he had worked in Korea Atomic Energy Research Institute (KAERI) as a Senior/Principal Researcher. Since 2003, he has been with GIST as an Associate/Full Professor and served as the Chair of Department, and the Dean of the GIST College. He served as the Director of Natural Sciences at the National Research Foundation of Korea (2019-2021) and the President of the Optical Society of Korea (2022-2023). He is currently serving as the Director of the Advanced Photonics Research Institute (APRI) of GIST in Korea.

Ultrafast ionization and spin correlation in few electron systems.

Camilo Ruiz
EMC3 research group and Instituto Universitario de Física Fundamental y Matemáticas. Universidad de Salamanca

Ultrafast dynamics in few electrons systems are an important benchmark for the understanding how atoms interact with light. We discuss the challenges of describing the intricate interplay between ultrashort laser pulses and three-electron systems that has emerged as a compelling frontier in contemporary ultrafast science [1]. In particular, we present a universal mechanism of ultrafast 2-electron orbital swap in the 2-photon sequential double ionization of Li [2]. When this atom interacts with an XUV attosecond pulse, a 1s electron in Li can be ionized absorbing one photon trigger a correlated dynamics in the remaining ion. The other 2 bound electrons located on 2 different shells can have either parallel or antiparallel spin orientations which results in different ionization dynamics. In the antiparallel case, these 2 electrons are in the superposition of the singlet and triplet states with different energies, forming a quantum beat and giving rise to the 2-electron orbital swap with a period of several hundred attoseconds that can be observed and characterize. The swap mechanism that we have identified can be used to manipulate the spin polarization of photoelectron pairs. Pump-probe attosecond experiments can be designed to control spin-resolved multielectron ultrafast dynamics opening new routes to study correlation in these three electron systems.

TBD

Camilo Ruiz is a professor at the Salamanca University in Spain. He is part of the Instituto Universitario de Física Fundamental y Matemáticas and PI of the EMC3 research group. His research interest are in the theoretical description of non linear ionization in correlated systems and experimental studies of Laser Driven Plasma accelerators (LDPA).

Harmonic suppression induced by three-eelctron dynamics of Li in strong lasers

Feng He
Key Laboratory for Laser Plasmas (Ministry of Education) and School of Physics and Astronomy, Collaborative Innovation Center for IFSA, Shanghai Jiao Tong University

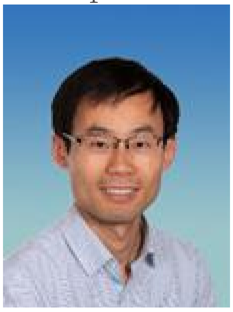
In this talk, I will present a dual investigation into correlated electron dynamics in high-order harmonic generation (HHG). Firstly, we employ all-electron ab initio simulations on three-dimensional real alkali-metal atoms to explore the dynamical electron correlation in HHG. The resulting harmonic spectra exhibit notable features, including an extended plateau beyond the typical cutoff and a prominent resonance peak above the plateau. These characteristics stem from the dramatically enhanced cation response triggered by laser-induced electron recollision, a pivotal process in attosecond science. This underscores the potential of high-order harmonic spectroscopy as a tool to delve into dynamical electron correlation in the presence of strong laser pulses. Secondly, we develop a model to elucidate high harmonic generation in combined extreme ultraviolet (EUV) and mid-infrared laser fields, incorporating spin-resolved three-electron dynamics. The EUV pulse initiates inner-shell electron ionization, while the mid-infrared laser concurrently influences photoelectron trajectories and guides electron-ion rescattering. Depending on the photoelectron spin, the residual ion, housing two bound electrons, adopts either a single spin configuration or a coherent superposition of different spin configurations. Notably, in the latter case, an intriguing phenomenon emerges wherein the two electrons in the ion swap their orbits, resulting in a distinct deep valley in the harmonic spectrum. Model results align with time-dependent Schrödinger equation simulations involving three active electrons. Importantly, the elucidated picture differs fundamentally from reported scenarios relying on spin-orbit coupling, originating instead from the exchanges asymmetry of two-electron wave functions. Together, these investigations contribute to a comprehensive understanding of the intricate interplay between electron dynamics and laser fields in the context of high harmonic generation.

Feng He, a professor at Shanghai Jiao Tong University, is a distinguished scientist in China, recognized as a National Outstanding Youth and the Chief Scientist of the National Key Research and Development Program. He completed his undergraduate studies at Beijing Normal University in 2000 and earned his Ph.D. from the Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, in 2005. After obtaining his doctorate, he conducted postdoctoral research at the Max Planck Institute in Germany and Kansas State University in the United States. He joined Shanghai Jiao Tong University in 2010. Prof. He's primary research focuses on the interaction between ultra-short laser pulses and atomic molecules. He has authored over 100 SCI papers in this field.

Vortex and vector air lasing

Yi Liu
University of Shanghai for Science and Technology

Cavity-free lasing of nitrogen ions has attracted many attentions, not only due to the rich physics involved, but also due to its unique potential to create a virtual laser source in the sky. Very recently, the concept of orbit angular momentum (OAM) was introduced into the study of nitrogen ions lasing. In this talk, I will mainly discuss our recent progress on vortex and vector lasing of nitrogen ions. We first demonstrated that a vortex seed pulse injected into the nitrogen gas plasma excited by a Gaussian pulse is amplified substantially and its OAM property can be maintained. Second, we show that a vortex superfluorescent radiation at 391.4 nm carrying the same photon orbital angular momentum as the pump beam is obtained by focusing a vortex pump beam at 800 nm on N2 gas. With the injection of a Gaussian seed beam at 391 nm, the radiation is amplified with the vorticity unchanged. Finally, we employed a pump beam with a cylindrical vector mode, the Gaussian seed beam is correspondingly amplified into a cylindrical vector beam. Surprisingly, the spatial polarization state of the amplified radiation is identical to that of the vector pump beam, independent of the Gaussian seed beam. The above results open the interesting perspective of OAM beam amplification and manipulation in the ambient air, which is of interest for free-space optical communication, remote sensing, and quantum information relay in atmosphere.



Yi Liu received his Ph. D degree from Peking University, China in 2006. He worked as a postdoctor at Ecole Polytechnique, France from 2006 to 2009. From 2009 to 2015, he was hired as a permanent researcher of French scientific research center (CNRS), in Laboratoire d’Optique Appliquée. In 2016, he became a professor of University of Shanghai for Science and Technology, China. His research interests focus on the interaction of intense femtosecond with gases, air lasing, the terahertz radiation from air plasma, strong field terahertz radiation, laser micro- and nanofabrication. He has published more than 90 peer-reviewed articles including 11 papers in Physical Review Letters and Optica, with a H-index of 30.

Measuring pure and mixed photoelectron quantum states by high-resolution ultrafast interferometer

Sizuo Luo[1,2]
1Institute of atomic and molecular physics, Jilin University
2Department of Physics, Lund University

The discovery of the photoelectric effect during the 20th century has been crucial for the development of quantum mechanics and the field of photoelectron spectroscopy. The advent of attosecond science has further improved the field through measurements of both the amplitudes and phase variations of the photoelectrons. Recently, we built an ultra-stable and versatile high-energy resolution setup for attosecond photoelectron spectroscopy [1], it provides the possibility of performing RABBIT and KRAKEN measurements [2]. Here, we demonstrate the KRAKEN protocol experimentally, where the density matrix of photoelectrons is measured by the use of a bichromatic laser field. By scanning over the pump-probe delay for different wavelength separations, $\delta\omega$, the energy-resolved oscillation amplitudes are extracted. From which the sparse density matrix is retrieved, combined with a Bayesian estimation algorithm, this allows for the full reconstruction of the continuous-variable density matrix of photoelectrons for both pure and mixed quantum states.

Professor, Institute of atomic and molecular physics, Jilin University

Line shape control in ultrafast XUV transient absorption Spectroscopy

Peng peng
ShanghaiTech University

The 2nd International Conference on UltrafastX 2023 will be held in Xi' an, the starting point of Silk Road as well as the famous ancient capital city of China, from November 16th to 19th, 2021. This conference is a frontier forum for discussing the latest developments of ultrafast science, technologies, and applications. The topics include but not limited to: attosecond science and technology, ultrafast lasers and applications, ultrafast terahertz photonics, ultrafast imaging and spectroscopy, ultrafast phenomena and dynamics, as well as ultrafast particle science, technology and application. We warmly welcome you to the conference!

TBD

TBD

Generation of the Highest Laser Intensity with Multi-PW Laser Pulses

Jin Woo Yoon[1,2], Il Woo Choi[1,2], Jae Hee Sung[1,2], Seong Ku Lee[1,2], and Chang Hee Nam[1,3]
1Center for Relativistic Laser Science, Institute for Basic Science, Gwangju
2Advanced Photonics Research Institute, Gwangju Institute of Science and Technology
3Dept. of Physics and Photon Science, Gwangju Institute of Science and Technology

One of the most important laser parameters in strong field physics experiments is a laser intensity, since it determines the laser-matter interaction regime. In recent years, ultra-high power lasers with petawatt (PW) output have been constructed in several institutes worldwide. Focused intensities of PW lasers are mostly in the range of 1019~1022 W/cm2. However, higher intensity over 1023 W/cm2 is required for studying strong-field quantum electrodynamics (QED) phenomena. In order to achieve intensity exceeding 1023 W/cm2, ultrahigh power lasers with outputs over 10 PW are under construction in a few institutes around the world. In this research, we have tried to generate ultraintense laser pulse by tight focusing and wavefront correction of the CoReLS PW laser pulse.

To generate an ultraintense laser pulse, one should focus the laser pulses to the spot as small as possible. In this work, we focused the PW laser beam with the peak power of 2.7 PW by using a small f-number (f/1.1) off-axis parabolic mirror (OAP). In addition, we used two deformable mirrors (DM) to compensate for the wavefront aberration of the PW laser beam. A small DM with 100 mm diameter and 48 electrodes, placed after the final amplifier, corrects the wavefront distortion accumulated from the front-end to the booster amplifiers. After the first DM, the beam diameter is enlarged to 280 mm by a mirror-based expander, and then laser pulses are compressed to 20 fs by the pulse compressor. To correct the additional wavefront distortion arising from the beam expander to the target chamber, another large DM with 300 mm diameter and 128 electrodes was installed after the pulse compressor. Then the wavefront-corrected laser beam is tightly focused at the target chamber by an f/1.1 OAP (300 mm effective focal length). The minimum focal spot size (FWHM) after the correction was 1.1 μm. This focal spot gives the peak intensity of 1.4×1023 W/cm2, the highest intensity ever reached. The average peak intensity for the 80 consecutive shots were 1.1×1023 W/cm2.

In this work, we achieved the record-breaking laser intensity of 1023 W/cm2. The PW laser with the level of 1023 W/cm2 will enable us to study strong-field QED phenomena, such as the nonlinear Compton scattering and the nonlinear Briet-Wheeler processes.

Jin Woo Yoon is a principal research scientist in Advanced Photonics Research Institute(APRI) at Gwangju Institute of Science and Technology(GIST) and a research fellow in Center for Relativistic Laser Science at Institute for Basic Science(IBS). He received his Ph.D. in physics from KAIST in 2009. His research interests include ultra-high intensity lasers, high power lasers, and Mid-IR lasers.

3-GHz Kerr-lens mode-locked Yb:KGW laser

Haijing Mai [1], Li Zheng [2], Hanze Bai [1,] Quanming Li [1], Wenlong Tian [2], Jiangfeng Zhu [2], [*], Zhiyi Wei [3,4,5], and HongwenXuan [1,5], [*]

1GBA branch of Aerospace Information Research Institute, Chinese Academy of Sciences
2School of Physics and Optoelectronic Engineering
3Institute of Physics, Chinese Academy of Sciences
4Songshan Lake Materials Laboratory
5University of Chinese Academy of Sciences

Dual-comb is currently a useful apparatus in ranging, terahertz time-domain spectroscopy etc. by use of the asynchronous sampling method. Single-cavity dual-output laser is a promising solution of the dual-comb laser source in terms of making the dual-comb system to be compactness.

The laser diode (LD)-pumped Yb:KGW Kerr-lens-mode-locked(KLM) oscillator could achieve bidirectional mode-locked operation with the bow-tie ring cavity scheme.

By laser cavity and dispersion designing, we achieve a 3-GHz repetition rate, Yb:KGW KLM oscillator which could be switchable between bidirectional and unidirectional status by careful alignment of one cavity mirror. In the unidirectional mode-locking status, the average output power was 250 mW, the optical-to-optical efficiency was more than 25%, and the pulse duration was ~240 fs. Switching to the bidirectional operation, the average output power is both 128 mW for two outputs, and the pulse duration is 265 fs and 260 fs pulse, respectively.

Due to the asymmetrical Kerr nonlinearity, the repetition rate difference of bidirectional operation is at ~kHz level, making this laser applicable for single-cavity dual-comb.

In conclusion, a high-repetition rate of 3-GHz mode-locked Yb:KGW oscillator was reported. The mode-locked operation status could be switchable between bidirectional and unidirectional. The pulse duration is about ~260 fs(bidirectional)/~240 fs(unidirectional). It is a potential solution for high-repetition rate dual-comb application when it is at bidirectional mode-locked operation.

Towards a space-qualified Kerr-lens mode-locked femtosecond laser within a 40-mL volume

Feng Ye, Zhang Tong, Wang YiShan
Xi' an Institute of Optics and Precision Mechanics, CAS

Due to the advantage of high-frequency phase noise, under the control of a phase-locked loop, femtosecond lasers produce precision comb-shaped spectrum, known as optical frequency combs. The stability of the comb teeth allows femtosecond lasers to be applied in precision metrology, such as ranging and spectroscopy, while the tunability of the repetition rate makes the femtosecond lasers ideal voltage-controlled oscillator to the microwave photonics and optical clocks. However, some drawbacks limit the application of traditional lasers in aerospace fields. Fiber lasers are very sensitive to gamma radiation, while solid-state lasers suffer from high power consumption and thermal drift.

Ytterbium-doped sesquioxide ceramics, which have high nonlinear refractive index, are ideal gain media for low-power operated Kerr-lens mode-locked laser. A 2.4-GHz Kerr-lens mode-locked laser was built within 40-mL volume base on the Yb: Y2O3 ceramic. Then, we observed a center wavelength of 1076 nm, a spectrum exceeding 8 nm (full-width half-maximum), and a timing jitter of 13 fs (100 Hz to 10 MHz). When it is free running, the repetition rate drifts can reach ~10-7/hr. Most importantly, the laser only requires a 1 W pump source to drive, completely getting rid of high-power pumping and water cooling.

High-Performance Ultrafast Thin Disk Laser

Xing Liu1*, Qitao Lv2, Shuangchen Ruan1*
1.Shenzhen Technology University, China; 2.Han’s Laser Technology Industry Group, China

High-repetition-rate and high-power lasers hold a crucial and prominent role in the domain of ultrafast research, presenting exceptional and pioneering capabilities. Their profound impact is evident in a variety of fields, particularly in spectroscopy, materials processing, and laser micromachining.

We present an available approach to efficient and high-power ultrafast amplification through a custom-designed 48-passes Yb:YAG thin-disk regenerative amplifier pumped by a zero-phonon line (ZPL) 969 nm laser diode (LD). Our experimental results showcase impressive performance, with the amplifier delivering an output power exceeding 154 W. Exceptional thermal management on the thin disk is demonstrated through high-quality bonding, efficient heat dissipation and fully locked spectrum, resulting in a remarkable optical-to-optical efficiency of 61% and a near-diffraction-limit beam with an M2 factor of 1.06. To the best of our knowledge, this represents the highest conversion efficiency in ultrafast thin-disk regenerative amplifiers reported in detail. Furthermore, our amplifier operates at room temperature and exhibits exceptional stability at a repetition rate of 1 MHz, with RMS stability of less than 0.33%. This study significantly advances the field of laser amplification systems, particularly in terms of efficiency and power. The demonstrated Yb:YAG thin-disk regenerative amplifier holds great promise for a wide range of applications, including materials processing, scientific research, and laser manufacturing, where high-power and efficient laser sources are paramount. This improvement contributes significantly to the advancement of ultrafast laser technology, paving the way for numerous practical and scientific innovations.

Track 3- Ultrafast Terahertz Photonics

Stimulated terahertz emission from molecular crystalline and phase-changing media

Alexander Shkurinov
Lomonosov Moscow State University
Tomsk State University

The growth in the number of methods and devises for generation terahertz (THz) radiation and improvement of their performance are essential for the progress of THz science and technology. In the recent years THz radiation below 3 THz realized with a reasonably high efficiency in the range of widegap solid crystals like GUHP, under the irradiation of femtosecond near-IR laser pulses. Typical for such sources is a single-cycle THz splash at the very beginning of generated pulse, and the prolonged oscillation radiation, the frequency of which corresponds to the frequency of a Raman active mode(s) in the samples. While the splash accounted for in terms of the optical rectification of pump radiation, the prolonged oscillation attributed to the dipole emission by coherent phonons generated in an optically transparent solid medium when a sufficiently short laser pulse passes through the phenomenon was called the impulsive stimulated Raman scattering (ISRS)). Their THz radiation is possible because the correspondent phonon modes are both Raman and infrared active.

The present talk studies narrow-band terahertz (THz) emission stimulated by femtosecond laser pulse in molecular crystal guanylurea hydrogen phosphite (GUHP). We demonstrate that this emission is closely connected with the excitement of high-quality phonon oscillations in the crystal, which is proved by the temperature dynamics of the spectra and DFT calculations. For the purposes of studying the origin of this stimulated THz emission and creation of the adequate model of the phenomenon, we analyzed the polarization sensitive spectra of spontaneous Raman scattering and THz transmission spectra while considering their polarization features in relation to crystallographic axes of GUHP crystal. In this paper we show that molecular crystals provide an effective means to convert vis-NIR laser light regardless of wavelength into the THz frequency range. This approach can lead to the creation of "laser-like" source with the desired THz frequency for a range of medical, scientific, and technological applications.

Alexander Shkurinov in 1985 graduated with honours from the M.V. Lomonosov Moscow State University (MSU), Moscow, Russia. He received his Ph.D. degree in Physics from MSU in 1988. Since 2004 he is a full-time Professor at the Department of Physics of the MSU where he is Head of the Laboratory of terahertz optoelectronics. The research interests of Alexander Shkurinov are mainly centered around the development and application of femtosecond laser techniques, time-resolved spectroscopy of molecules in liquid phase, nonlinear optics and THz techniques and spectroscopy. The results obtained by Alexander Shkurinov have been published in more than 350 scientific papers in peer-reviewed journals.

Terahertz emission based on ultrafast opto-spintronics

Zuanming Jin
Terahertz Technology Innovation Research Institute, Terahertz Spectrum and Imaging Technology Cooperative Innovation Center, Shanghai Key Lab of Modern Optical System, University of Shanghai for Science and Technology

Terahertz radiation falls between infrared and microwave radiation in the electromagnetic spectrum and can be used for a different types of material characterization. As the core part towards the development of terahertz science and technology, terahertz emitters can still not realize their wide application due to the huge size, complicated system, expensive materials, and optical field parameters that can be only tuned in a limited range. We paid great efforts to solve the above-mentioned problems related to terahertz emitters based on ultrafast opto-spintronics, and obtained the following innovative results.

First, a non-contact accurate measurement of spin-dependent densities and momentum scattering time on the sub-picosecond timescale is realized to solve the problem that the fundamentals of magneto-transport cannot be measured. Second, by demonstrating and using ultrafast demagnetization effect, anomalous Nernst effect, and inverse spin Hall effect, the all-optical ultrafast manipulation of spins on sub-picosecond timescale is realized and further used to generate broadband terahertz radiation. Third, based on the above achievements, a cascaded ferromagnetic multilayer heterojunction with large size is adopted to realize a strong terahertz emitter with low cost, nanometer thickness, and flexible control of its optical field parameters.

Zuanming Jin is an associate professor at the University of Shanghai for Science and Technology. He obtained his PhD degree in 2013 from Shanghai University. Supported by the Max Planck Society, he joined Prof. Mischa Bonn and Prof. Dmitry Turchinovich’s group at the Max Planck Institute for Polymer Research as a visiting student in 2012 for one year, and subsequently continued as a postdoctoral scientist for two years. From 2015 to 2019, Zuanming Jin served as an associate professor at Shanghai University, and in 2019 he became an associate professor at the University of Shanghai for Science and Technology.

Zuanming Jin has published more than 40 papers (as the first or the corresponding author) in international scientific journals, including Nature Physics, Light: Science &Applications, etc. He is also in charge of the National Natural Science Foundation of China (both the general, youth, and outstanding youth foundation programs) and the basic strengthening plan project of the Science and Technology Commission of the CMC. He was selected as Shanghai Rising-Star Program by the Science and Technology Commission of Shanghai Municipality, Young Eastern Scholar and Chen Guang Project by Shanghai Municipal Education Commission etc.

Temporal loss boundary engineered terahertz metamaterials

Longqing Cong
Southern University of Science and Technology

Losses are ubiquitous and unavoidable in nature inhibiting the performance of most optical processes. Manipulating losses to adjust the dissipation of photons is analogous to braking a running car that is as important as populating photons via a gain medium. Here, we introduce the transient loss boundary into a photon populated cavity that functions as a ‘photon brake’ and probe photon dynamics by engineering the ‘brake timing’ and ‘brake strength’. Coupled cavity photons can be distinguished by stripping one photonic mode through controlling the loss boundary, which enables the transition from a coupled to an uncoupled state. We interpret the transient boundary as a perturbation by considering both real and imaginary parts of permittivity, and the dynamic process is modeled with a temporal two-dipole oscillator: one with the natural resonant polarization and the other with a frequency-shift polarization. The model unravels the underlying mechanism of concomitant coherent spectral oscillations and generation of tone-tuning cavity photons in the braking process. By synthesizing the temporal loss boundary into a photon populated cavity, a plethora of interesting phenomena and applications are envisioned such as the observation of quantum squeezed states, low-loss nonreciprocal waveguides and ultrafast beam scanning devices.

Longqing Cong, Associate Professor and National Distinguished Youth Expert at SUSTech. His research interests are terahertz photonics and metamaterials for applications in sensing, imaging, and communications. He has published over 50 peer reviewed papers with more than 5400 citations, and h index 36. He serves as a long-term reviewer for scientific journals, e.g., Science Advances, Advanced Materials, Light: Science and Applications, and in the editorial board for Science journal Ultrafast Science and Chinese Laser Press. He was awarded the gold medal of “MRS Singapore best PhD thesis”, Best Young Scientist award by IEEE Photonics Society, IEEE senior member, and WuSi Medal by Shenzhen government.

Ultrafast Molecular Dynamics of Liquids Revealed by Terahertz Techniques

Liangliang Zhang
Department of Physics, Capital Normal University

Terahertz (THz) wave generation and detection using liquids has long been considered impossible due to the high absorption shown in polar liquids at THz range, especially liquid water. Specifically, liquids have a comparable material density to that of solids, meaning that laser pulses over a certain area will interact with three orders more molecules than an equivalent cross-section of gases. In contrast with solids, the fluidity of liquid allows each laser pulse to interact with a fresh area of the target. Therefore, material damage threshold is not an issue even with high repetition rate laser pulses. This makes liquids very promising candidates for the study of high energy density plasma, ultrafast dynamics of ionized particles in the process of laser-matter interaction. We explore the potential of liquid water as efficient scheme of table-top THz generator and detector. Further underlying physical mechanism, such as the ultrafast electron migration and solvation need to be considered. The complex molecular motions of water in the THz range has also been successfully identified by the THz Kerr effect technique on the sub-picosecond time scale.

Liang-liang Zhang is currently a full professor at the Department of Physics, Capital Normal University, Beijing, China. She received her Ph.D. degree from Beijing Institute of Technology in 2008. Her research interests include strong terahertz aqueous and air photonics, terahertz spectroscopy and imaging. She has published over 100 papers in scientific journals, including the top journals such as Physical Review Letters and Light: Science and Applications. She possesses 26 granted Chinese patents. She won the award of National Excellent Doctoral Dissertation of China and the First Prize of Scientific Research Excellence Award from the Chinese Ministry of Education. She took charge of sixteen research projects, including the National Key Scientific Instrument and Equipment Development Project of China, Beijing Science Foundation for Distinguished Young Scholars and National Natural Science Fund of China. She is now a topical editor for Journal of the Optical Society of America B (JOSA B).

Ultrafast carrier dynamics in film solar cells revealed by terahertz spectroscopy

Juan Du
School of Physics and Optoelectronic Engineering, Hangzhou Institute for Advanced Study, University of Chinese Academy of Sciences

The ultrafast photoelectric conversion processes in solar cells are considered crucial for guiding the structural design, composition synthesis, and growth orientation design of the solar cells. Here, the modulation of the hot carrier extraction, carrier transportation and the strong coupling between the carriers and the lattice in solar cells are investigated by the time resolved terahertz spectroscopy. The hot electron extraction process in ~2ps has been found to suppress the carrier trapping process in Sb2Se3 solar cells.[1] It is revealed by the terahertz spectroscopy that when the perovskite composition of (FAPbI3)0.85(MAPbBr3)0.15 was changed to (FAPbI3)0.95(MAPbI3)0.05, the polaron mobility can be enhanced by 30% from 8-15 to 10-18 cm2V-ls-l.[2] Additionally, we have developed terahertz emission spectroscopy and observed terahertz radiation from the photocurrent in (FAPbI3)x(MAPbI3)y films. A non-harmonic coupling model is employed to interpretated the observed two different polaron modes in LIP, which could open new pathways for studying exciton transport in solar cells [3].

Professor Juan Du has conducted to the development of micro-nano laser devices, ultrafast transient spectroscopy, and time domain terahertz spectroscopy. In recent years, she has published over 50 high-quality SCI papers, including in journals such as Nature Communications, Advanced Materials, ACS Nano, ACS Energy Letters, Nano Energy, Advanced Science, Small, Journal of Energy Chemistry, etc. Her papers have accumulated over 5000 citations, with individual articles receiving more than 370 citations. Several of her papers have been selected as ESI Hot Papers, Highly Cited Papers, Best Papers of the Year, and featured on the covers of journals. Furthermore, professor Juan Du have served as the Deputy Secretary-General of the Laser Technical Committee of the Chinese Optical Society, executive member of the Zhejiang Optical Society, and serve as young editorial board member of Frontiers of Physics and Chinese Journal of Luminescence.

Spatial characteristics of air lasing inside femtosecond laser filaments

Weiwei Liu
Institute of Modern Optics, Nankai University

Remote air lasing induced by femtosecond laser filamentation is expected as an effective way to produce a characteristic emission with high energy conversion efficiency and high signal to noise ratio. In practice, spatial intensity profile of air lasing plays a significant role in signal collection of remote sensing technology and also has arouse great interests. In this work, Spatial characteristics of air lasing inside femtosecond laser filaments has been studied. Non-uniform azimuthal distribution of N2+ fluorescence emitted from the femtosecond laser filament in air was discovered. Besides, our numerical simulation results show that Kerr effect plays a significant role in the spatial distributions and the far field divergence angles of air laser. The energy and far field divergence angle of air laser are strongly dependent on the external focus and the incident pump laser energy.

Prof. Liu received his Ph. D degree in 2005 from Université Laval, Canada, and jointed Nankai University in 2007 as a full professor. His research interest focuses on the ultrafast laser optics and THz Photonics. He has already published more than 250 scientific papers in peer-reviewed journals, and H-index reaches 52 (Google scholar). Prof. Liu has given more than 100 invited talks in international conferences worldwide. Now, he is serving as the Optica fellow, topic editor of Optics Letters, the director of Institute of Modern Optics, member of the standing committee of Chinese Optical Society et. al.

On-chip nonlinear photonics for terahertz applications

Ileana-Cristina Benea-Chelmus
EPFL

Advantage of Pulse Front Tilting in Organic Crystal Based THz Sources

Gyula Polónyi[1,2,3], György Tóth[2], János Hebling[1,2,3]
1HUN-REN–PTE High-Field THz Research Group
2University of Pécs, Physics Department
3University of Pécs, Szentágothai Research Centre

In the last 20 years the success of tilted pulse front pumping (TPFP) technique enormously increased the available THz pulse energies and conversion efficiencies in inorganic materials. The conversion efficiency was increased by 5 orders of magnitude in lithium niobate (LN) [1,2] and by 2.5 orders of magnitude in semiconductors [3,4]. The highest THz pulse energy was achieved by a LN crystal in TPFP geometry [2].
Organic crystals are well proven terahertz sources with high conversion efficiencies (> 1%), and peak electric fields (~MV/cm) [5] in the 0.1 – 10 THz frequency range. However, they require special pumping wavelengths in the near infrared to achieve these parameters, which are determined by the phase matching condition. Their two major limitations are the need for special wavelength pumping and the low damage threshold.
We recently proposed to overcome these restrains by applying TPFP to organic materials, with which we can achieve phase matching in a much wider wavelength range allowing to select a pumping wavelength with smaller absorption (optical or multi photon) enabling even higher conversion efficiencies, broader spectral range and higher damage threshold [6].
Methods
Schneider et al. defined a generation length (Lgen) that may serve as figure of merit as a function of THz frequency and optical wavelength and which leads to an approximately good expectation of the resulting THz spectrum [7], if the pumping parameters are also considered:

where is the THz frequency, is the wavelength, z is the crystal thickness, and are the absorption coefficients in THz and optical ranges respectively, and is the coherence length, which is defined as , which determines the phase matching, where c is the speed of light, is the refractive index in THz range and is the optical group index. By applying TPFP the phase matching can be extended for longer pumping wavelengths allowing lower absorptions (hence increased damage threshold) and better conversion efficiencies. This can be modelled by introducing the pulse front tilt angle , and changing to to analyze the effect of TPFP on the generated spectrum.

Results and Discussions

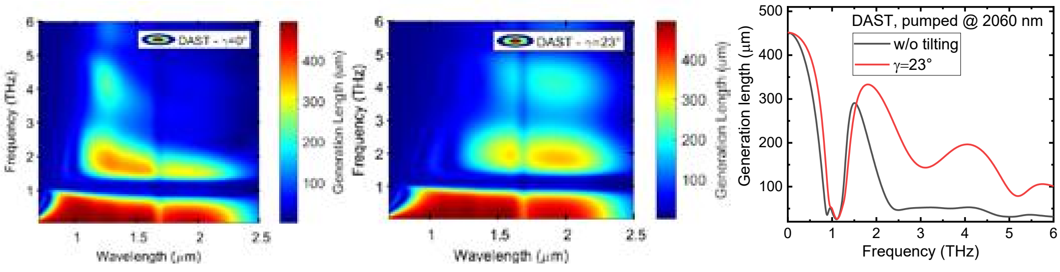


Fig. 1 – Generation length of DAST as a function of THz frequency and pumping wavelength without (a) and with pulse front tilt (b,c).

Fig. 1 presents the effect of TPFP on generation length in DAST crystal. Although at 2 m pumping wavelength the two-photon absorption can be avoided, but without TPFP the phase matching is lost resulting in a narrowed spectrum [5]. However, a broader spectrum can be restored if TPFP is applied, which make it possible to extract all the advantages from a longer pumping wavelength. For TPFP, there are many options from a regular grating with imaging system to a simplified case by using a volume phased holographic grating [6]. In this work we present our numerical findings for DAST, DSTMS, OH1, HMQ-TMS, BNA and MNA crystals with experimental designs.

Extreme terahertz radiation from relativistic laser plasmas

Guoqian Liao[1,2*], Fangzheng Sun[1,3], Hao Chen[1,3], Yanyu Wei[1,3], Yutong Li[1,2,3,4]

1Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences

2Songshan Lake Materials Laboratory

3School of Physical Sciences, University of Chinese Academy of Sciences

4Collaborative Innovation Center of IFSA (CICIFSA), Shanghai Jiao Tong University

High-power terahertz (THz) radiation sources are essential for many applications. Nevertheless, the generation of gigawatt-to-terawatt THz pulses remains thus far a formidable challenge. In this talk, relativistic laser-plasma interactions will be presented as a promising approach toward extreme THz generation. The underlying physical mechanisms and recent progresses will be reviewed. Extreme THz radiation with a ~200-mJ pulse energy and ~1-TW peak power, which is to our knowledge the most intense THz pulse reported in the laboratory, has been demonstrated from a thin solid foil irradiated by a high-intensity laser pulse. By tuning the laser or target parameters, the THz waveform and spectrum can be manipulated effectively, and the laser-to-THz energy conversion efficiency is boosted up to ~1%. By employing newly-developed single-shot THz metrology scheme, the THz radiation enables an in-situ, real-time, femtosecond-resolved diagnostic for the ultrafast dynamics of laser-accelerated fast electrons. Besides, the intense THz radiation has also been applied as a unique pump for the ultrafast control over matter. Some preliminary results on this will also be presented.

Development of optical rectification based THz pulse sources pumped by CO2 laser

György Tóth[1,2], Gergő Illés[1] , Gabit Nazymbekov[1] , Gábor Almási[1,2], János Hebling[1,2,3]
1 Institute of Physics, University of Pécs
2Szentágothai Research Centre, University of Pécs
3HU-REN-PTE High-Field THz Research Group

Objective + Methods + Results and Discussions + Conclusions Optical rectification in nonlinear material is a well-established technique for efficiently producing single-cycle terahertz pulses. The application of high pump intensities in semiconductor materials in the near-infrared region is unfeasible due to the pronounced multiphoton absorption effects [1]. Currently, CO2 lasers with pulse durations as short as 2 picoseconds are available [2], offering a sufficiently long pump wavelength to eliminate low-order multiphoton absorption. Numeric 1D+1 calculations were used with pump pulse durations between 0.5-2.5 ps and intensities from 20 to 100 GW/cm2 for investigation. The computational model comprehensively considers optical rectification, the cascading up- and down-conversion of the pump pulse, self-phase modulation (SPM), and the second harmonic generation (SHG) of the pump pulse. Due to the relatively long coherent length of the SHG, taking into account SHG is crucial for the calculations, as it can result in a reduction of terahertz (THz) conversion efficiency by as much as 50%. Gallium-Arsenide (GaAs) was selected as the nonlinear medium of interest. The outcomes for a 1.5 picosecond long pulse with a peak intensity of 80 GW/cm2 are depicted in Figure 1. According to the results, CO2 laser pumped GaAs crystal is capable of generating THz pulses with good efficiency and high field strength. At 2 mm crystal length the shape of the THz pulse is usable for applications that require single-cycle THz pulses. The efficiency at 2 mm is 0.19%, the peak field strength is 250 kV/cm and by focusing 10 MV/cm peak field strength is achievable [3]. At 3 mm crystal length the conversion efficiency increases to 0.78%, however, the THz pulse becomes modulated. The efficiency achieves a maximum (1.25%) at a crystal length of 3.5 mm, but then the THz pulse shape becomes very stochastic. Based on the detailed calculations, the modulation is primarily caused by the combined effect of SPM and SHG. The simulations conclude that if CO2 lasers can reach sub-picosecond pulse durations, they could open up new ways of high energy THz generation. **References** [1] N. M. Mbithi, G. Tóth, Z. Tibai, et al. "Investigation of terahertz pulse generation in semiconductors pumped at long infrared wavelength," J. Opt. Soc. Am B, 39 2684-2691 (2022). [2] M. N. Polyanskiy, I. V. Pogorelsky, M. Babzien, and M. A. Palmer, "Demonstration of a 2 ps, 5 TW peak power, long-wave infrared laser based on chirped-pulse amplification with mixed-isotope CO2 amplifiers," OSA Continuum 3, 459-472 (2020). [3] Z. Tibai, G. Krizsán, G. Tóth, et al. "Scalable microstructured semiconductor THz pulse sources," Opt. Express, 30 45246-45258 (2022).

Ultrafast lasers as a tool of high-precision micromachining

Wenhu Zhao
Suzhou Bellin Laser Co, Ltd

Edwards Vacuum Product and Ultrafast Application

Jie Yang
Edwards Technologies Trading(Shanghai) Co, Ltd

Coded Optical Streaking for Multi-scale Real-time Ultrafast Imaging

Jinyang Liang
Institut National de la Recherche Scientifique (INRS)–Université du Québec

Visualizing transient events in the durations of their occurrences (i.e., real time) is indispensable to understanding many physical, chemical, and biological processes. Among existing methods, real-time ultrahigh-speed imaging based on coded optical streaking has received increasing attention because it can overcome many limitations in existing techniques to achieve high image quality, high adaptability, and broad applicability. The concept of coded optical streaking can be embodied in various systems for real-time ultrafast imaging with microsecond to femtosecond temporal resolutions. First, I will present how the synergy of coded apertures and scanning optics can enable two-dimensional lifetime-based photoluminescence thermometry for biomedicine [Nat Commun 12, 6401 (2021)] and reconfigurable single-pixel video imaging [Nat Commun 13, 7879 (2022)]. Second, I will show how the transition between two encoding masks loaded onto a programmable grating can enable the development of a new ultrafast framing camera to image the plasma-cavitation process and the laser ablation on a biological sample [Optica 10,1223 (2023)]. Finally, I will show our recent progress on all-optical compressed ultrafast photography for femto-magnetism on metal alloys and transient absorption on semiconductors.

Dr. Jinyang Liang is an Associate Professor at the Institut National de la Recherche Scientifique (INRS) – Université du Québec. He holds the Canada Research Chair in Ultrafast Computational Imaging (Tier II). He directs the Laboratory of Applied Computational Imaging (LACI). His research interests cover ultrafast imaging, high-precision laser beam shaping, optical physics, and biophotonics. He has published >100 journal papers and conference proceedings. He has applied for >20 patents on ultrafast optical imaging technologies. He is a Senior Member of Optica and SPIE and serves as an Associate Editor of Optica’s Photonics Research and a Senior Editor of Springer’s PhotoniX. He received many awards, including the 2019 Young Scientist Prize from the International Union of Pure and Applied Physics (IUPAP) and the 2017 Educational Award–Gold from Edmund Optics. He received his Ph.D. degree in Electrical Engineering from the University of Texas at Austin in 2012. From 2012 to 2017, he was a postdoctoral trainee at Washington University in St. Louis and the California Institute of Technology.

Single-shot ultrafast photography based on spectral-temporal coupling

Feng Chen
Xi’an Jiaotong University

Nowadays, ultrafast observation of transient phenomena occurring on different time scales has become indispensable in many fields. Developing ultrafast imaging methods with ultra-high frame rates, high frame depth, and high spatial resolution is necessary to record many significant ultrafast and non-repetitive processes. Here, we developed a group of single-shot ultrafast imaging methods based on spectral-temporal coupling, in which different spectral slices of an observing pulse observe the corresponding temporal slices of an ultrafast process. We can achieve the highest frame rate of over 5×1012 frames per second and capture over 100 frames with single-shot detection. Through the application of a high-channel compressed camera system, the spatial resolution of our ultrafast photography methods can be greatly improved. In addition, in our recent work, the detecting time window was promoted to nanosecond scale. Our work can provide advanced ultrafast imaging methods and theoretical guidelines for a deeper understanding of many important ultrafast processes such as laser ablation, filaments and ultrafast plasma dynamics.

Feng Chen is a full professor of Electronic Engineering at Xi’an Jiaotong University, where he directs Ultrafast Photonic Laboratory (UPL) and has severed as the director of Shaanxi key laboratory of Photonics Technology of Informtion (PTI), deputy director of the International Joint Research Center for Micro/Nano Manufacturing and Measurement Technologies. Chen received the B.S. degree in physics from Sichuan University in 1991 and received the Ph. D. in Optics from Chinese Academy of Science in 1997. He joined Chinese Academy of Science in 1991, where he was promoted to a full professor in 1999. In 2002, Dr. Chen joined the Xi’an Jiaotong University as a professor and a group leader. His current research interests are Femtosecond laser microfabrication, Bionic microfabrication and Ultrafast photonics. Dr. Chen took charge in over 30 research projects including the National Key Research and Development Program, key projects of NSFC, the National key scientific instruments and equipment development of China, 863 projects, etc, and has published over 300 peer-reviewed papers including Chem. Soc. Rev., Adv. Funct. Mater., Phys. Rev. Lett., etc.

Molecular Electronic-vibrational coupling revealed by two-dimensional electronic coherence spectroscopy

Yuxiang Weng
Institute of Physics, Chinese Academy of Sciences

Two-dimensional electronic spectroscopy is a powerful tool in elucidating the coherent energy transfer, exciton delocalization and many other coherent processes, especially in photosynthetic process. An important phenomenon is the electronic coherence observed in earlier studies such as in FMO, and later it is generally accepted as coupling of the electronic and vibronic coherences owing to the rapid decay of the electronic coherence. Thus investigation of the coupling of the vibrational modes to the electronic state would be of particular interest since the vibtrational mode could extend the lifetime of the electronic coherence. In this presentation, I shall report the recent progress in the investigation of the coupling of the vibrational modes to the electronic state in small molecules as well as in light-harvesting antenna complex.

Multiple-vibtrantional wavepacket in bacteriochlorophyll a. Low vibrational modes in a range of 80-400 cm-1 for bacteriochlorophyll a limited by the band width of the excitation laser were excited and observed as beating dynamics in two-dimensional electronic spectra (2DES). We found that these low frequency vibrational modes are coupled to each other. We proposed a model of multi-vibrational mode coupled to displaced oscillator to account for the observed multiple vibrational coherence, in contrast to the well-established single vibrational mode coupled to an electronic state [1].

Energu ladder crossing between different normal mode in oxazine 720. For a harmonic oscillator, crossing between different normal modes is not optical-transition allowed. Using 2DES, we resolved the multi-mode wavepackets of oxazine 720 in the excited- and ground-state respectively. We also resolved an excited-state vibrational mode of 586 cm-1 with a dephasing time of 0.7 ps and a ground-state vibrational mode of 595 cm-1 with a dephasing time of 1.3-1.7 ps. We found some of the lower frequency modes are coupled to the high frequency modes around 1150 cm-1, indicating that the during the resonance Raman excitation process, different normal modes are coupled. This is interpreted as the non-harmonic potential of the excited state [2].

Vibrational and vibronic coherences in the energy transfer of light-harvesting complex II (LHCII). We revisit the coherent dynamics and clarify different types of coherences in the energy transfer processes of LHCII using a joint method of the high-S/N transient grating and two-dimensional electronic spectroscopy. We find that the electronic coherence decays completely within 50 fs at room temperature. The vibrational coherences of chlorophyll a dominate over oscillations within 1 ps, whereas a low-frequency mode of 340 cm-1 with a vibronic mixing character may participate in vibrationally assisted energy transfer between chlorophylls a. Our results may suggest that vibronic mixing is relevant for rapid energy transfer processes among chlorophylls in LHCII [3].

Yuxiang Weng, Professor, Director of Laboratory of Soft Matter Physics,Institute of Physics (IOP), Chinese Academy of Sciences (CAS)

1980-1985 B.S. in Chemistry, East China Normal University, Shanghai, China
1985-1988 M.S. in Physical chemistry, East China Normal University, China
1990-1993 Ph.D. in Laser Physics, IOP , CAS
1994-1997 Postdoctoral Research fellow, Department of Chemistry, University of Hong Kong

1997-1999 Postdoctoral Research fellow, Department of Chemistry, Emory University, USA
1999-2000 Associate Professor, Laboratory of Optical Physics, IOP, CAS
2000-present.Professor, Laboratory of Softmatter Physics, IOP, CAS
Awards and Honors: 1999 Hundred talent program of CAS
2009 Awarded with distinguished young scientist fund by NSFCC
Research Interests:
Ultrafast spectroscopy, Energy and electron transfer in artificial and real photosynthetic process, Fast folding of protein

Ultrafast observation and manipulation of spin coherence in quantum dots

Kaifeng Wu
State Key Laboratory of Molecular Reaction Dynamics, Dalian Institute of Chemical Physics, Chinese Academy of Sciences

Coherent manipulation of solid-state spins is important for quantum information processing. Current solid-state spin systems either operate at very low temperatures or are difficult to scale-up. Colloidal quantum dots (QDs), by contrast, can be synthesized in large quantity in solution at low cost, yet with high finesse in size and shape control. Further, they are usually strongly quantum-confined, thus their carriers well isolated from the phonon bath, which could enable long-lived spin coherence at room temperature. We studied coherent spin dynamics in solution-grown perovskite QDs using transient magneto-optical spectroscopy. We observed ensemble-level quantum beats resulting from an exciton fine-structure gap and quantitatively controlled the gap energy using temperature-programmable lattice distortion. This unique mechanism has important implications for the application of perovskite QDs in quantum light-sources and coherent exciton control. Further, by dissociating excitons using ultrafast interfacial electron transfer, we achieved room-temperature all-optical initialization, manipulation and readout of hole spins in $CsPbBr_3$ QDs. This represents a milestone towards a scalable and sustainable future of spin-based quantum information processing.

Dr. Kaifeng Wu obtained his B.S. degree in materials physics from University of Science and Technology of China (2010) and his PhD degree in physical chemistry from Emory University (2015). After his postdoctoral research at Los Alamos National Laboratory, he moved to China to start his independent research in 2017. His current work focuses on the ultrafast spectroscopy of carrier and spin dynamics in low-dimensional optoelectronic materials, as well as relevant applications in quantum information and energy conversion technologies. He is the winner of the 2023 Xplorer Prize, 2022 Distinguished Lectureship Award by the Chemical Society of Japan, 2021 Future of Chemical Physics Lectureship Award by the American Physical Society, 2020 Chinese Chemical Society Prize for Young Scientists, 2019 Robin Hochstrasser Young Investigator Award by the Chemical Physics journal, and 2018 Victor K. LaMer Award by the American Chemical Society. He serves on the Editorial Advisory Board (EAB) of J. Phys. Chem. Lett. and ACS Energy Lett., and the youth EAB of Ultrafast Science.

Spatiotemporal charaterization of femtosecond to attosecond laser pulses

Zhengyan Li
Huazhong University of Science and Technology

Femtosecond or attosecond laser pulses enable probing of ultrafast dynamics of atoms or electrons in the microscopic word. The characterization of these ultrafast pulses, especially ones with spatiotemporal coupling in nature, is necessary to control the process of laser matter interactions. Here we discuss several techniques of measuring the three-dimensional spatiotemporal optical field (including amplitude, phase, polarization) profiles of femtosecond laser pulses and attosecond pulses based on high harmonic generation. One direct application of these pulse characterization techniques is videography of ultrafast dynamics in pump-probe experiments.

TBD

TBD

High-fidelity single-shot ultrafast optical imaging techniques

Yunhua Yao

State Key Laboratory of Precision Spectroscopy, School of Physics and Electronic Science, East China Normal University

Compressed ultrafast photography (CUP) is the fastest receive-only optical imaging technology so far, which combines stripe imaging and compressed sensing to restore the original dynamic scene by image encoding and decoding. By now, CUP has been applied in lots of areas, such as laser pulse propagation, ultrafast temporal focusing, plasma dynamics, shockwave dynamics, fluorescence lifetime microscopy, optical chaos, and so on. However, there are still some issues for CUP in practical applications. Especially, the low image quality limits the detailed analysis of the dynamic scene. The low image quality of CUP mainly results from the information loss due to spatial encoding and the imperfect unmixing of the spatiotemporally compressed data. To address this issue, we have proposed some solutions from two aspects: increasing the collected information during sampling and improving the algorithm for imaging reconstruction. Besides, some active illumination based ultrafast imaging techniques are also developed, which record the ultrafast scene in a single shot by transferring the temporal information into other domains, such as spectral and polarization ones. For example, in chirped spectral mapping ultrafast photography(CSMUP), a chirped broadband laser pulse with temporal dispersion works as the illumination source to record the ultrafast dynamics, and a hyperspectral camera works as the detector to obtain the spectral and spatial information. In polarization-resolved ultrafast mapping photography technique(PUMP), a rotationally polarized laser pulse generated by an optical rotatory dispersion crystal is used as the illumination light of a dynamic scene, and a polarization filtering method and deconvolution reconstruction algorithm are jointly adopted to recover the original temporal and spatial information.

Yunhua Yao is an associate professor from the State Key Laboratory of Precision Spectroscopy at East China Normal University. He obtained his PhD in Optics in 2018 and finished his post-doctor research in 2021 at East China Normal University. His current research interest focuses on ultrafast optical imaging and high-speed super-resolution microscopy techniques. He has published 43 articles in scientific journals including Adv. Photonics, Photonics Res., Opt. Express and so on.

Study on high resolution atomic time videography

Jingzhen Li, Shixiang Xu, Ci Yi, Lu Xiaowei, Zeng, Xuanke Hu Long, Qifan Zhu, Yongle Zhu

Institute of Photonic Engineering, College of Electron Sci. & Tech., Shenzhen University

Shenzhen Key Laboratory of Micro·Nano Photonic Information

The important basic science of atomic time scale and the innovative research of major scientific engineering, such as the formation of vortex plasma shock wave, super-strong laser tail field acceleration, and so on, urgently needs to reveal the internal evolution law of its transient process, discover new phenomena and explore new laws. Based on the important achievements of microsecond imaging technology, our research group has gradually shifted its focus to atomic time imaging for basic research. Through 15 years of concentrate on research, we have recently achieved four world-leading research results on the total amount of time-space information in dynamic light field. Three of them and some of international important results, such as CUP ,GRAME, etc., will be involved in this report.

Firstly, based on a multiple non-collinear optical parametric amplifier principle, MOPA readily reached up to the frame rate of 1.5×1013fps and the intrinsic spatial resolution higher than 30 lp/mm, which has no limitation of Heisenberg uncertainty relation and has far higher performance indexes than the international level created by American and Japanese scientists reported internationally. Secondly, OPR femtosecond imaging, consisting of sequentially timed module, spectral-shaping module and raster framing part, is an all-optical high spatial resolution imaging technique on the strength of raster principle, which can capture a large sequence depth of 12 frames by the reconstruction data cube of 1626×1236×12 with the frame rate 2×1012fps. Thirdly, FIP Single-shot framing integration photography with the inverse four F system has achieved amazing indexes: the frame rate of 5.3×1012 fps and the outstanding intrinsic spatial resolution of 110.4 lp/mm because of limited by only imaging lenses itself and consistent with the principle of optimal femtosecond imaging. These mentioned above can meet the high imaging quality requirements of quasi-femtosecond time resolution, or rather a few fs of resolution, depending on the pulse width and its energy of femtosecond laser pulse and the optical quality of the imaging system, which can probe unrepeatable ultrafast intra- and inter-atomic/molecular dynamics, different in size and duration.

Prof. Jingzhen Li, doctoral supervisor, graduated from Tsinghua University, graduate of the Chinese Academy of Sciences, is the director of Shenzhen Key Laboratory of Micro/Nano Photonic Information Technology, the director of Photonic Engineering Research Institute, the deputy director of High-speed Photography and Photonics Committee of Chinese Optical Society, and the deputy director of Optical Testing Committee of Chinese Optical Society.

His main research interests are the theory and technology of ultra-high speed photography to explore what happens in the process of super-fast physical and chemical and biological picture and its evolution rule, and to make a significant contribution to the development of the national defense /civil scientific research in our country. He is an expert with outstanding contributions in the field of international optical mechanical high-speed photography and a pioneer of international all-optical extremely-high speed imaging technology

So far, as the project leader, he has won 6 national science and Technology Awards including the Grand Prize of The State Science and Technology Award and 13 provincial and ministerial science and technology Awards from the Chinese Academy of Sciences, Central Military Commission Science and Technology Commission, National Defense Industry Commission, Guangdong Province and Shaanxi Province. At the same time, he was awarded the mayor award, that is the highest award of Shenzhen Science, and Technology Award in 2014. In 2014, he was named as the National Outstanding Scientific and Technological Worker. In 2012, he was selected into the Overview of academic achievements of Famous Scientists in China in the 20th century.He has published 10 academic monographs (about 17 million words), including 3 monographs such as optical manual and Laser Measurement (about 10 million words), and more than 233 paper.

Single-shot pseudo-direct time-of-flight depth image sensors with charge-domain signal compression

Keiichiro Kagawa
Research Institute of Electronics

Computational CMOS image sensors based on temporally compressive sensing in the charge domain can realize a new implementation of light detection and ranging (LiDAR), i.e., pseudo-direct time-of-flight (pseudo-dToF) depth imaging. They are based on the multi-tap charge modulator typically used in indirect ToF (iToF) image sensors and compress high-speed optical temporal signals in the charge domain in pixel. Therefore, large digital circuits for time-to-digital conversion or building histograms prepared in conventional dToF image sensors using the single photon avalanche diode (SPAD) are unnecessary. Nevertheless, they can detect multiple reflections under multipath interference, which is one of the advantages of dToF. Exploiting the small pixel size of the pseudo-dToF image sensor, high-resolution image sensors will be possible. In my talk, I will show extended depth range and detection of multiple reflections in dynamic scenes in a single shot. The operation frequency of the image sensor was 606MHz, and the charge modulation frequency was 303MHz. The depth resolution was enhanced by the oversampling technique that does not require any modification on the hardware or any additional sweeping.

Keiichiro Kagawa received the Ph.D. degree in engineering from Osaka University, Osaka, Japan, in 2001. In 2001, he joined Graduate School of Materials Science, Nara Institute of Science and Technology as an Assistant Professor. In 2007, he joined Graduate School of Information Science, Osaka University as an Associate Professor. In 2011, he joined Shizuoka University as an Associate Professor. Since 2020, he has been a Professor with Shizuoka University, Hamamatsu, Japan. His research interests cover high-performance computational CMOS image sensors, imaging systems, and biomedical applications.

Micro-region ultrafast spectroscopy and the applications

Xinfeng Liu
National Center for Nanoscience and Technology

Ultrafast spectroscopy is an important technical means for the characterization of charge carriers, which are widely used in the fields of materials, information, physics and chemistry. In recent years, we have been committed to developing spectral measurement systems with spatial, temporal, and momentum resolution capabilities, studying the carrier characteristics in semiconductor material systems, and laying an important foundation for a deeper understanding of their photoelectric properties and related devices. In this talk, I mainly introduce some progress by using our micro/nanoscale ultrafast spectroscopy platform in the study of carrier mobility, electron phonon coupling, as well as the spectral characteristics and related carrier dynamics of nanoscale semiconductor materials induced by the edges.

TBD

Photochemical reaction mechanism studies of organic molecules

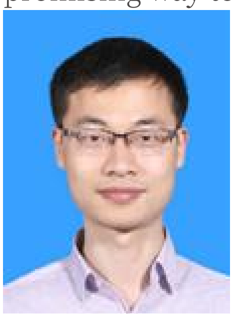
Jiani Ma
Shaanxi Normal University

TBD

Excited-state Dynamics in Organics Photovoltaic Blends Studied by Ultrafast Spectroscopy

Rui Wang
College of Physics, Nanjing University of Aeronautics and Astronautics

Organic solar cells (OSCs) based on blends of electron donors and acceptors hold the advantages of flexibility, environment-friendly and low cost, which attracts numerous interests recently. Owing to the development of nonfullerene acceptors, the certified power conversion efficiency (PCE) of OSCs has exceeded 19%. Nevertheless, the PCEs of OSCs still lag behind their inorganic counterparts, which is mainly because of the existence of additional energy loss channels in OSCs. To solve the problem, we systematically study the excited-state dynamics in organics photovoltaic (OPV) blends utilizing broadband transient absorption spectroscopy with improved sensitivity. In model OPV systems, we find charge separation is mediated by intra-moiety delocalized excitations (i-EX) in the hole transfer channel. The i-EX shows reduced binding energy, which can lower the driving forces needed for charge separation. In addition, we find the non-radiative triplet loss channel is suppressed in OPV blends with fluoridized acceptors, which can be explained by the modified energy arrangement of singlet and triplet states at donor:acceptor interfaces. Moreover, we find a conformation dependent trapping loss channel of local excitations in polymer blends, which can be efficiently reduced by detuning the dielectric constant with additives. These findings suggest modifying the intra-moiety and interfacial intermolecular interactions to optimize charge separation and recombination dynamics may be a promising way to further improve the device performance of OSCs.



Rui Wang earned his B.S. in physics from Nanjing University in 2013. He obtained his Ph.D. degree in physics from Nanjing University under the supervision of Prof. Chunfeng Zhang in 2018. He now works as a professor in College of Physics, Nanjing University of Aeronautics and Astronautics. His recent research focuses on developing high-precision ultrafast spectroscopy method and exploring new mechanisms of excited-state dynamics in organics photovoltaic system.

Quartz Tuning Fork based Laser Spectroscopy and Its Application for Gas Sensing

Yufei Ma

National Key Laboratory of Science and Technology on Tunable Laser, Harbin Institute of Technology

Quartz tuning fork (QTF) is originally used to provide the clock rate in crystal watches and electronic circuits. Standard commercial QTFs possess a resonance frequency of 32.768 kHz and a Q-factor of ~10000 in a standard atmosphere pressure. Photoacoustic spectroscopy (PAS) is identified as an advanced technique for trace sensing. A recent improvement of microphone-based PAS is quartz-enhanced photoacoustic spectroscopy (QEPAS), which was first reported in 2002. This technique uses a piezoelectric QTF as an acoustic wave detector which possesses a high detection sensitivity and immunity to ambient acoustic noise. However, QEPAS is a contact measurement technique. This feature limits its application in many fields, such as combustion diagnosis, long distance measurement and remote sensing. In the year of 2018, a new technique of light-induced thermoelastic spectroscopy (LITES) was invented. In LITES, the QTF can be placed far from the target gas. Therefore, LITES is a non-contact measurement method and can be used for remote and standoff gas detection. In this presentation, the latest research progress about QEPAS and LITES based gas sensing will be discussed.

Yufei Ma received his PhD degree in physical electronics from Harbin Institute of Technology, China, in 2013. From September 2010 to September 2011, he spent as a visiting scholar at Rice University, USA. Currently, he is a professor at Harbin Institute of Technology, China. He is the winner of National Outstanding Youth Science Fund. His research interests include optical sensors, trace gas detection, laser spectroscopy, and solid-state laser. He has published more than 100 publications and given more than 40 invited presentations at international conferences. He serves as area editor/associate editor/topical editor for Optics Express, Photoacoustics, Chinese Optics Letters, Optical Engineering, Microwave and Optical Technology Letters, Frontiers in Physics, Sensors, and Applied Sciences. He also serves as young editor for Ultrafast Science.

Uncovering thrombosis with ultrafast optofluidic imaging

Yuqi Zhou
The University of Tokyo

Thrombosis remains a global health concern, prompting extensive investigations into its underlying mechanisms. In this groundbreaking study, we harnessed the power of ultrafast optofluidic imaging through a state-of-the-art high-speed bright-field microscope, integrating optical frequency-division multiplexing and microfluidic technology. This cutting-edge approach allowed us to perform real-time image-based single-cell profiling and continuous monitoring of circulating platelet aggregates, recognized as precursors to thrombosis. Our comprehensive analysis encompassed a cohort of thrombosis patients, COVID-19 patients, and healthy subjects. By scrutinizing the morphological changes exhibited by platelet aggregates in response to thrombosis, COVID-19, and COVID-19 vaccination, we unveiled distinctive alterations in platelet aggregate morphology under various conditions. These findings provide valuable insights into the intricate relationship between platelet aggregation and thrombotic events, advancing our understanding of thrombosis pathogenesis.

Yuqi Zhou is a Research Assistant Professor in the Department of Chemistry at the University of Tokyo. She obtained a B.S. degree from UIUC and a Ph.D. degree from the University of Tokyo. There, she continued her academic pursuits in chemistry, specializing in the areas of ultrafast imaging, platelet biology, and thrombosis. Her research has had a significant impact on the scientific community, and her work has been published in renowned journals such as Nature Communications, Trends in Biotechnology, and eLife. Yuqi’s dedication to her research and contributions to the scientific community have been recognized with numerous awards, including the Young Excellence Award at The Quantum Life Science Conference in 2023, the Hamamatsu Best Presentation Award at The International SPIE Photonics West Conference in 2020, and the ImPACT Serendipity Award as part of the Cabinet Office Innovative Research and Development Program in 2019, among others.

Ultrafast Multidimensional Spectroscopy for Electron Dynamics of Molecules: from Quantum Light to X ray

Zhedong Zhang[1],* and Markus Kowalewski[2]
1City University of Hong Kong, 2Stockholm University

Advancements of quantum optical technology and X-ray source have opened new frontiers for the study of light-matter interactions during ultrafast timescales. These enabled incredible control and imaging of electron and phonon motions in molecules, not accessible by classical light. Two key issues emerge: quantum correlations and ultrafast electron dynamics, which will be the themes in this talk. I will present our recent works on ultrafast coherent spectroscopy, ranging from quantum light to X ray interactions as probes of ultrafast electron and exciton dynamics in molecules and 2D semiconductors. I will discuss various schemes with a foci of multidimensional probes and strong light-matter couplings with quantum states of light and X ray. Microscopic models using density matrix and Heisenberg-Langevin equation will be discussed, for a unified understanding of the spectroscopic signals that significantly capture the electron dynamics.

Prof. Zhedong Zhang is now an Assistant Professor of Physics at City University of Hong Kong. He obtained his Ph.D. in physics from Stony Brook University in 2016. Since then, he has been working as a postdoctoral fellow at University of California Irvine and Texas A&M University until 2020 when he moved to Hong Kong. He has received the Robert A. Welch Postdoctoral Fellowship. Prof. Zhang is a member of American Physical Society.

Prof. Zhang’s research interest is the theoretical quantum physics, focusing on two fields: (1) Nonlinear optical spectroscopy with quantum states of light and X ray for learning new knowledge about nanomaterials; (2) Nonequilibrium quantum thermodynamics transiting from microscopic to larger scales. He has more than 30 professional publications, on high-profile journals including Nature, Phys. Rev. Lett., Optica, J. Phys. Chem. Lett., Phys. Rev. A and Phys. Rev. B.

Ultrafast Dynamics in Iron-Based Superconductors and Innovation of On-site in situ High Pressure Ultrafast Spectroscopy

Jimin Zhao[1,2,3*]
1 Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences
2 School of Physical Sciences, University of Chinese Academy of Sciences,
3 Songshan Lake Materials Laboratory

I will address two parts of our recent ultrafast spectroscopy investigation of quantum materials. First, I will talk about our ultrafast spectroscopy investigations of iron-based high temperature superconductors. Ultrafast dynamics of single-unit cell layer FeSe/SrTiO3 [1], intercalated iron-based superconductors (Li0.84Fe0.16)OHFe0.98Se, Fe1.05Se0.2Te0.8, and Fe1.01Se0.2Te0.8 [2] have also been investigated, for which the e-phonon coupling strengths are experimentally obtained. With these, for the first time a universal positive correlation between the superconducting transition temperature Tc and the e-phonon coupling strength λA1g or λ is discovered to exist among all known optimally doped iron-based superconductors (including FeSe-based, FeAs-based, and monolayer FeSe systems). Thus, we found that the e-phonon coupling may play an important role in all iron-based superconductors, especially including the single-layer system.
Then I will talk about our recent innovation of on-site in situ high pressure ultrafast pump-probe spectroscopy. Both ultrafast spectroscopy and high-pressure physics is important fields of materials physics. Combining the two is nontrivial, because conventional efforts cannot remove potential artifacts caused by repositioning fluctuations. In conventional ways, usually the DAC is taken out of the light path to tune and calibrate pressure and then put back. This will often introduce sample motion and rotation (i.e. repositioning fluctuation), which likely introduces artifacts in signals. We innovated and realized an on-site in situ high pressure pump-probe ultrafast spectroscopy technique, for which the DACs and samples remain within the light path, thus successfully removing repositioning fluctuation. With such, we successfully constructed an on-site in situ high pressure ultrafast pump-probe spectroscopy instrument [3]. Before, colleagues report mainly normalized data. Now this achievement allows for precision measurements in both the amplitude and lifetime. Standard description has also been initiated to greatly enhance the data comparability among different groups [3]. Using this instrument we studied the ultrafast dynamics of strongly correlated iridate Sr2IrO4 under high pressure. For the first time we found pressure-induced phonon-bottleneck effect (needs experimental data in both amplitude and lifetime), whereby conventional phonon-bottleneck effects are all driven by temperature. [4]. These achievements critically help the inauguration of high-pressure ultrafast dynamics—to become a new branch of material physics research. This will also greatly contribute to the investigations of material physics under extreme conditions.

Professor Jimin Zhao, Institute of Physics, Chinese Academy of Sciences, is the Group Leader of SF10i. He obtained his BS and MS degrees from Tsinghua University and PhD degree from University of Michigan (Ann Arbor). He investigated the interface superconductivity in single-layer FeSe/SrTiO3, experimentally obtained its crucial electron-phonon coupling strength. He also investigated (Li0.84Fe0.16)OHFe0.98Se and discovered that for all optically-doped iron-based superconductors, the superconducting transition temperature Tc is universally positively correlated to the electron-phonon coupling strength λ (or λA1g). This shows that electron-phonon coupling plays an essential role in iron-based superconductors. He innovated “on-line in situ” high-pressure ultrafast pump-probe spectroscopy in both technique and instrument, using which he discovered pressure-induced phonon bottleneck effect, thus making high-pressure ultrafast dynamics a new frontier area of condensed matter physics. He discovered the laser-induced electron coherence in 2D materials, based on which he innovated all-optical switching, employing spatial self-phase modulation (i.e., optical Kerr effect). He also extensively investigated coherent phonons and photo-thermal-acoustic effect. He has published more than 60 papers on PRL, PNAS, Adv. Mater., Nano Lett. etc. and presented more than 70 invited talks on APS, SPIE, etc. He also chaired a few international conferences. He serves on the editorial board for a few SCI journals. He is a Board Member of the Academic Committee of Light Scattering, Chinese Physical Society and the Vice Chair, Technical Group of Ultrafast Phenomena, Optica.

An ultrafast picosecond framing camera based on electron pulse dillation technoloy

Yongsheng Gou
Xian Institute of Optics and Precision Mechanics of CAS

A new method to realize a picosecond-resolution framing camera is proposed. The main principle is to first use a high voltage electrical pulse to disperse the speed of the photoelectron impulse, and then to use a drift area to stretch the photoelectron impulse in the axial direction. Finally, a traditional framing camera based on microchannel plate (MCP)-gated technology is used to image the photoelectron impulse after it is stretched. In this way, picosecond-scale time resolution can be achieved for the camera system. A framing camera with picosecond temporal resolution has been designed and built based on this method. With this camera we have obtained bang time imagine within 10ps at Shenguang- Ⅲ prototype facility.

Off-resonant pumping exciton dynamics in quasi-2D perovskite for all-optical logic gates

Yulan Fu[1],*, Yi Zhang[1], Yiwei Zhang[1], Xinping Zhang[1]

1 Institute of Information Photonics Technology and Faculty of Science, Beijing University of Technology

Quasi-2D perovskite materials achieve a series of progress in solar cells, photodiodes, and spintronic devices due to their excellent optoelectronic properties and stability exceeding that of 3D perovskite. Although high exciton binding energy enhanced by strong dielectric confinement in quasi-2D perovskite materials is not conducive to improving the photoelectric conversion efficiency of solar cells, it provides a platform to study the exciton behavior and realize ultrafast all-optical devices. Moreover, the strong spin-orbit coupling originating from the heavy atoms in perovskite predicts the possibility of spin photonic devices. The femtosecond pump-probe method has been used to investigate carrier and exciton dynamics in perovskite materials, including spin-relaxation, hot carrier cooling, biexciton effect, etc. However, all-optical logic devices with femtosecond time response have not yet been realized due to the long exciton lifetime.

Here, we report the spin-selective optical Stark effect (OSE) in quasi-2D perovskite PEA2(FAPbBr3)2PbBr4 films under off-resonance pumping with photon energy lower than the exciton absorption energy. Meanwhile, biexciton could be generated through two-photon absorption (TPA), and the hot-biexciton effect on a hundred-femtosecond time scale is observed. Unlike the biexciton dynamics pumping by single-photon absorption of the same energy, the TPA pumping biexciton dynamics does not have spin dependence when using different circular polarization configurations of pump and probe pulses. Under the combination of OSE and the biexciton effect, we proposed an optical spin logic XOR gate with a response time of 130 fs. Our study of the exciton dynamic behavior in two-dimensional perovskite materials helps improve the performance of quasi-2D perovskite optoelectronic devices and provides a tragedy for realizing spin logic devices with femtosecond response time using perovskite materials.

Ultrafast topography of femtosecond laser ablation using structured illumination

Jielei Ni[1], Xu Jie[2], Qianyi Wei[1], Yuquan Zhang[1], Xiaocong Yuan[1,3*], Changjun Min[1*]
1Nanophotonics Research Center, Institute of Microscale Optoelectronics & State Key Laboratory of Ra dio Frequency Heterogeneous Integration, Shenzhen University,
2Guangdong Laboratory of Artificial Intelligence and Digital Economy (Shenzhen)
3Research Center for Humanoid Sensing, Research Institute of Intelligent Sensing, Zhejiang Lab

Ultrafast laser ablation is an emerging technique for micro-/nano-fabrication that involves a series of interesting nonlinear processes. To precisely control and optimize the fabrication process, advanced temporal and spatial diagnostic techniques need to be implemented to accurately monitor the evolution of these processes. Early approaches combined pump-probe techniques with wide-field reflective imaging, enabling the observation of the spatiotemporal evolution of the object' s surface during ultrafast laser irradiation. Recently developed single-shot ultrafast imaging methods, using streak cameras or hyperspectral cameras, have provided a new way to capture the unrepeatable information during femtosecond laser ablation within a single pulse. However, these ultrafast imaging techniques are limited to two-dimensional (2D) imaging, which is insufficient for investigating three-dimensional (3D) structural changes on the surface during femtosecond laser ablation.

To address this challenge, we proposed two wide-field three-dimensional imaging methods: single-probe structured light microscopy (SPSLM) and single-probe ultrafast interferometry-based microscopy (SUIM). In SPSLM, a structured light is generated by a DMD device and projected obliquely onto the sample surface to retrieve depth information through the triangulation method. SPSLM provides a temporal resolution of approximately 256 fs, and spatial lateral and axial resolutions of approximately 478 nm and 22 nm, respectively. On the other hand, SUIM employs a different configuration based on the interference of a sample beam reflected from the ablated surface and a reference beam reflected from a flat surface. By analyzing the phase of the interference fringe, the depth distribution of the ablated surface can be retrieved. SUIM extends the lateral resolution to approximately 236 nm, providing a more accurate retrieval of the transient ablation morphology.

By employing SPSLM and SUIM, we conducted a series of studies on the spatial-temporal evolution of laser-induced periodic surface structures (LIPSS) on the surfaces of Si and SiC under femtosecond laser irradiation. We revealed the ablation dynamics of linear LIPSS including excitation of the electronic system, ultrafast melting, and material removal followed by resolidification. Additionally, Using SUIM as a robust tool, we demonstrated the manipulation of ablation process to generate complex ablation features by double cross-polarized femtosecond pulses with variable pulse delay. Our findings highlight the robustness of SPSLM and SUIM in accurate three-dimensional measurement of the interaction between femtosecond lasers and materials, offering high spatial and temporal resolution capabilities.

Quantum electrodynamics of strong laser-matter interaction

Marcelo Ciappina

Department of Physics, Guangdong Technion - Israel Institute of Technology
Technion -- Israel Institute of Technology
Guangdong Provincial Key Laboratory of Materials and Technologies for Energy Conversion, Guangdong Technion - Israel Institute of Technology

Strong laser-matter interactions are at the center of interest in research and technology since the development of high-power lasers. They have been widely used for fundamental studies in atomic, molecular, and optical physics, and they are at the core of attosecond physics and ultrafast optoelectronics. Although the majority of these studies have been successfully described using classical electromagnetic fields, recent investigations based on fully quantized approaches have shown that intense laser-atom interactions can be used for the generation of controllable high-photon-number entangled coherent states and coherent state superpositions. In this talk, we provide a summary about how to deal with a quantized description of intense laser-atom interactions. We elaborate on the processes of high-harmonic generation, above-threshold ionization, and we discuss new phenomena that cannot be revealed within the context of semiclassical theories. Finally, we discuss the extension of the approach to more complex materials, and the impact to quantum technologies for a new photonic platform composed of the symbiosis of attosecond physics and quantum information science.

DSc Dr Marcelo Ciappina completed the PhD in Physics at Balseiro Institute, Argentina, in March 2005 and the Research Professor in Physico-Mathematical Sciences (DSc) dissertation (Habilitation) at the Czech Academy of Sciences, Czech Republic in June 2019. After several years of Postdoctoral and Senior positions all around the world, including, amongst others, various Max Planck Institutes in Germany (MPI-K Heidelberg, MPQ Garching and MPI-PKS Dresden), the Institute of Photonic Sciences (ICFO) in Spain, the Extreme Light Infrastructure (ELI)-Beamlines in Czech Republic, the Institute of High Performance Computing (IHPC) (A* STAR, Singapore) and the Auburn University (USA), he joined the GTIIT in fall 2020 as an Associate Professor. DSc Dr Marcelo Ciappina is a top-class expert in theory and numerical simulations of nonlinear laser interactions with atoms, molecules and complex systems. The most important effects during these interactions are high-harmonic generation (HHG), the generation and application of attosecond extreme ultraviolet (XUV) pulses, above-threshold ionization (ATI) and non-sequential ionization (NSI). In a few recent years he is one of the pioneers in a novel and fascinating field that merges two relatively new areas of research: attosecond and nanoscale physics. This research area particularly studies how nanometer-spatially inhomogeneous laser induced fields modify the laser-driven electron dynamics. Consequently, this field property has profound impact on pivotal processes such as ATI and HHG. DSc Dr Ciappina is developing analytical and numerical methods for the description of the above physical processes and he is carrying out numerical simulations supporting different strong laser-matter experiments worldwide. He participates in the interpretation of experimental results and also in the proposals for new experiments. DSc Dr Ciappina regularly publishes in very prestigious scientific journals (Nature Physics, Nature Communications, Physical Review X, Physical Review Letters, Physical Review A). He is author or co-author of around 180 papers in impacted journals listed in WoS, including several authoritative review articles. According to WoS (at Nov 2023), DSc Dr Ciappina has an h-index 31 and his papers were cited 3580 times with an average of more than 300 times during the last 6 years.

Ultrafast imaging and control of molecular dynamics

M. Li[1], Y. Liu[2], M. Zhang[2], H. Yang[2], Z. Li[2], L. Cao[1], S. Zhang[3], G. Wang[4], H. Xu[5], C. Wang[6], D. Ding[6], Z. Li[2]

1 HUST 2 PKU 3 SNNU 4 DTU 5 NJU 6 JLU

The Jahn-Teller effect is a fundamental mechanism of spontaneous symmetry breaking in molecular and solid state systems, and has far-reaching consequences in many fields. Up to now, to directly image the onset of Jahn-Teller symmetry breaking remains unreached. Here we employ ultrafast ion-coincidence Coulomb explosion imaging with sub-10 fs resolution and unambiguously image the ultrafast dynamics of Jahn-Teller deformations of CH4+ cation in symmetry space. It is unraveled that the Jahn-Teller deformation from C3v to C2v geometries takes a characteristic time of 20+/-7 fs for this system. Classical and quantum molecular dynamics simulations agree well with the measurement, and reveal dynamics for the build-up of the C2v structure involving complex revival process of multiple vibrational pathways of the CH4+ cation.

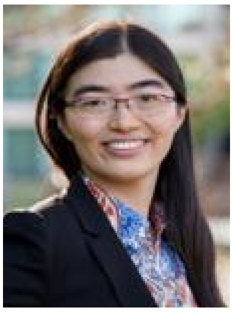
At the same time, we have proposed an analysis method for ultrafast diffraction imaging, which can be used to reconstruct the quantum state of molecular dynamics processes. And through external field control and quantum Zeno effect, we have achieved a selection of quantum states in the molecular dynamics process.

TBD

Ultrafast magnetization and coherent magnon dynamics in a 2D antiferromagnet $MnBi_2Te_4$

Luyi Yang
Tsinghua University

Atomically thin van der Waals magnetic materials have not only provided a fertile playground to explore basic physics in the two-dimensional (2D) limit but also created vast opportunities for novel ultrafast functional devices. Here we systematically investigate ultrafast magnetization dynamics and spin wave dynamics in few-layer topological antiferromagnetic MnBi2Te4 crystals as a function of layer number, temperature, and magnetic field. We observe laser-induced (de)magnetization processes that can be used to accurately track the distinct magnetic states in different magnetic field regimes, including showing clear odd-even layer number effects. In addition, strongly field-dependent antiferromagnetic magnon modes with tens of gigahertz frequencies are optically generated and directly observed in the time domain. Surprisingly, the magnetic state dependence and magnons are observed not only in time-resolved Kerr rotation and but also in time-resolved reflectivity measurements, indicating a strong correlation between the magnetic state and the electronic structure. These measurements present the first comprehensive overview of ultrafast spin dynamics in this novel 2D antiferromagnet, paving the way for potential applications in 2D antiferromagnetic spintronics and magnonics as well as further studies of ultrafast control of both magnetization and topological quantum states.



Prof. Luyi Yang received her B.S. in physics and mathematics from Tsinghua University (2007). She earned her Ph.D. in physics from the University of California at Berkeley (2013). Then she worked as a Los Alamos Director's Postdoctoral Fellow at the National High Magnetic Field Laboratory at Los Alamos. She became an Assistant Professor at the University of Toronto in 2016. She joined the Department of Physics, Tsinghua University as an Associate Professor in September 2019. Her research interests focus on the development of novel optical spectroscopies and their application to problems at the forefront of condensed matter and materials physics.

Time-resolved multi-electron coincidence spectroscopy: from gas towards liquid

Pengju Zhang
Laboratory for Physical Chemistry, ETH Zürich

The relaxation processes, originating from an inner-shell vacancy induced by high-energy photons, can lead to emissions that are either radiative or non-radiative in nature. In the latter case, the unstable vacancy is filled by a valence electron and the extra energy liberates another valence electron. Depending on the amount of released energy, this autoionization can be initiated either locally within the system via so-called Auger-Meitner (AM) decay or nonlocally between adjacent spatially separated entities through interatomic (intermolecular) Coulombic Decay (ICD). The interest in and significance of studying these ultrafast processes originate from the prominent role that electron correlation plays in the two cases. Here, we introduce a lab-based technique so-called time-resolved multi-electron coincidence spectroscopy to this endeavor. We applied it to unfold the dynamics of double AM emissions following Xenon 4d photoionization, extracting the lifetime of the transiently populated Xe2+ ∗ state for the first time. Furthermore, we extended its utilization to investigate the relaxation dynamics of liquid water following inner-valence ionization, verifying the presence of ICD and its interplay with proton transfer within the relaxation process. This methodology reveals the potential of ultrafast spectroscopy based on table-top high-harmonic-generation source to understand dynamics of multiple cascaded radiationless decay processes in atoms, molecules and solutions.

Pengju Zhang received his MS and PhD degrees from the Institute of Modern Physics, Chinese Academy of Sciences in AMO physics in 2013 and 2016, respectively. He worked as a postdoctoral researcher at the Atomic, Molecular & Optical Physics Laboratory, RIKEN from 2013 to 2016. Since 2018, he joined in the group of Ultrafast Spectroscopy and Attosecond Science, ETH Zürich as a postdoctoral researcher. His current research interests include time-resolved electron-electron coincidence spectroscopy, liquid micro-jet (round & flat), electronic structure of liquid water, dynamics of Auger-Meitner (AM) decay and interatomic (intermolecular) Coulombic Decay (ICD) in both gas and liquid phases, extreme-ultraviolet time-resolved photoelectron spectroscopy (XUV-TRPES), non-adiabatic excited-state dynamics in both gas and liquid phases, evolution of Fano resonance in benchmark atomic and molecular systems.

High harmonics in classical ultrafast studies of non-adiabatic dynamics and quantum squeezing generation

Konstantin Dorfman[1,2*]
1Center for Theoretical Physics and School of Sciences, Hainan University
2State Key Laboratory of Precision Spectroscopy, East China Normal University

We will discuss a novel method for monitoring electronic coherences using ultrafast spectroscopy. This method is based on the time-domain high-order harmonic spectroscopy where a coherent superposition of the electronic states is first prepared by the strong optical laser pulse using a three-step mechanism. The coherent dynamics can then be probed by the higher order harmonics generated by the delayed probe pulse. A a semi-perturbative model based on the Liouville space superoperator approach is developed for the bookkeeping of the different orders of the nonlinear response for the high-order harmonic generation using multiple pulses. Coherence between bound electronic states is monitored in the harmonic spectra from both the first and the second order responses and investigate nonadiabatic dynamics of conical intersections and avoided crossings. Furthermore, the nature of the multi-wave mixing in high harmonic regime allow to modify the statistics of light and give rise of quantum squeezing between higher harmonics suitable for higher signal-to-noise ratio measurements of electronic properties in multi-eV range.

TBD

High-repetition-rate,few-cycle pulse compression and wavelength-tunable UV dispersive-wave generation in hollow-capillary fiber

Meng Pang
Shanghai Institute of Optics and Fine Mechanics, CAS

Hollow-core fiber is a good platform to study nonlinear gas-light interactions, especially important for generating high-quality laser pulses with ultrashort pulse durations and broad wavelength-tuning range. In this talk, we demonstrate our recent work in this field, including a pulse-compression set-up that can deliver few-cycle, hundreds-of-uJ pulses at 10~100 kHz repetition rate and the a dispersive-wave-emission set-up that can generate ultraviolet ultrshort pulses with tunable central wavelengths from ~200 to ~400 nm.

Meng Pang graduated from Tianjin University (with bachelor degree), Tsinghua University (with Master degree) in 2004 and 2007 and HongKong PolyU (With PhD degree) in 2011. Then, he worked at University of Ottawa, Canada as a postdoc fellow from 2011 to 2013, and from 2013-2019 he worked in Russell division, Max-Planck Institute for Science of Light (MPL), Germany. He joined Shanghai Institute of Optics and Fine Mechanics (SIOM, CAS) as senior researcher and professor in 2019. His research topics include nonlinear fiber optics, photonic crystal fiber and ultrafast fiber laser. Until now, he published more than 40 journal papers, including Nature Photonics, Nature Communications, Light S&A, Optica and Laser & Photonics Reviews.

Intense, highly monochromatic high-order harmonics from gallium plasma

Tsuneyuki Ozaki
Institut national de la recherche scientifique – Centre Énergie Matériaux Telécommunications

High-order harmonic generation (HHG) is an excellent tabletop source of coherent extreme ultraviolet and soft X-ray radiation. Since high-order harmonics are intrinsically generated in attosecondbursts, it is also opening a new domain of attosecond science. The HHG process from most nonlinear media is well explained by the three-step model. However, for some media (such as the laser ablation plume), the intensity of a specific harmonic order could be enhanced by one to two orders of magnitude compared with the neighbouring harmonics generated due to the conventional three-step process. This has been observed when the wavelength of a harmonic is in close proximity to an autoionizing resonance of the nonlinear medium. In this talk, I will first review past works on HHG from laser ablation plume, and then present our recent studies on intense and highly monochromatic high-order harmonics from gallium plasma.

Experiments were performed at the Advanced Laser Light Source (ALLS) facility of the INRS. In these experiments, we used the second harmonic of the Ti:sapphire laser to pump the gallium laser ablation plume. Ga+ (ionization potential Ip = 20.52 eV) exhibits a strong resonance in the photoionization cross-section, with a magnitude of 300 Mbar centred at 21.9 eV, corresponding to the strong radiative transition 3d104s2 1S0 → 3d94s24p 3P1. The state 3d94s24p 3P1 corresponds to the autoionizing state (AIS) of Ga+, and the electronic transition from AIS into the ground state 3d104s2 1S0 is resonant with 7 photons of the 400 nm laser field. We see an intense resonant harmonic (RH) at the 7th harmonic. Here, we define the experimentally observed enhancement ratio (ER) for the RH with the equation ER = 2Iq /(Iq − 2 + Iq +2), where Iq is the integrated intensity of RH having the qth order. The ER observed using the 400 nm pump laser is 714. The highest ER value reported so far is from indium plasma, generating an intense RH with an ER of ~100. Therefore, the ER of 714 observed in our experiment is the highest value reported so far using the LAP technique, making gallium LAP a source of intense RH with unprecedented monochromaticity from a high-order harmonic source. The FWHM bandwidth of the generated 21.9 eV RH is 0.28 eV, which is broad enough to support a 6.5 fs pulse duration for a Fourier-transform limited pulse.

Tsuneyuki Ozaki (PhD) is a Professor at the Institut national de la recherche scientifique (INRS) near Montreal, Canada, serving from 2006 to 2012 as the Director of the Advanced Laser Light Source (ALLS), an international laser user facility. He joined the INRS as an Assistant Professor in 2003, after being a Research Associate at the Institute for Solid State Physics, University of Tokyo from 1990 to 2000, and a Research Specialist at Nippon Telegraph and Telephone (NTT) Basic Research Laboratories, Atsugi, Japan from 2000 to 2003. His main research interests include high-intensity THz radiation and its applications, intense high-order harmonic generation, and the use of lasers in medicine, biology and the environment.

Are Weyi fermions in Weyi semimetals are tryly massless

Gopal Dixit
Indian Institute of Technology Bombay

Dynamical spin-interlayer shear coupling in a van der Waals antiferromagnet

Faran Zhou[1*], Alfred Zong[2], Qi Zhang[3], Thomas Gage[4], Haihua Liu[4], Ilke Arslan[4], Donald Walko[4], Chong Wang[5], Kyle Hwangbo[5], Qianni Jiang[5], Jiawei Zhang[4], Jiun-Haw Chu[5], Richard Schaller[4], Nuh Gedik[6], Xiaodong Xu[5], Di Xiao[5], Haidan Wen[4]

1Institute of Physics, Chinese Academy of Sciences
2.University of California Berkeley
3.Nanjing University
4.Argonne National Laboratory
5.University of Washington
6.Massachusetts Institute of Technology

Interlayer interactions in van der Waals (vdW) materials, though much weaker than the intralayer covalent bonding, have played vital roles in determining materials' properties. Of particular, in vdW magnetic materials, interlayer coupling has been shown to affect the transition temperature and long-range magnetic order. To clarify the role of interlayer coupling in the formation of magnetic order, we performed ultrafast pump-probe measurements to study the interlayer spin-lattice coupling in a prototype vdW antiferromagnet FePS3. In relatively long timescales (ns to μs), using time-resolved optical polarimetry and x-ray diffraction, we discovered an interlayer shear motion whose relaxation is synchronized to the recovery of antiferromagnetic order in FePS3, direct evidence of the strong coupling between the two degrees of freedom. Such synchronized relaxation is not seen in the other lattice parameters (a, b, c) but only seen in the monoclinic angle β. This is explained by a Ginzburg-Landau model which considers the symmetry of the zigzag antiferromagnetic order. In ultrafast timescales (fs to ps), we observed a pronounced interlayer shear oscillation with ultrafast electron microscopy. The oscillation amplitude is huge in the antiferromagnetic phase but decreases drastically above the Néel temperature, indicating a strong coupling between the acoustic oscillation and magnetic order. Since ultrafast demagnetization occurs in sub-picosecond while the acoustic oscillation happens in tens of picosecond or longer, such coupling can be seen as a shear acoustic oscillation triggered by ultrafast demagnetization, a phenomenon that has been less explored in antiferromagnets so far. The strong spin-interlayer shear coupling demonstrated here can be applied for acoustic cavities whose amplitude and quality factor can be readily controlled by the magnetic order, paving the way for nanomechanical applications in the gigahertz band.

Dynamics and Artificial Control of Triplet Excited States in DNA

Jinquan Chen[1*]
1State Key Laboratory of Precision Spectroscopy, East China Normal University

DNA is the carrier of genetic information for life on Earth. Ultraviolet radiation (wavelength <400nm) from sunlight is recognized as one of the most widespread and threatening damages to life on Earth. Although the yield of the triplet excited state induced by UV in DNA is low(10-5-10-3), it has been shown to be the starting point of DNA photo-damage. Clarifying the chemical reaction kinetics of the triplet state involved in DNA photo-damage can help understand the starting steps of DNA photo-damage from the source, and has been at the forefront of research in photo-biochemistry. We studied the reaction kinetics of the triplet state in DNA with the goal of deciphering the mechanism of UV-induced excited-state chemistry and regulating the reaction processes. We broke through the detection sensitivity of conventional ultrafast spectroscopy techniques and achieved real-time monitoring of the triplet excited state dynamics induced by UV in the DNA system.[1-2] We proposed the mechanism of intramolecular charge transfer state to promote ultrafast intersystem crossing in DNA and revealed the effect of epigenetic modifications on the triplet excited state in DNA. [3-5] We also designed and developed new drugs targeting DNA and achieved preliminary artificial regulation of the triplet excited state in DNA. [6-9] Our research has deepened the understanding of the mechanism of UV-induced DNA photo-damage, and laid the foundation for the prevention of related diseases and the development of subsequent drugs.

Auger-assisted secondary hot carrier transfer in a type I $MoS_2/PtSe_2$ heterostructure

Yang Jin[1], Gong Shaokuan[1], Zhang Xiaguang[2], Liu Jianxun[1], Luo Wen[1], Lu Zhouguang[1], Liu Yanjun[1], Chen Xihan[1], Lienau Christoph[3], Zhong Jin-hui[1*]

1. Southern University of Science and Technology

2.Key Laboratory of Green Chemical Media and Reactions, Ministry of Education, Collaborative Innovation Center of Henan Province for Green Manufacturing of Fine Chemicals, College of Chemistry and Chemical Engineering

3.Institut für Physik, Carl von Ossietzky Universität

Based on the mature understanding of the carrier dynamics in type II heterostructures, many functional materials with excellent electronic and optoelectronic properties have been constructed by stacking two-dimensional materials. However, the dynamics and mechanism of hot carrier transfer in type I heterostructure remains elusive. Particularly, it is not clear whether such hot carrier transfer from small to large bandgap layers can be realized in a type I TMD/TMD heterostructure. If so, how fast will this process be and what are the underlying microscopic transfer mechanisms? Addressing these fundamental questions will be highly beneficial for the design of novel optoelectronic materials/devices with new functionality. In this work, we utilized transient absorption spectroscopy to study the carrier dynamics of a type I heterostructure constructed with 1L MoS2 and 2L PtSe2 (Figure 1). By exclusively exciting the small bandgap PtSe2, we observed clear exciton peaks of MoS2 that directly probes the primary hot carrier transfer from PtSe2 to MoS2 within 70 fs, with a quantum efficiency of 34%. Importantly, we also found a secondary charge transfer process at delays of several tens of picosecond, which we attribute to hot carriers that are regenerated in the PtSe2 by intralayer Auger scattering. Moreover, we observed a continuous blue shift of the exciton peaks within 100 ps, which probes the dynamic buildup of an internal electric field across the heterostructure interface. These results are rationalized by coupled rate equation calculations and transient absorption spectra simulations. Our work uncovers two-step (primary and secondary) charge transfer processes and reveals Auger-assisted hot carrier transfer mechanism in type I heterostructures. This finding suggests the possibility for designing optoelectronic and photocatalytic devices by optical sub-bandgap excitation in type I heterostructures made of two-dimensional materials, largely expanding the scope of their applications. In addition, the observed charge transfer from small to large bandgap materials may stimulate the exploration of new ultrafast hot carrier photo-physics/chemistry of type I heterostructure.

Figure 1. Secondary charge transfer in the heterostructure. (a-b) Comparison of TA spectra of the MoS2/PtSe2 heterostructure with 800 nm pump excitation (a) and of 1L MoS2 with 400 nm pump excitation (b); (c-d) Dynamics of negative exciton bleaching peaks in MoS2 (solid black lines) and the MoS2/PtSe2 heterostructure (solid red lines) probed at 1.86 eV (A exciton) and 2.0 eV (B exciton), respectively; (e-f) Dynamics of the peaks at the low energy sides of the A and B exciton resonances in MoS2 and MoS2/PtSe2 probed at 1.80 eV and 1.93 eV, respectively. All four transients of the heterostructure (c-f) displays a secondary increase in signal amplitude in stage III, the signature of an Auger-assisted secondary charge transfer from PtSe2 to MoS2.

Dynamics and Artificial Control of Triplet Excited States in DNA

Zi Wang
Xian Zhongke Micro-precision Photonics Manufacturing Technology Co, Ltd

Track 6- Ultrafast Particle Science Technology and Application

Ultrafast Neutron Source driven by intense laser pulses

Bin Qiao
Peking University

Compared with charged particles and X-rays, uncharged neutrons have unique penetration and detection capabilities. Neutron-based scattering and diffraction methods are used in a wide range of fields such as medicine, materials science, and energy security. The ultrafast neutron source driven by intense lasers has the characteristics of small size, short pulse duration, high peak flux and high spatial and temporal resolution, which, brings novel advantages in many prospective applications such as fast neutron radiography, radiation therapy and others. Therefore, investigations of ultrafast neutron source driven by intense laser pulses have aroused broad interest recently. Among the various configurations of laser-driven neutron sources, the beam target configuration (Pitcher-Catcher) , which can control the energy range, pulse duration, direction and other characteristics of the neutron source product by selecting proper laser ion acceleration mechanisms and different nuclear reaction processes, is currently the most widely studied and concerned configuration. This talk will introduce the latest theoretical and experimental research progress of laser-driven ultrafast neutron sources at Peking University, and explore the unique advantages of laser-driven neutron sources in various applications.

Bin Qiao is a full professor, Boya Distinguished Professor at School of Physics, Dean of the Institute of Advanced Technology, in Peking University. He is also the winner of the National Science Fund for Distinguished Young Scholars, chief scientist of the National Key R&D Program, council member of the Computational Physics Branch of the Chinese Nuclear Society, deputy editor-in-chief of the Fusion and Plasma Physics Department of Journal "Frontiers in Physics", and editorial board member of the Journal "Journal of Intense Lasers and Particle Beams". He is mainly engaged in theoretical and experimental research on plasma physics and high energy density physics, and has achieved a series of internationally influential results in research on inertial confinement fusion energy, laboratory astrophysics, new particle and radiation sources driven by intense lasers. He has published more than 150 SCI papers in important academic journals such as Nature Physics and Phys. Rev. Lett.

Ultra-bright sources of MeV particles and radiation based on direct laser accelerated electrons

Olga N. Rosmej[1,2]
1GSI Helmholtzzentrum für Schwerionenforschung GmbH
2Goethe University

Direct laser acceleration (DLA) of electrons in plasma of near critical density (NCD) is used to generate ultra-bright sources of MeV particles and radiation. Low-density polymer foam was converted in NCD plasma by an additional ns pulse. In experiments with the PHELIX at ~ 1019 W/cm2 intensity, we were able to demonstrate the generation of ultra-bright Bremsstrahlung with photon energies of up to 50-60 MeV and a record-breaking conversion efficiency of 2-3 % for photons > 7.5 MeV (giant dipole resonance); Record neutron production efficiency in gamma-driven nuclear reactions; ultra-intense betatron radiation and enhanced proton acceleration. DLA proves to be very robust and can be used to generate ultra-bright laser-driven particle and photon sources with energies of tens of MeV already at moderate relativistic laser intensity, which is typical for large kJ-class PW laser facilities used in ICF research.

Olga Rosmej is a senior scientist at GSI Darmstadt and professor at the Goethe University Frankfurt, Germany. After studying in Moscow, where she received her PhD in experimental plasma physics from the Kurchatov Research Center, she continued her career in Germany and completed her habilitation in 2012 at the Goethe University in Frankfurt am Main, where she is currently a professor at the Institute for Applied Physics. Her research interests include x-ray spectroscopy, physics of heavy ion interaction with plasmas, laser-plasma interaction, secondary laser-based photon and particle sources, nanostructured materials and applications. She has been principal investigator of 25 international and national experimental projects with intense heavy ion and laser beams and has more than 100 publications in peer-reviewed journals.

Laser-driven sources of ultra-relativistic electrons and MeV gammas

Nikolay E. Andreev[1,2]

1Joint Institute for High Temperatures, Russian Academy of Sciences
2Moscow Institute of Physics and Technology (State University)

Intense beams of photons and particles in the MeV energy range are effective tools in many areas of research, such as the creation and diagnostics of matter in extreme states in experiments on CTS, nuclear physics and materials science, as well as in other applications. Various processes of laser-plasma acceleration of electrons are considered, starting with the mechanism of wakefield acceleration in the regime of self-modulation of a laser pulse [1]. This mode of generation of ultrarelativistic electrons underlies the creation of a platform for diagnosing compressed target matter in a number of large laboratories conducting research in the field of thermonuclear fusion with inertial confinement [2].

A more efficient concept for creating sources of γ-radiation and neutrons based on the generation of relativistic electrons in the regime of direct laser acceleration is currently being discussed. PW-class laser systems capable of generating subpicosecond and femtosecond pulses focused to ultrarelativistic intensity, are good candidates for creating high-current beams of ultrarelativistic electrons in an extended plasma with a density close to critical [3, 4], which was confirmed in experiments [5].

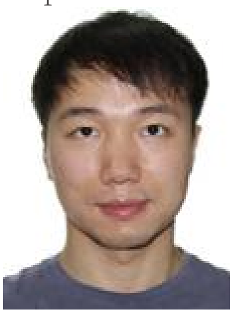
The dependences of the parameters of laser-generated electron bunches and hard radiation on the laser radiation intensity and plasma density for subpicosecond and femtosecond laser pulses are obtained and analyzed taking into account current and future experiments [5, 6, 7]. The developed approach indicates the possibility of a significant increase in the efficiency of existing kJ PW class laser systems used for research in the field of thermonuclear fusion with inertial confinement, and can be applied to improve the efficiency of a wide class of secondary laser sources, such as sources of electrons, positrons, betatron and bremsstrahlung radiation, protons and neutrons sources for various purposes.

TBD

Metrology and development of coherent XUV sources

Lu LI
Shenzhen Technology University

Ultrafast coherent extreme ultraviolet (XUV) sources are adequate to capture dynamics in molecules, surfaces, and materials at the atomic timescales. The primary challenges for the XUV sources to ensure nano- femto-imaging are pulse energy, pulse duration, beam coherence and wave front. Based on our newly developed high numerical aperture XUV Hartmann wave front sensor, we studied the spatial properties of XUV beam from free electron laser (FLASH) and the high harmonics from relativistic plasmas. Current talk included both numerical and experimental results on the XUV focusing, source characterization and plasma diagnostics. Finally, a brief introduction of the XUV source lab establishment at Shenzhen Technology University will be presented.



Dr. Lu LI received his PhD from Ecole Polytechnique (France) in 2015. He has been engaged in postdoctoral research at Queen’s University Belfast (UK) and the Helmholtz Institute Jena (Germany) for more than three years. From 2018 to 2019, he worked at the Singapore Agency for Science, Technology and Research (SIMTech, A*STAR). In middle of 2019, he joined Shenzhen University of Technology. His research topic is on the ultrafast coherent extreme ultraviolet sources. The main physical mechanisms of related light sources include high harmonic generation from gas and surface plasmas, as well as seeded soft X-ray lasers.

Ultrafast free-electron laser based on laser wakefield accelerator

Wentao Wang, Ke Feng, and Ruxin Li
Shanghai Institute of Optics and Fine Mechanics (SIOM), Chinese Academy of Sciences (CAS)

Free-electron lasers (FELs) are essential tools for studying ultrafast chemistry, ultrafast physics, and dynamic imaging of biological structures. Laser wakefield accelerators (LWFA) can sustain accelerating gradients more than three orders of magnitude higher than those of radio-frequency accelerators, and are regarded as an attractive option for driving compact X-ray FELs. The research team from SIOM present an experimental demonstration of undulator radiation amplification in the exponential-gain regime by using electron beams based on an LWFA. The amplified undulator radiation, which is typically centred at 27 nanometres, yields a maximum radiation energy of about 150 nanojoules and a femtoseconds level pulse width. Currently, various attosecond-level FEL schemes based on LWFA have been proposed, which will greatly contribute to the advancement of ultrafast science.

Wentao Wang is a professor of Shanghai Institute of Optics and Machinery, Chinese Academy of Sciences. He is winner of the National Outstanding Youth Fund. His research interests include laser wakefield electron accelerator and compact radiation sources, with a preference for experimental physics. He and his colleagues have published more than 70 papers in Nature, Physical Review Letters and others. He was awarded “2021 Wang Daheng Optical Award”, “2016 China Optical Important Achievement Award”, “2019 Excellent Member of Youth Innovation Promotion Association, Cas” and other honors.

Atomic and nuclear processes in laser-accelerated intense ion beam interaction with dense plasmas

Jieru Ren
Xi'an Jiaotong University

Dense plasma widely exists in our universe and is the intermediate state of matter in inertial confinement fusion. Laboratory research into dense plasma is of great importance for astrophysics as well as fusion sciences. Various models are developed to describe the basic processes in dense plasma. However, the experimental data are scarce for the model benchmark, because research into the matter under extreme conditions represents a frontier of experimental techniques, and requires infrastructure at the most technologically advanced level. A well-defined, uniform, relatively large-scale ~millimeter plasma sample was generated through heating a Tri-Cellulose Acetate (TCA) foam with the high-power-laser-driven hohlraum radiation and was applied in the investigation of the energy loss, charge transfer, radiation and proton-boron nuclear reaction processes in laser-accelerated intense ion beam interaction with dense plasmas. The main findings are as follows.

1) we studied the laser-accelerated intense proton beam stopping process. It was demonstrated that owing to a collective effect, the energy loss is enhanced by about one order of magnitude compared to individual ion stopping theory predictions [Nat. Commun. 11, 5157 (2020)];

2) The temperature and the C/O ratio of the plasma sample are similar to those of White Dwarf (WD) H1504+65's atmosphere. We obtained the well-resolved emission lines of the plasma sample and make detailed comparison with Chandra telescope observations. Our well-resolved results help to distinguish the weak lines and provide reference data to benchmark the related models [Astrop. J 920, 106 (2021)];

3) We observe the average charge states passing through the plasma to be higher than those predicted by the commonly used semiempirical formula. Through solving the rate equations, we attribute the enhancement to the target density effects, which will increase the ionization rates on one hand and reduce the electron capture rates on the other hand. For the first time, we are able to experimentally prove that target density effects start to play a significant role in plasma near the critical density of Nd-glass laser radiation [PRL 130, 095101 (2023)];

4) A novel intense beam-driven scheme for high yield of the tri-alpha reaction 11B(p,α)2α was investigated. We observed up to 1010/sr alpha particles per laser-shot. This constitutes presently the highest yield value normalized to the laser energy on target. The measured fusion yield for per proton exceeds the classical expectation of beam-target reactions by three to four orders of magnitude under high proton intensities. We attribute this enhancement to the resulting strong electric fields and the induced non-equilibrium thermo-nuclear fusion reactions between boron and protons of the target plasma [arXiv:2308.10878 (2023)].

PERSONAL DATA

Name: Jieru Ren
Affiliation: Xi'an Jiaotong University
Position: Associate professor
Email: renjieru@xjtu.edu.cn
Research fields: High energy density physics, plasma physics

EDUCATION & EMPLOYMENT

- [2006.09] – [2010.07]: Bachelor, Xi’an Jiaotong University, Xi’an, China
- [2010.09] – [2016.07]: PhD , Institute of Modern Physics (IMP), Chinese Academy of Sciences ,Lanzhou ,China, location
- [2013.11] – [2015.7]: visiting scholar, GSI Helmholtzzentrum für Schwerionenforschung , Darmstadt, Germany
- [2016.07] – [2020.04]: assistant professor , Xi’an Jiaotong University, Xi’an, China
- [2020.04] – [present]: associate professor , Xi’an Jiaotong University, Xi’an, China

Quantum Splitting of Electron Peaks in Ultra-Strong Fields

Bo Zhang
Laser Fusion Research Center

Effects of multiple nonlinear Compton scatterings on electrons in ultra-strong fields are described analytically. Based on this analytic theory, a new pure quantum effect of multiple nonlinear Compton scattering called quantum peak splitting is identified: the electron peak splits into two when the average number of nonlinear Compton scatterings per electron passes the threshold of ~5.1 and is below ~9. One of the split peak is formed by electrons emit 0-3 times and the other is formed by electrons emit ⩾ 4 times. This new effect provides a new mechanism to form electron peaks, puts a new beamstrahlung limit on future colliders and corrects the picture of quantum radiation reaction. Experiment can be performed on lasers with intensity ⩾ 1021W/cm2, which is reachable on PW scale facilities. This new phenomenon can be employed as an in-situ, prepulse insensitive and comparatively precise method to measure the intensity of 0.3-10 PW ultra-strong lasers.

Bo Zhang（张博）is from Laser Fusion Research Center, and his field of research is strong field quantum electrodynamics. He predicted and named vacuum radiation, which is emitted by imaginary electron loops extract energy from time varying electric field in vacuum (Phys. Lett. B 767, 431(2017).). He improved the model of nonlinear Compton scattering and nonlinear Breit-Wheeler process in LCFA by including the energy of involved laser photons into consideration (Sci. Rep. 8, 16862 (2018)). He also proposed and named a new principle of particle acceleration called quantum acceleration, in which electrons/positrons/gammas absorb the energy of a vast number of laser photons in NCS/NBW and generate high energy particles through these quantum processes (Sci. Rep. 9, 18876 (2019)).

Theoretical Studies on the Ultrafast Decay Mechanism of Excited States of Metallofullerenes

Tao Yang
School of Physics, Xi'an Jiaotong University

The electronic excited state dynamic process of metallofullerene widely exists in its photophysical or photochemical process. From a basic research perspective, metallofullerene is a typical three-dimensional quantum many-body system. Studying its electronic excited state dynamics will promote the understanding of the excitation/decay dynamics of quantum many-body systems in radiation environments such as strong lasers and high-energy electron beams. From a perspective of practical applications, when metallofullerenes were applied to functional devices including single-molecule quantum devices, organic photovoltaic devices, and catalytic devices, their electronic excited state dynamics process plays an important role in its photoelectric conversion efficiency, catalytic efficiency, etc. In this talk, we will report the ultrafast electronic excited state decay process of the metallofullerenes Be@C60 and Lu2@C76 by using the time-dependent Kohn-Sham (TDKS) method based on the Kohn-Sham orbital approximation. Through detailed comparison and analysis, the influence of orbital energy level and fullerene cage size on the decay mechanism was revealed.

Prof. Tao Yang got his PhD degree from Xi'an Jiaotong University in 2014 and then worked as a postdoctoral fellow at the Institute of Molecular Science in Japan and the University of Marburg in Germany. Since 2019, he has become the Professor in Xi'an Jiaotong University. His research interest focuses on ab initio calculations on the structures, dynamics, and properties of carbon-based clusters. Up to now, he has published more than 60 papers in international academic journals and was awarded by Humboldt Fellowship, Institute of Molecular Science Fellowship, and Xi'an Jiaotong University Youth Talent Support Program.

High spatiotemporal resolution diagnosis for laser plasma by femtosecond laser

Dacheng Zhang*, Zhongqi Feng, Hanxing Ge, Jiajia Hou
School of Optoelectronic Engineering, Xidian University

The high spatiotemporal resolution diagnosis for transient evolution behavior of laser plasma has acquired great interests in recent years [1]. The measurement of plasma parameters such as the species distribution and evolution with high spatiotemporal resolution is significant for understanding the evolution of plasma, high energy density physics, laser-induced breakdown spectroscopy (LIBS), and so on. Optical method has become popular in the measurement of plasma for its high sensitivity and real-time process [2]. It allows fast contact-less analysis and has unique versatility and capabilities for real-time composition determination. However, it is difficult to investigate inner state plasma by conventional spectral method for the spectra integrated the spatial and even temporal information. Femtosecond filamentation and supercontinuum (SC) laser provide a high spatiotemporal resolution spectroscopy probe for diagnosing plasma. In our work, the femtosecond filamentation laser-induced breakdown spectroscopy (FIBS) technology was employed for high spatiotemporal resolution diagnosis of laser plasma. A Nd:YAG laser was used to produce plasma on the sample. A plasma channel formed by femtosecond filamentation probe was used to detect different regions of the plasma generated by nanosecond laser. The species distribution spectrum of plasma was obtained, as shown in Figure 1a. For the fine diameter and short pulse duration of femtosecond filamentation, the spatial resolution of FIBS can be better than 100 μm, and the temporal resolution about tens of femtoseconds can be obtained. The femtosecond laser has also been demonstrated as a powerful tool for studying atomic and molecular dynamics [3]. The SC laser was generated by nonlinear effects of femtosecond laser propagating in medium, and then the plasma was irradiated by SC laser at different delay times. When the femtosecond SC laser with wider spectrum (up to hundreds of nanometers) was generated and probe the laser plasma, multiple atoms and molecules in laser plasma can be detected simultaneously. For its wide spectrum and short pulse duration, the formation and dissociation of molecules, the evolution of ions and atoms in plasma are all can be studied. As shown in Fig.1b, the plasma evolution spectra at different delay time were detected by SC laser. In the early stage of plasma evolution, the significant changes in atomic and ion emission lines such as Ca II 396.7 nm and Ca I 422.7 nm indicated their higher particle density. With the cooling of plasma, the CaO molecular band was significantly affected by SC laser after 4.0 μs delay, which mean the CaO molecules were formed for the combination of Ca atoms and oxygen atoms in the plasma at this point. From above results, it can be found that femtosecond filamentation and supercontinuum laser provide new tools for studying the high spatiotemporal distribution characteristics and evolution process of laser plasma.

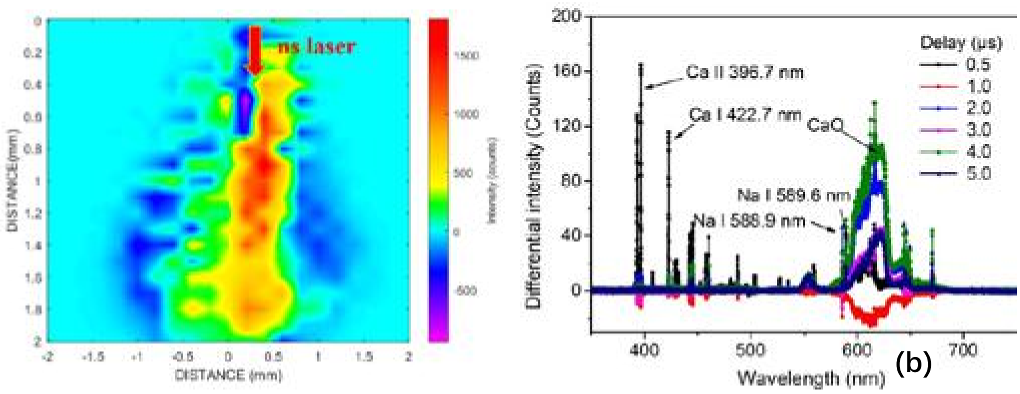


Fig. 1. (a) Species distribution FIBS spectrum of plasma and (b) plasma evolution spectra by femtosecond supercontinuum laser probe.

Hybrid DLA-LWFA acceleration of electrons in near-critical density plasma

Diana Gorlova[1,2*], Ivan Tsymbalov[1,2], Konstantin Ivanov[1,3], Ekaterina Starodubtseva[1], Roman Volkov[1], Ilia Tsygvintsev[4], Andrei Polonski[2], Andrei Savel'ev[1,3]
1Faculty of Physics, M.V. Lomonosov Moscow State University
2Institute for Nuclear Research of the Russian Academy of Sciences
3P.N. Lebedev Physical Institute
4Keldysh Institute of Applied Mathematics

It has been experimentally demonstrated that the interaction of a femtosecond laser pulse with 1 TW peak power and intensity of 5x1018 W/cm2 (a0=1.5) with a several hundred microns plasma layer with an 0.1ne/ncr electron density leads to the generation of an electron beam with a charge of tens to hundreds of pC, an exponential spectrum with an average energy 2-3 MeV, angular width 0.1-0.3 rad in the direction of laser pulse propagation. Near-critical layer was created through ablation of 16 μm mylar tape with additional controlled nanosecond prepulse (intensity ~1012 W/cm2).
Using 3D PIC simulations, it has been established that electrons are accelerated via hybrid acceleration mechanism: direct laser acceleration - self-modulated wakefield acceleration (DLA-SM-LWFA). The injection mechanism is a combination of ionization injection and wavebreaking of SRS plasma waves. It is shown that, due to hard focusing and relativistic self-focusing, the laser pulse has a longitudinal field EA,x of significant amplitude (a0~0.05-0.1). Thus, to correctly establish electron acceleration mechanism, it was necessary to separate the fields into curl-free and divergence-free components.
Regime of interaction in question can in principle be reproduced on the state-of-art kHz laser facilities. Further simulations indicate that electron beam charge increases nonlinearly with laser pulse energy, with the possibility to achieve collimated beam with 1 nC charge (E>1 MeV) with increase in a0 from 1.5 to 5, which can also easily be reached on modern experimental setups.
Near-critical plasma, direct laser acceleration, laser wakefield acceleration, terawatt laser

Directly imaging excited state-resolved transient structures of water induced by valence and inner-shell ionization

Z. Wang[1], X. Hu[2], X. Xue[3], S. Zhou[1], X. Yu[1], Y. Yang[1], J. Zhou[3], B. Zhao[1], Z. Shu[2], M. Gong[4], Z. Wang[4], X. Li[1], P. Ma[1], Y. Wu[2], J. Wang[2], X. Ren[3], C. Wang[1] and D. Ding[1]

1Institute of Atomic and Molecular Physics, Jilin University
2Institute of Applied Physics and Computational Mathematics
3 School of Physics, Xi' an Jiaotong University,
4Department of Modern Physics, University of Science and Technology of China

Capturing the transient position of nuclei with sub-Angstrom and femtosecond spatiotemporal resolution for a specific electronic state can visualise the ultrafast structural dynamics of polyatomic molecules, which is a key step towards a better understanding and controlling of the chemical reaction. The CEI was developed decades ago to study the molecular structure by ionising the target to a highly charged state upon various radiation sources. The molecular structure prior to Coulomb explosion (CE) can be reconstructed from the momentum information of all the fragments in the molecular frame of reference. Benefited from the ion momentum imaging technique, CEI has equal sensitivity for the probing of light and heavy atoms. However, retrieval the accurate electronic-state resolved structure of molecules with CEI is still elusive.

By developing the laser-induced electron recollision-assisted Coulomb explosion imaging approach and molecular dynamics simulations, snapshots of the vibrational wave-packets of the excited (A) and ground states (X) of D2O are captured simultaneously with sub-10 picometer and few-femtosecond spatiotemporal precision. We visualized that bond length and angle are significantly increased by around 50° and 10 pm, respectively, within 8 fs after initial ionisation for the A state of cation, and the ROD further extends 9 pm within 2 fs along the ground state of the dication. Moreover, the ultrafast nuclear relaxation along the autoionisation state of dication has been studied, where the ROD can stretch more than 50 pm within 5 fs after double inner-shell ionisation induced by electron impact[Nat. Commun. 14, 5420 (2023)].

These results provide comprehensive structural information for studying the fascinating molecular dynamics of water, and show rich electronic states-resolved nuclei dynamics triggered by the inner-shell and valence level ionisation. Our studies pave the way towards to make a movie of excited state-resolved ultrafast molecular dynamics.

Extreme-ultraviolet (XUV) frequency comb and its applications in precision measurements

Xiaojun Liu
Innovation Academy for Precision Measurement Science and Technology (APM), Chinese Academy of Sciences (CAS)

Extreme-ultraviolet (XUV) frequency comb has led to a joint frontier of precision spectroscopy and ultrafast science since its first demonstration in 2005. In this talk, we will introduce the generation of an XUV frequency comb with the aid of intra-cavity high-harmonic generation (HHG) at APM, CAS. With this established XUV frequency comb, we are able to explore the strong field and ultrafast physics with an unprecedented laser repetition rate of 100MHz and to perform precision spectroscopic measurements of atoms and molecules in XUV regime. Some recent experimental progresses will be introduced.

Prof. & Dr. Xiaojun Liu, a principle investigator (PI) at Innovation Academy for Precision Measurement Science and Technology (APM, former Wuhan Institute of Physics and mathematics, WIPM), Chinese Academy of Sciences (CAS). Major research interests include: Ultrafast dynamics of atoms and molecules; Femtosecond optical frequency comb; Optical multi-dimensional coherent spectroscopy.

Large-scale lithium niobate integrated photonic circuits

Ya Cheng
Northweatern Polytechnical University

Terahertz spin currents resolved with nanometer spatial resolution

Xiaojun Wu
School of Electronic and Information Engineering, Beihang University

The ability to generate, detect, and control coherent terahertz (THz) spin currents with femtosecond temporal and nanoscale spatial resolution has significant ramifications. The diffraction limit of concentrated THz radiation, which has a wavelength range of 5 μm-1.5 mm, has impeded the accumulation of nanodomain data of magnetic structures and spintronic dynamics despite its potential benefits. Contemporary spintronic optoelectronic apparatuses with dimensions 100 nm presented a challenge for researchers due to this restriction. In this study, we demonstrate the use of spintronic THz emission nanoscopy (STEN), which allows for the efficient injection and precise coherent detection of ultrafast THz spin currents at the nanoscale. Furthermore, STEN is an effective method that does not require invasion for characterising and etching nanoscale spintronic heterostructures. The cohesive integration of nanophotonics, nanospintronics, and THz-nano technology into a single platform is poised to characterize the spin state at the micro-to-nanoscale density, accelerate the development of high-frequency spintronic optoelectronic nanodevices and other revolutionary technical applications.

Xiaojun Wu received his PhD degree in the Institute of Physics, Chinese Academy of Sciences. She joined in Beihang University in the May of 2017 after she completed his Humboldt postdoctoral research at DESY in Germany. In the past 10 years, she has been engaged in researches on ultrafast THz science, technology, and applications, especially focusing on generating high-energy high-field THz radiation and its applications, spintronic THz devices and systems. She has published >80 academic papers on top journals including Nature Photonics, Nature Communications, Optica, Advanced Materials etc, and given >40 keynote and invited talks on FiO, IRMMW-THz, UP, OTST, ISUPTW, POEM and so on. She was awarded the first Zhenyi Wang Award for Excellence for achievements in the development of high-power THz sources and the generation and manipulation of chiral THz waves by International Society of Infrared, Millimeter, and THz Waves: IRMMW-THz, the first Women in Ultrafast Science Global Award, and the first prize of the first China Science and Technology Youth Forum.

Dynamically Reconfigurable Terahertz Metadevices Enabled by MEMS

Xiaoguang Zhao
Tsinghua University

During the past decade, metasurfaces have emerged as a new paradigm in electromagnetism with a focus on creating ultrathin, planar optical devices. The integration of natural materials and micromechanical structures with metasurface unit cells can enhance their functionalities leading to dynamic responses, for example, frequency tunable responses, switching and modulation, and novel detectors, spanning from microwave to visible light. In this talk, I will present our recent research on the integration of metasurface and microsystems, from the fundamental physics to functional metasurfaces devices. I will start with an analytical model based on coupled mode theory to describe the metasurface response. Then, Advanced dynamic manipulation of the electromagnetic waves including group delay and polarization state actuated by MEMS actuators will also be presented. In addition, I will demonstrate that nonuniformly actuated metasurfaces with 2 phase coverage may convert the incident plane wave to surface wave. The synergy of microsystem and metasurfaces provides a platform to efficiently manipulate electromagnetic waves.

Xiaoguang Zhao (Ph.D.) is an Associate Professor in the Department of Precision Instruments at Tsinghua University. Dr. Zhao received his Ph.D. in Mechanical Engineering from Boston University and his M.E. and B.S degree from Tsinghua University. Dr. Zhao’s research interests include metamaterials, magnetic resonance imaging (MRI), terahertz science and technology, microelectromechanical system (MEMS), and RF circuits and system design. Dr. Zhao has more than 40 peer-reviewed journal publications, including Advanced Materials, Optica, ACS Photonics, etc. He holds 3 patents on metamaterials for MRI and wireless communication. Recently, Dr. Zhao developed intelligent magnetic metamaterials to enhance the signal to noise ratio of MRI by in excess of 10-fold. This work won the 2019 Institution of Engineering and Technology (IET) Innovation Awards. His published works on magnetic metamaterials for MRI have attracted more than 70 worldwide media reports, including Science Daily, Physics World, EurekAlert!, Medgadget, Radiology Business, etc.

Highly efficient octave-spanning long-wavelength infrared generation in a χ^2 waveguide

Houkun Liang
Sichuan University

The realization of integrated broadband mid-infrared (MIR) laser sources has enormous impacts
in promoting MIR spectroscopy for important applications such as molecular sensing and monitoring. On-chip MIR supercontinuum and frequency combs have been demonstrated based
on cubic nonlinearities, but unfortunately third-order nonlinear conversions inherently have low efficiencies. Here, we propose and demonstrate for the first time a χ (2) optical parametric integrated device based on birefringence phase matching with a high quantum efficiency and a low pump threshold. In a $ZnGeP_2$-based integrated waveguide, an octave-spanning spectrum covering 5 – 11μm is generated. A quantum conversion efficiency of 74% as a new record in MIR parametric processes is achieved, owing to the efficient χ (2) response, tight spatial/temporal confinement and elongated interaction length. The threshold energy of optical parametric generation is found to be as low as ~616 pJ, reduced by more than 1-order of magnitude as compared to the state-of-the-art MIR parametric conversions based on bulk media. Moreover, a universal fabrication technique for integrated nonlinear photonics is demonstrated with combined processes of nonlinear crystal bonding, χ (2) wafer lapping and ultrafast laser direct writing, which could be extended to other χ (2) birefringence crystals and trigger new frontiers of MIR integrated nonlinear photonics.

TBD

Polychromatic Soliton in Fiber Laser

Dong Mao
Northwestern Polytechnical University, China

By introducing the periodic group delay and phase modulations, we demonstrate multi-wavelength soliton compounds composed of similar and dissimilar solitons in a mode-locked fiber laser. The soliton properties can be actively managed by tuning the group delay function and phase amplitude. The synchronization and overlap of different solitons rely on the group-delay compensation and saturable absorption effect. This work opens an interesting direction in the study of laser mode-locking, and may facilitate applications of terahertz wave generation and nonlinear spectroscopy.

TBD

Attosecond photoionization time delays in atoms and molecules

Xiaochun Gong
State Key Laboratory of Precision Spectroscopy, East China Normal University

Attosecond chronoscopy is central to the understanding of ultrafast electron dynamics in matter from gas to the condensed phase with attosecond temporal resolution or even shorter. By developing the advanced attosecond coincidence interferometer, we proposed an idea of atomic partial wave meter in atomic photoionization and utilized it to resolve the pathway interference in the quantum interference black box. Based on the molecular frame construction, we further realized the angle-resolved photoemission observation from the viewport of the molecule itself by standing on each atomic element of the molecules. To bridge the gap between atoms/molecules and condensed matter, we developed a new technique named attosecond size-resolved cluster spectroscopy to probe the photoionization in small clusters by adding one fundamental unit each time. In this talk, I will briefly show our recent attosecond photoionization time delay measurements based on the attosecond coincidence metrology

Dr. Xiaochun Gong received his PhD in Optics from East China Normal University of shanghai China, in 2017, where he studied the electron-ion coincidence measurement in strong field physics with Prof. Jian Wu. He spent one year doing post-doc research in Prof. Hans Jakob Wörner's group at the ETHzürich, where he started his attosecond science research by constructing a new attosecond coincidence interferometer. He officially joined ECNU staff in 2017. He received the Fresnel Prize for fundamental aspect in 2023 for outstanding contributions to the field of attosecond science and for developing attosecond coincidence metrology to ultrafast photonics. Dr. Gong is interested in attosecond science from atoms to condensed matter with the help of the advanced attosecond metrology through 3D-momenta and/or optical spectroscopy.

Attosecond-resolved Non-dipole Electron Dynamics

Jintai Liang,[1] Meng Han,[2] Yijie Liao,[1] Jia-bao Ji,[2] Leung Chung Sum,[2] Wei-Chao Jiang,[3] Kiyoshi Ueda,[2,4] Yueming Zhou,[1] † Peixiang Lu,[1]Hans Jakob Wörner[2]

1School of Physics, Huazhong University of Science and Technology
2Laboratorium für Physikalische Chemie, ETH Zürich
3College of Physics and Optoelectronic Engineering, Shenzhen University
4Department of Chemistry, Tohoku University

The advanced attosecond technology has enabled measurement of the ultrafast electron dynamics in atom/molecule photoionization with unprecedented temporal resolution. However, only the electric dipole transition dynamics has been accessed. The non-dipole dynamics is not touched yet, mainly because the non-dipole effects are typically orders of magnitude smaller than that of the dipole contribution. All non-dipole observations reported so far are limited to single-pulse, single-color measurements. We advance attosecond time-resolved spectroscopy into the non-dipole interaction regime. Using a self-referenced attosecond photoelectron interferometry on helium atoms, we resolve the electron sub-cycle motion along the light propagation direction in the range of 15 picometers driven by the magnetic component of a near-infrared laser field. Furthermore, we measured a time delay of about 15 attoseconds between the electric dipole and quadrupole transitions in photoionization of helium by resolving the asymmetry of the photoelectron forward-backward yields with attosecond resolution. Our work opens a research direction of attosecond non-dipole physics.

Yueming Zhou is a professor in Huazhong University of Science and Technology. His research interest is the ultrafast dynamics in the intense laser-atom/molecule interaction. He has developed the theory of attosecond photoelectron holography in strong-field tunneling ionization, and demonstrated the application of attosecond photoelectron holography in probing the attosecond electron dynamics in atoms and molecules. He has also developed a classical ensemble model for studying the multiple-electron dynamics, which has been widely used in strong-field double and multiple ionization. Recently, he has focused on the nondipole electron dynamics in photoionization. He has more 110 publications, including 9 publications in Phys. Rev. Lett. He is winner of the National Outstanding Youth Fund, leader of the Young Scientist Project of the Key Research Program of the Ministry of Science and Technology, and a key member of the Innovation Group of the Fund Committee.

Ultrafast dynamics and phonon-assisted upconverted emission of 2D excitons

Pengfei Qi
Institute of Modern Optics, Nankai University, Tianjin Key Laboratory of Micro-scale Optical Information Science and Technology

Devices operating with excitons have special advantages on energy consumption, processing speed and integration, which can be expected to meet the demand of ultra-low power and high-speed integrated devices in the future information field. Owing to quantum confinement effect, reduced dielectric screening, enhanced Coulomb interactions and large exciton binding energy, 2D materials can provide an ideal platform for developing excitonic devices at room temperature. Firstly, limited by the ultrashort lifetime and low carrier mobility, the long-range directional transport and corresponding ultrafast dynamics of excitons become a critical science problem in the frontier of excitonic devices. We have explored the regulation of grain boundary on the long-range transport and ultrafast dynamic for the 2D excitons, and clarify physical mechanism behinds the limits of phonon scattering and exciton localization on 2D excitons diffusion. Secondly, due to limited interaction distance between excitation photons and TMDC monolayer, the efficiency of phonon-assisted upconversion for 2D excitons is too weak for applications like optical refrigeration, we have realized the upconversion enhancement in doubly resonant plasmonic nanocavity and twisted bilayer.

Pengfei Qi is an associate professor in the Institute of Modern Optics, Nankai University, China. Focusing on the ultratast dynamics and devices of 2D excitons, he has achieved outstanding results recently. As the first/corresponding author, he has published more than 20 academic papers in high-impact journals such as Light: Science & Applications, ACS Nano, eLight, Small.

R&D of the fast microchannel plate photo multiplier tube

Ping Chen
Xian Institute of Optics and Precision Mechanics,CAS

Triple ionization and fragmentation of benzene trimers following ultrafast intermolecular Coulombic decay

Jiaqi Zhou[1], Sizuo Luo[2], Shaokui Jia[1], Xiaorui Xue[1], Xinyu Zhang[2], Lanhai He[2], Chuncheng Wang[2], Dajun Ding[2], Xueguang Ren[1*]
1School of Physics, Xi' an Jiaotong University
2Institute of Atomic and Molecular Physics, Jilin University

The noncovalent π-π interaction between aromatic molecules has been associated with cooperative phenomena such as protein folding, DNA base stacking, self-assembly, crystal synthesis, and so on. However, our knowledge of the structures and dynamics of high-order aromatic clusters remains incomplete due to the increased difficulty in isolating artificial model systems. In this work, we study the ionization and subsequent reaction dynamics of benzene trimer by electron impact (260 eV). The experiments were performed using a multiparticle imaging spectrometer (reaction microscope), where the resulting cations are measured in coincidence and their three-dimensional momentum vectors are determined [1]. In our experiment, the C6H6+ · C6H6+ · C6H6+ trications are primarily produced via two channels, i.e., (i) The double sequential ionization plus intermolecular Coulombic decay (dSI+ICD), where one outer-valence and one inner-valence vacancy are created separately at two molecules of the trimer and the following ICD process causes the ionization of the third benzene molecule (Fig. 1a); (ii) The double intermolecular Coulombic decay (dICD), which is initiated by electron-collision with the removal of a deep-lying carbon 2s (C2s) inner-valence electron. Afterward, an electron from the outer-valence shell of C6H6+ fills the C2s − 1 vacancy, and the energy released ionizes the neighboring two molecules (Fig. 1b).

Our further strong-field laser experiments show that electron-collision-induced dSI+ICD and dICD processes can take place in the fs regime. The nuclear dynamics during the ultrafast timescale are nearly frozen, which allows us to reconstruct the structure of the benzene trimer by Coulomb explosion imaging. The results indicate that the cyclic structure is the main conformer of benzene trimers in the gas jet. Due to the prevalence of aromatic trimers in proteins and DNA [2], and the crucial role of secondary electrons in radiation effects in biological tissues [3], the present findings could have significant implications for our comprehension of radiation biology at the molecular level.

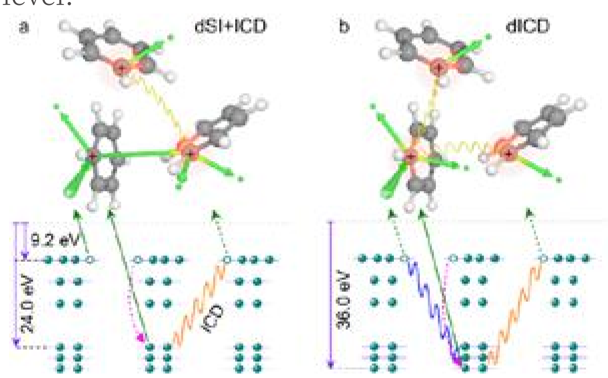


Figure 1. (a) Schematic of electron-impact induced double sequential ionization plus ICD (dSI+ICD) and (b) double ICD (dICD) processes.

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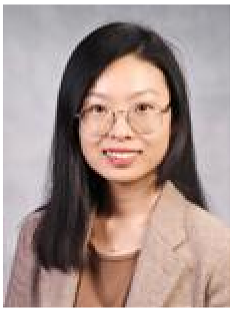
Jiaqi Zhou (1995-), Male, Assistant Professor of xi’an jiaotong university (Professor Xueguang Ren’s team), engaged in the study of ionization and dissociation dynamics of atoms, molecules, and clusters induced by electron impact. Several research achievements have been published in Nature Chemistry, Nature Communications, Physical Review Letters, Journal of Physical Chemistry Letters, and Physical Review R/A.

Coherent Synthesis of Arbitrary Ultrafast Space-time Wave Packets

Lu Chen
School of Physics, Nankai University

The ability to fully engineer the evolution of an ultrafast optical pulse, in space and in time, forms the backbone of modern ultrafast science and technology; which, depending on the repetition rate and bandwidth of the laser, could require simultaneous and independent control over thousands of spectral lines constituting an ultrafast pulse train. Here, by leveraging ultra-high spectral resolution of a Fourier-transform pulse shaper [1] and multifunctional responses at the nanoscale provided by a single-layer transmission dielectric metasurface [2], we present a universal approach to arbitrary controlling the full space-time evolution of near-infrared sub-10 fs optical pulses. The metasurface is composed of hundreds of superpixels, each contains a two-dimensional array of rectangular Si nanopillars. We achieve simultaneous and independent control over the temporal state of light via engineering the metasurface at the superpixel level, and the spatial wavefront evolution via engineering individual nanopillars within each superpixel. Two representative analogs of complex space-time wave packets: a light-coil with helical intensity distribution; and another, exhibiting coherently multiplexed time-varying OAM orders, are experimentally synthesized. To the best of our knowledge, generation of these complex light states was previously either only proposed theoretically [3] or limited to the EUV regime via high-harmonic generation [4]. Comprehensive analyses, including numerical simulations and analytical modeling, are also performed to explain their spatiotemporal evolution. We expect our approach to be easily extended to synthesis of other forms of structured light or space-time wave packets via superpixel engineering, or wavelength regimes via nonlinear control.



Lu Chen, an associate professor in the School of Physics at Nankai University, China. She received a Ph.D. in Physics from the University of Pittsburgh, USA in 2018. Before joining Nankai University in 2023, she was a PML/UMD Postdoctoral Researcher at the National Institute of Standards and Technology, USA. Her research interests include low-temperature transport and ultrafast optical studies of complex oxide nanostructures, spatiotemporal shaping of light field, and various light-matter interactions.

Response time of photoemission at quantum-classic boundary

Jiayin Che1 , Chao Chen1 , Jianan Wu1 , Guoguo Xin2 * and Yanjun Chen1
1College of Physics and Information Technology, Shaan’xi Normal University
2School of Physics, Northwest University

The response time of electron to light in photoemission is difficult to define and measure. Tunneling ionization of atoms induced by a strong laser field provides a semiclassical case for visiting the problem. Here, we show that the response time can be determined at the boundary between quantum and classic. We answer the question with constructing a response-time theory, which we call as TRCM. According to TRCM, the response time corresponds to the measurable time of strong three-body interaction between electron, Coulomb and laser. It can be determined at the boundary between quantum and classic. Specifically, the TRCM assumes that after tunneling, the electron is located at a quasi-bound state which agrees with the virial theorem. The electron needs a finite response time to acquire an impulse from the laser field so that it can break the symmetry imposed by the Coulomb potential of the residual ion. Then a compact expression for the re-sponse time, consisted of basic laser and atomic parameters, can be obtained. With this expression, a simple mapping between the response time and the observable can also be established. The TRCM is able to quantitatively reproduce a series of recent experimental curves of attoclock for the offset angle. Our theory can also be applied to different forms of laser fields such as orthogonal two-color laser field. Our results shed light on definition and measurement of the response time of photoemission. Some results are shown in Che J Y et al 2021 arXiv:2111.08491 and Wu J N et al 2023 arXiv:2301.12335.

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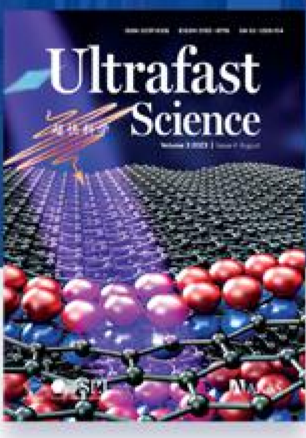

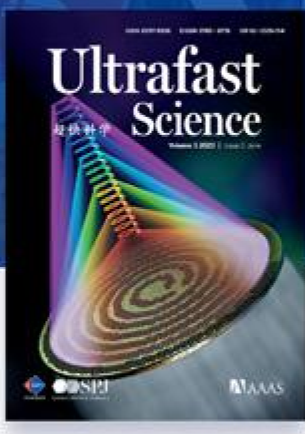

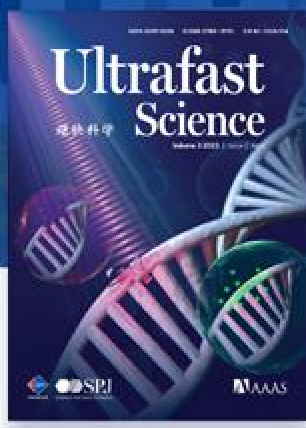

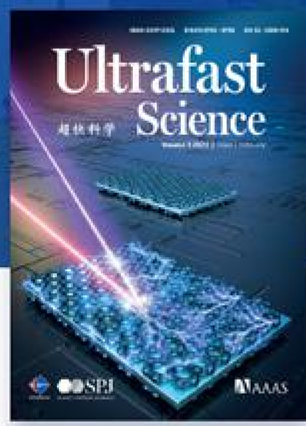

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