The 13th International West Lake Symposium on Extreme Radiation Physics

PROGRAM

May 4-6, 2019

Hangzhou, China

Organized and sponsored by

Institute for Fusion Theory and Simulation (IFTS)

Zhejiang University

Contents

Introduction to the 13th West Lake Symposium

About IFTS

Institute for Fusion Theory and simulation (IFTS) at the Zhejiang University (ZJU) at Hangzhou, China is founded in 2006. The mission of IFTS is to carry out cutting-edge research in fusion (MCF and ICF), space, and other plasma physics. IFTS organizes the International West Lake Symposiums (IWLS) on different topics in plasma physics each year. IWLS in 2019 will focus on extreme radiation physics (ERP).

Purpose

Laser power is reaching 10 PW thanks to CPA. Intense lasers have led to many new research areas and applications, including novel schemes for laser-driven particle acceleration, fusion ignition, generation of extreme radiation in the X/γ-ray, THz and microwave regimes, as well as laboratory modeling of astrophysical radiation sources. IWLS-ERP2019 will mainly be on extreme-radiation generation and related, including cross-disciplinary, topics. Presentations of theoretical, computational, and experimental results from scientists and graduate students worldwide are welcome.

Topics

- Intense laser technology
- Laser-plasma interaction
- Laser particle accelerator
- Extreme radiation sources (x/ ray, THz, microwave etc.)
- Extreme radiation-matter interaction

Conference form

Invited talks (30 mins), Oral talks (20 mins), and Posters.

Program committee (alphabetical order)

Xian-Tu He	PKU/IAPCM/ZJU/China
Yu-Xin Leng	SIOM/China
Ru-Xin Li	SIOM/China
Yu-Tong Li	IOP/China
Chuan-Sheng Liu	U. Maryland/USA
Zheng-Ming Sheng	SJTU/China
Zhi-Yi Wei	IOP/China
Hui-Chun Wu	ZJU/China
Ming-Yang Yu	SZTU/ZJU/China

Organizing committee

Hui-Chun Wu	ZJU
Zheng-Mao Sheng	ZJU
Dong Wu	ZJU

Sponsor

Institute for Fusion Theory and Simulation, Zhejiang University

Venue

Hangzhou Liutong Hotel (referred to as conference hotel in the agenda 杭州六通宾馆)
Address: 149 SanTaiShan Road, Hangzhou (杭州市三台山路 149 号)

Transportation

It takes about 1 hour to get to Hangzhou Liutong Hotel from Hangzhou Xiaoshan (萧山) International Airport by taxi, and costs around CNY 150. It takes about 30 mins to get to Liutong Hotel from Hangzhou East Railway Station (杭州东站) or Hangzhou Railway Station (杭州站) by taxi, and costs about CNY 50.

Website

http://ifts.zju.edu.cn/IWLS-ERP19

Registration

Registration sites are located in the lobby of Hangzhou Liutong Hotel. Registration fee can be only paid in cash: Chinese Yuan (CNY) or US Dollar (USD).

Participants	Regular	Student
Registration Fee	USD 300 or CNY 1,800	USD 150 or CNY 900

Reception & Banquet

At 17:30 of May 3 (Friday), receptions will be held in Hangzhou Liutong Hotel. At 17:30 of May 4 (Saturday), banquet will be held in Pinzhen Xuan of the same hotel.

Emergency contact

Contact	Jia-Ning Li (李嘉宁)	Hui-Chun Wu (武慧春)
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Agenda

13th West Lake International Symposium on Extreme Radiation Physics

Friday May 3rd	
15:00-20:30	Registration (Location: Lobby of Hangzhou Liutong Hotel)
17:30-19:30	Reception with buffet dinner (Hangzhou Liutong Hotel)

Saturday May 4th Venue: Jusi Hall of conference hotel, 2F, Bld. 3	
08:50-09:00	Guoyong Fu (IFTS/ZJU), Opening Ceremony
Session 1 (Chair: Zhengmao Sheng)	
09:00-09:30	Yutong Li (Institute of Physics, Chinese Academy of Sciences, China), [I] Over millijoule terahertz pulses generated from relativistic laser-plasma interactions
09:30-:10:00	Dongfang Zhang (Deutsches Elektronen-Synchrotron, Germany), [I] STEAM - A Terahertz driven electron accelerator and manipulator
10:00-10:30	Photo session and coffee break
Session 2 (Chair: Yutong Li)	
10:30-11:00	Bin Qiao (Peking University, China), [I] Impact of kinetic effects on relativistic astrophysical jet transport
11:00-11:30	Zhe Zhang (Institute of Physics, Chinese Academy of Sciences, China), [I] Laser driven intense microwave radiation
11:30-12:00	Hui-Chun Wu (IFTS, Zhejiang University, China) (I) Relativistic microwave theory of ball lightning
12:10-14:00	Buffet Lunch Venue: Tianfu Ju of conference hotel, 1F, Bld. 6
Session 3 (Chair: Wenjun Ma)	
14:00-14:30	Yasuaki Kishimoto (Kyoto University, Japan) [I] Internal and external collision-less shock generation and associated quasi-monoenergetic ion acceleration by the interaction between high intensity laser and clustered medium
14:30-15:00	Hongbin Zhuo (Nation University of Defence Technology, China) [I] Enhancement of target normal sheath ion acceleration using a long wire-array attached plane target
15:00-15:20	Coffee break
Session 4 (Chair: Yasuaki Kishimoto)	
15:20-15:50	Wenjun Ma (Peking university, China) [I] Applications of carbon nanotube foams as near-critical-density targets for laser-driven ion acceleration and X-ray/Gamma-ray generation

15:50-16:20	Kazumasa Takahashi (Nagaoka University of Technology, Japan) [I] Control of laser ion source using solenoid magnetic field
16:20-16:40	Obaydur Rahman (IFTS, Zhejiang University, China) [O] Enhancement of proton beam energy and conversion efficiency by double-laser pulses plasma interactions
16:40-17:00	Zhongming Cheng (IFTS, Zhejiang University, China) [O] Formation of relativistic solitons in plasmas
17:30-	Banquet Venue: Pinzhen Xuan of conference hotel, 2F, Bld. 6

Sunday May 5th **Venue: Jusi Hall of conference hotel, 2F, Bld. 3**	
Session 5 (Chair: Li-Ming Chen)	
09:00-09:30	Matteo Tamburini (Max Planck Institute for Nuclear Physics, Germany) [I] Giant Collimated Gamma-Ray Flashes
09:30-09:50	Boyuan Li (Shanghai Jiao Tong University, China) [O] Efficient and robust high-order harmonic generation through preplasma truncation
09:50-10:10	Jiaolong Zeng (National University of Defense Technology, China) [0] Evolution dynamics in the interaction of solid-density materials with ultra-intensive x-ray free electron lasers
10:10-10:30	Coffee break
Session 6 (Chair: Matteo Tamburini)	
10:30-11:00	Li-Ming Chen (Institute of Physics, Chinese Academy of Sciences, China), [I] High charge electron acceleration from solid target
11:00-11:30	Dong Wu (IFTS, Zhejiang University, China) [I] Intense beam solid interactions: theory, simulation and applications in experiments
11:30-12:00	Kun Li (ELI Beamlines, Czech Republic) [I] Collisional heating of over-dense magnetized plasma with Nd:YAG laser
12:00-14:00	Buffet Lunch Venue: Tianfu Ju of conference hotel, 1F, Bld. 6
Session 7 (Chair: Yin Yan)	
14:00-14:30	Qingzheng Lyu (Max-Planck-Institut für Kernphysik, Germany) [I] Numerical Simulation of QED processes in Strong Laser Fields
14:30-15:00	Jianxing Li (Xi'an Jiaotong University, China) [I] Ultrarelativistic electron and positron beams polarization in single-shot interaction with an ultraintense laser pulse and the polarization determination
15:00-15:20	Coffee break

Session 8 (Chair: Qingzheng Lyu)	
15:20-15:50	Yin Yan (National University of Defense Technology, China) [I] Copious positron production by femto-second lasers via laser absorption enhancement in a nanolayer target
15:50-16:20	Meng Wen (Max-Planck-Institut für Kernphysik, Germany) [I] Spin polarized electron beam acceleration in laser plasma field
16:20-16:40	Benzheng Chen (Xi'an Jiaotong University, China) [O] Particle-in-cell simulation of propagation of intense proton beams in gas plasmas: role of hydrodynamic instabilities
Poster Session **Venue: Jusi Hall of conference hotel,2F, Bld.3**	
16:40-17:30	P1. Yongtao Zhao (Xi'an Jiaotong University, China) Stopping of laser-accelerated ion beam in dense matter P2. Ji Yu (University of science and technology of China, China) Convective amplification of stimulated Raman rescattered modes in a pico-second laser plasma instability P3. De-Bin Zou, DeYao Yu, Xiang, Rui Jiang (National University of Defence Technology, China) Enhancement of target normal sheath ion acceleration using a long wire-array attached plane target P4. Rentong Guo (Xi'an Jiaotong University, China) Ultrarelativistic electron and positron beams polarization in single-shot interaction with an ultraintense laser pulse and the polarization determination P5. Yao Zhao (Shanghai Institute of Optics and Fine Mechanics, CAS, China) Absolute instability modes due to rescattering of stimulated Raman scattering in a large nonuniform plasma
17:30-19:30	Buffet Dinner Venue: Tianfu Ju of conference hotel, 1F, Bld. 6

Monday May 6th **Venue: Jusi Hall of conference hotel, 2F, Bld. 3**	
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09:00-09:30	Wenpeng Wang (Shanghai Institute of Optics and Fine Mechanics, CAS, China) [I] New Optical Manipulation of Relativistic Vortex Cutter
09:30-10:00	Yin Shi (University of California San Diego, USA) [I] Magnetic field generation in plasma waves driven by co-propagating intense twisted lasers
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Session 10 (Chair: Wenpeng Wang)	

10:20-10:50	Shiyi Zhou (Shanghai Institute of Optics and Fine Mechanics, CAS, China) Self-organized kilo-Tesla magnetic fields irradiated by kHz femtosecond laser pulses
10:50-11:10	Changwang Lian (University of Science and Technology of China) [I] Laser Plasma Instabilities at Large-Angle Oblique Laser Incidence
11:10-11:30	Qingsong Feng (Institute of Applied Physics and Computational Mathematics, China) [O] Stimulated Brillouin scattering behaviors in multi-ion species plasmas in high-temperature and high-density region
11:30-11:50	Yu Zhang (IFTS, Zhejiang University, China) [O] PIC-MCC simulation of high power microwave pulses discharge in air
12:00-14:00	Buffet Lunch　Venue: Tianfu Ju of conference hotel, 1F, Bld. 6

Abstracts

Over millijoule terahertz pulses generated from relativistic laser-plasma interactions

Yutong Li

Institute of Physics, Chinese Academy of Sciences, China

Relativistic electron beams with high charges up to nC-μC can be generated in the interactions of intense ultrashort laser pulses with high-density solid targets. Fast electrons transport forward through a foil target will induce transition radiation when crossing the rear surface-vacuum boundary. We have carried out picosecond laser-foil experiments using the Vulcan PW laser system at the Rutherford Appleton Laboratory to study THz generation. According to the experimental measurements and calculated spatial distribution of THz radiation, the total energy of THz pulses emitted from the target rear, at a pump laser energy of ~60 J, is determined to be ~55 mJ within 3 THz. This corresponds to a peak power of tens GW and a laser-THz energy conversion efficiency of ~0.1%. To our knowledge, this is the highest THz pulse energy and peak power reported so far.

STEAM - A Terahertz driven electron accelerator and manipulator

Dongfang Zhang

Deutsches Elektronen-Synchrotron (DESY), Germany

Terahertz based accelerators are prominent candidates for driving next-generation compact light sources, promising high-brightness, ultrashort x-ray and electron pulses. Here, we present a segmented terahertz electron accelerator and manipulator (STEAM) capable of performing multiple high-field operations on the 6D-phase-space of ultrashort electron bunches. With this single device, powered by few-micro-Joule, single-cycle, 0.3 THz pulses, we demonstrate record THz-acceleration of >60 keV, streaking with <10 fs resolution, focusing with >2 kT/m strength, compression to ~100 fs as well as real-time switching between these modes of operation. The STEAM device demonstrates the feasibility of THz-based electron accelerators, manipulators and diagnostic tools enabling science beyond current resolution frontiers with transformative impact.

Impact of kinetic effects on relativistic astrophysical jet transport

Bin Qiao

Peking University, China

Laser driven intense microwave radiation

Zhe Zhang

Institute of Physics, Chinese Academy of Sciences, China

High power microwave radiation with a peak power of 4.2 GW is demonstrated in intense picoseconds laser plasma interactions. The microwave radiation, which has a duration of hundreds of nanoseconds, is quasi-isotropically distributed in space, and the energy conversion efficiency is about 0.5 % from the laser to the microwave radiation. It is found that the observed microwave radiation is excited by the picosecond electromagnetic pulse, which is generated from the laser plasma interaction and reverbs in the metal vacuum chamber. A two-dimensional electromagnetic simulation is used to explain the microwave radiation dynamics. The results indicate a promising way to generate strong microwave radiation with the power of hundreds of gigawatts with existing laser facilities.

Relativistic microwave theory of ball lightning

Hui-Chun Wu

Institute for Fusion Theory and Simulation, Zhejiang University, China

Ball lightning (BL) is a fireball occasionally observed during thunderstorms [1], and it was recorded earliest by Aristotle. For centuries, BL had attracted great interests from scientists, including Musschenbrock, Arago, Faraday, Lodge, Tesla, Bohr, Kapitza and Ginzburg etc. About 100 models had been proposed for BL, but no consensus is reached about the nature of BL.

We will first introduce the characteristics and research history of BL, and then present a new BL theory [2]. Near the ground, lightning can produce a relativistic electron bunch, and the bunch excites an intense microwave pulse. This microwave is so strong to evacuate the ambient plasma and form a spherical plasma cavity. This formation process is demonstrated by particle-in-cell simulation. The microwave bubble model can explain many properties of BL, such as the occurrence site, relation to the lightning channels, appearance in aircraft, its shape, size, sound, spark, spectrum, motion, as well as the resulting injuries and damages. In particular, our theory is unique for a successful explanation of BL formation in aircraft.

Did someone ever detect radio signals with the same origin of BL? Yes, they are trans-ionospheric pulse pairs (TIPPs). TIPPs were first detected by a USA satellite in 1993 and are the most powerful natural radio sources on Earth. Using the BL-exciting mechanism, we quantitatively explain almost all the features of TIPPs [3]. Therefore, high-energy electrons from lighting can emit strong electromagnetic radiation, which is a fundamental assumption of our BL theory.

Finally, we point out further questions need to be answered in future and discuss experimental activities. Our work may drive the development of high-power microwave devices at an extreme level.

[1] M. Stenhoff, Ball Lightning: An unsolved problem in atmospheric physics (Kluwer & Plenum, NY, 1999).

[2] H.-C. Wu, Sci. Rep. 6, 28263 (2016).

[3] H.-C. Wu, Geophys. Res. Lett. 44, 2597 (2017).

Internal and external collision-less shock generation and associated quasi-monoenergetic ion acceleration by the interaction between high intensity laser and clustered medium

Yasuaki Kishimoto

Kyoto University, Japan

High energy density plasmas produced by high intensity laser have been utilized for exploring industrial and also academic applications. Various types of targets are chosen depending on application. Among them, clustered medium, a collection of tiny spherical particles with sub-micron size, has been found to play prominent characteristics individually and also collectively [1].

Recently, we present a new scheme which applies such prominent characteristics of cluster targets for achieving quasi-monoenergetic proton bunch acceleration with the energy over 200MeV. In this scheme, hemi- spherically converging collision-less shock dynamics inside the micron-size cluster subsequently coupled with relativistically induced transparency effect of high-intensity laser plays an important role. The dynamics associated with the cluster expansion due to the sheath field is also incorporated synergistically [2].

When such a target is immersed in high pressure ambient gas, a new class of interaction ascribed to the boundary layer in between two distinct plasmas takes place. A collision-less electrostatic shock, lunched at the Coulomb explosion front, is found to compress and reflect the gas ions in a fast time scale, allowing a high energy gas ion spectrum. A high energy density plasma state with a clumpy structure is found to be sustained via kinetic pressure balance as a BGK type equilibrium in a course of the relaxation process of the shock.

We have conducted proof-of-principle experiments for the proton bunch acceleration via interaction of micron-scale hydrogen cluster targets [3] with PW-class laser system of the J-KAREN-P laser facility at KPSI-QST [4].

[1] T.Tajima, Y. Kishimoto, M. Downer, Phys. Plasmas 6, 3759 (1999).

[2] R. Matsui, Y. Fukuda, Y. Kishimoto, Phys. Rev. Lett. **122**, 014804 (2019).

[3] R. Matsui, Y. Fukuda, Y. Kishimoto, submitted to Phys. Rev. E

[3] S. Jinno et al., Opt. Express **25**, 18774 (2017).

[4] H. Kiriyama et al., Opt. Lett. **43**, 2595 (2018).

Enhancement of target normal sheath ion acceleration using a long wire-array attached plane target

Hong-Bin Zhuo

Nation University of Defence Technology, China

Ion acceleration using relativistic hundreds of femtoseconds laser pulse to irradiate a long wirearray attached plane target is studied using two-dimensional particle-in-cell simulation. It is found that the radial electric field of the laser can pull up plenty of of dense attosecond electron bunches from the preposed array structure. These electrons are synergistically accelerated by the longitudinal electric field from the transverse magnetic mode excited inside the hollow channels between the wires and the laser ponderomotive force. They show a conspicuous two-temperature spectrum structure with the temperature of these energetic electrons close to twice the ponderomotive potential energy. When penetrating through the attached plane substrate, a strong and wide sheath electric-field at the rear surface of the target is induced, leading to about 3 times improvement of both the maximum ion energy and laser-to-ions energy conversion efficiency. With the laser of intensity 1.37 ×1020 W/cm2, duration 165 fs and energy 25.6 J, one can obtain 85 MeV protons and 31 MeV/u carbon ions, and the laser-to-ion energy conversion efficiency is 30% high. Besides, the influence of the laser polarization and wire-array size is also discussed.

Applications of carbon nanotube foams as near-critical-density targets for laser-driven ion acceleration and X-ray/Gamma-ray generation

Wenjun Ma

Peking University, China

Carbon nanotubes are allotropes of carbon with a cylindrical nanostructure. When they randomly bond with each other by van der Waals forces, so-called carbon nanotube foam (CNF) is formed. The average density of CNFs lies in the range of a few mg/cm^3 to tens of mg/cm^3. If fully ionized, such a thin foam can turn to a plasma slab with critical density. Here we report the recent progress on the fabrication and the applications of CNF as near-critical-density targets for laser-driven ion acceleration and X-ray/Gamma-ray generation. Our recent experimental results show that highly energetic carbon ions can be obtained by shooting a CNF-coated ultrathin solid foil with PW laser pulses. Ions in the solid foil undergo a cascaded accelerations process if the density of CNF is lower than 3 mg/cm^2. Our simulation study also reveals that such double-layer targets can be employed to efficiently generate bright X-ray/Gamma-ray pulses with currently available PW lasers in a very simple way. Preliminary experimental results using a 100 TW laser will be presented.

Control of laser ion source using solenoid magnetic field

Kazumasa Takahashi

Nagaoka University of Technology, Japan

Heavy ion inertial fusion (HIF) is considered as a candidate to realize power generation by nuclear fusion. The HIF requires heavy ion beams with high current to deposit sufficient energy to the target fuel. A laser ion source (LIS) is expected to be one of the candidates as the injector for providing the high current ion beam. To satisfy the requirements such as current, emittance and ion charge state for ion sources for HIF, applying a solenoid magnetic field to LIS has been investigated. In this study, the effects of solenoid magnetic field on ion beam characteristics in LIS are discussed.

Enhancement of proton beam energy and conversion efficiency by double-laser pulses plasma interactions

Obaydur Rahman [1, 2] and Zheng-Mao Sheng [1*]

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2. Department of Physics, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh
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A double-laser pulses plasma interaction scheme is proposed to improve the proton beam energy and conversion efficiency. It is found that the peak energy, the maximum energy, and the total number of accelerated protons are significantly enhanced for the present scheme over that of the usual single-laser pulse scheme. The acceleration proceeds in three distinct stages. First, the pre-pulse accelerates the foil electrons and generate a weak electric field, which accelerates the foil protons due to TNSA, and reduces the reflection of succeeding laser pulse so that more energy of the second-laser pulse is converted into the particle energy. Second, the main pulse not only accelerates the slower protons located deeper in the plasma but also accelerates the fast protons due to an enhanced TNSA. Finally, the protons are further accelerated due to the laser break-out afterburner, when the target becomes relativistically transparent to the laser pulse.

Giant Collimated Gamma-Ray Flashes

Matteo Tamburini

Max Planck Institute for Nuclear Physics, Germany

Powerful gamma-ray emissions are ubiquitous in astrophysics, from solar flares [1] to pulsars [2], energetic blazars [3] and neutron star mergers [4]. Here we show that astrophysical-like mechanisms yielding strong gamma-ray emission can be recreated in the laboratory. In fact, when a laser-generated dense ultrarelativisticelectron beam interacts with a millimetre-thickness solid conductor, electromagnetic instabilities develop [5] and the ultra-relativistic electrons travel through strong self-generated electromagnetic fields as large as 10^7-10^8 gauss [6]. This results into the production of a collimated gamma-ray pulse with photon energies ranging from 200 keV to GeV [6]. In addition to their intrinsic interest, these findings pave the way to generating dense electron − positron plasmas for reproducing astrophysical phenomena in the laboratory [7], and to novel investigations in strong-field QED and nuclear physics such as the interaction between real photons in vacuum [8].

[1] M Pesce-Rollins, N Omodei, V Petrosian, W Liu, F R da Costa, A Allafort and Q Chen, Astrophys. J. Lett. 805, L15 (2015)

[2] P A Caraveo, Ann. Rev. Astron. Astrophys. 52, 211 (2014)

[3] A A Abdo, M Ackermann, M Ajello et al., Astrophys. J. 708, 1310 (2010)

[4] B P Abbott, R Abbott, T D Abbott et al., Astrophys. J. Lett. 848, L12 (2017)

[5] F Califano, R Prandi, F Pegoraro and S V Bulanov, Phys. Rev. E 58, 7837 (1998)

[6] A Benedetti, M Tamburini and C H Keitel, Nat. Photon. 12, 319-323 (2018)

[7] S V Bulanov, T Zh Esirkepov, M Kando, J Koga, K Kondo and G Korn, Plasma Phys. Rep. 41, 1 (2015)

[8] A Di Piazza, C Müller, K Z Hatsagortsyan and C H Keitel, Rev. Mod. Phys. 84, 1177 (2012)

Efficient and Robust High-Order Harmonic Generation through Preplasma Truncation

Boyuan Li

Shanghai Jiao Tong University, China

High-order harmonic generation (HHG) from ultrain-tense laser-solid target interaction provides a unique way to produce bright coherent extreme ultraviolet (XUV) and X-rays. It has been shown that harmonics can be efficiently generated when a very short plasma scale length instead of a step-like density profile is introduced in front of the target. If the plasma scale length is somewhat long, the harmonic emission would also be destroyed. By introducing a preplasma truncation, high-order harmonics can be enhanced by one order of magnitude and the spectral width of each harmonics can be reduced. Numerical simulations show that under the optimal density cutoff, a compact electron sheet is formed to oscillate twice per laser cycle and enhanced harmonic generation is achieved. More importantly, the density cutoff makes the harmonic generation weakly dependent on the preplasma scale length, which signicantly relaxes the high requirement on the laser temporal contrast as normally demanded for high-order harmonic generation experiments.

Evolution dynamics in the interaction of solid-density materials with ultra-intensive x-ray free electron lasers

Jiaolong Zeng

National university of defense technology, China

In the interaction of solid-density materials with the X-ray free electron lasers, plasmas are produced with the free electrons being rapidly heated to a high temperature yet the ions still being cold. In such dense plasmas, ionization processes initiated by photons and electrons are strongly modified due to a transient space localization of electrons produced, which can significantly change the evolution dynamics. We pointed out that the photoionization and electron impact ionization processes are significantly enhanced during the interaction period. A theoretical formalism is developed to study the wavefunctions of the continuum electrons that takes into consideration the quantum decoherence caused by coupling with the plasma environment. Then we apply the theory to investigate the evolution dynamics in the interaction of solid-density aluminium and magnesium with ultra-intensive X-ray free electron lasers. Issues including the double-core states production and spectra are discussed. Our work opens new ways to the deep insight into investigation of extremely exotic states properties which is important in high energy density physics, astrophysics and laser physics.

High charge electron acceleration from solid target

Li Ming Chen[1,2,3,4]

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Collimated electron beams produced by intense laser pulses focused onto solid-density plasmas are studied intensively for many applications. Experiments and simulations have shown that the electron beams are emitted at an angle between laser specular and the target normal direction. In particular, an electron jet emitted along the target surface has been observed using large angles of incidence during laser irradiation of solid targets. However, the target surface electron energy spectrum shows a 100% energy spread in most cases, save for a few experiments [1] with low beam charge and large beam divergence angle (> 20^0).

We systematically studied the relationship between the guiding of target surface electrons and *fs* laser parameters. When a nanosecond prepulse was added without picosecond ASE, the electron beam became concentrated and intense. We obtained a 0.8-MeV peaked electron beam with a charge of 100 pC in a single shot and a divergence angle as small as 3^0 [2].

High-quality monoenergetic target surface accelerated electron beams with small normalized emittance (0.03π mm mrad) and large charge per shot have been observed from a 3 TW laser-solid interactions. The 2D PIC simulation reveals that a bubble-like structure as an accelerating cavity appears in the near critical density plasma region. A bunch of electrons is pinched transversely and accelerated longitudinally by the wake field in the bubble [3].

Besides these results obtained by using small size *fs* lasers, we also performed TSA experiment using sub-ps high power lasers such as PHELIX in GSI and TITAN in LLNL. Ten MeV monoenergetic and highly collimated (< 2^0) electron beam with 8nC was observed on PHELIX. The Maximum beam charge of 100nC are obtained on TITIAN [4]. The Direct Laser Acceleration might be the acceleration mechanism in ps-laser/solid interaction. The good pointing stability and reproducibility of such a ultra-high charge electron beam makes it possible an ideal beam for fast ignition on ICF and drive the warm/hot dense matter.

[1] T. E. Cowan *et al*, NIMA 455, 130 (2000); L. M. Chen *et al.*, Phys. Rev. Lett.100, 045004 (2008); A. G. Mordovanakis, Phys. Rev. Lett.103, 235001 (2009)

[2] J. Y. Mao *et al*, PRE 85, R025401(2012); W. M. Wang *et al*, HEDP 9, 578(2013)

[3] J. Y. Mao *et al*, Appl. Phys. Lett. 106, 131105(2015)

[4] Y. Ma *et al*, PNAS 115, 6980(2018); J. Y. Mao *et al,* Opt. Lett. 43, 3909(2018)

Intense beam solid interactions: theory, simulation and applications in experiments

Dong Wu

IFTS, Zhejiang University, China

Kinetic simulations are essential to explore many systems under high energy density physics regime, since such system is typically far away from thermal equilibrium. However, conventional PIC codes widely used now cannot provide complete description for such systems. Firstly, many atomic and plasma processes are coupled together. Secondly, given the very large number of possible ionization states, the need for a comprehensive treatment of these states can quickly become computationally intractable. Thirdly, the numerical simulation becomes extremely challenging in order to calculate solid density plasmas.

Dr. Dong Wu and his colleagues have been developing an advanced numerical simulation code to investigate strongly-coupled laser solid interactions. It includes: 1) an advanced ionisation dynamics model, which combines collision ionisation, electron-ion recombination and ionisation potential depression; 2) an advanced collision dynamics model, which combines both elastic and inelastic collisions among charged particles; and 3) an advanced numerical scheme, which can significantly remove the numerical self-heating when simulating solid density plasmas. These advantageous features provide a unique tool.

This code has already been successfully to explain the intense laser solid interaction experiments, conducted by Peking University, Shanghai Jiaotong University, Xi'an Jiaotong University, Chinese Academy of Engineering Physics.

Collisional heating of over-dense magnetized plasma with Nd:YAG laser

Kun Li

ELI Beamlines, Czech Republic

Propagation of CP laser in magnetized homogeneous over-dense collisional plasma was investigated, and characters such as attenuation length, specific energy deposition and blue shift are obtained. The capability of propagation of circularly polarized laser in longitudinally, strongly magnetized over-dense collisional plasma opens up a totally different region where many "old" properties are worth to be re-examined, such as collisional heating in over-dense plasma. With the quick development of magnet with higher field and powerful laser with longer wavelength, it is anticipated that the above characters could be realized in experiments in the not-too-far future. The above properties might find applications in various fields of laser plasma interactions, such as enhanced generation of secondary-particle, inertial-confinement fusion, high-energy-density plasma, laboratory cosmic and et al.

Numerical simulation of QED processes in strong laser fields

Qingzheng Lyu

Max-Planck-Institut für Kernphysik, Germany

The exact solution of the Dirac equation in the presence of a background plane-wave electromagnetic field has been widely employed in order to describe quantum electrodynamical processes occurring in the presence of a strong laser field in a plane-wave approximation. However, a realistic laser field has a complex space-time structure and cannot be always approximated by plane-wave. In order to study the strong-field QED process in a more general background field, we need the exact solution of the Dirac equation, which is analytically impossible but can be obtained numerically. This numerical wave functions in general field configurations have been extensively employed to investigate various strong-field QED processes such as non-linear Compton scattering, nonlinear Breit-Wheeler pair production and vacuum decay process in combined fields.

Ultrarelativistic electron and positron beams polarization in single-shot interaction with an ultraintense laser pulse and the polarization determination

Jianxing Li

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Spin-polarization of an ultrarelativistic electron beam head-on colliding with an ultraintense laser pulse is investigated in the quantum radiation-reaction regime. We develop a Monte-Carlo method to model electron radiative spin effects in arbitrary electromagnetic fields by employing spin-resolved radiation probabilities in the local constant field approximation. Due to spin-dependent radiation reaction, the applied elliptically polarized laser pulse polarizes the initially unpolarized electron beam and splits it along the propagation direction into two oppositely transversely polarized parts with a splitting angle of about tens of milliradians. Thus, a dense electron beam with above 70% polarization can be generated in tens of femtoseconds. The proposed method demonstrates a way for relativistic electron beam polarization with currently achievable laser facilities.

Besides, relativistic spin-polarized positron beams are indispensable for future electron-positron colliders to test modern high-energy physics theory with high precision. However, present techniques require very large-scale facilities for those experiments. We put forward a novel efficient way for generating ultrarelativistic polarized positron beams employing currently available laser fields. For this purpose, the generation of polarized positrons via multiphoton Breit-Wheeler pair production and the associated spin dynamics in single-shot interaction of an ultraintense laser pulse with an ultrarelativistic electron beam is investigated in the quantum radiation-dominated regime. A specifically tailored small ellipticity of the laser field is shown to promote splitting of the polarized particles along the minor axis of laser polarization into two oppositely polarized beams. In spite of radiative de-polarization, a dense positron beam with up to about 90% polarization can be generated in tens of femtoseconds. The method may eventually usher high-energy physics studies into smaller-scale laser laboratories.

Finally, we demonstrate a way of single-shot determination of polarization for ultrarelativistic electron beams via nonlinear Compton scattering.

Copious positron production by femto-second lasers via laser absorption enhancement in a nanolayer target

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A novel mechanism of positron production by using a femto-second laser irradiating a nano-layer target is proposed and numerically verified by particle-in-cell and Monte Carlo simulations. Both the temperature and the maximum kinetic energy of electrons can be greatly enhanced by using a nano-layer target instead of a planar target. When these energetic electrons shoot into a high Z target, copious positrons are produced via Bethe-Heitler mechanism. It is shown that approximately 10^{10} positrons can be obtained by femto-second laser with the intensity of 10^{21}W/cm^2 .

Spin polarized electron beam acceleration in laser plasma field

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High-flux polarized particle beams are of critical importance for the investigation of spin-dependent processes such as physics beyond the Standard Model. We demonstrate that kiloampere polarized electron beams can be generated via laser-wakefield acceleration from a pre-polarized gas target. A simple theoretical model for determining the electron beam polarization is presented and supported with self-consistent three-dimensional particle-in-cell simulations that incorporate the spin dynamics. Compared to currently available sources of polarized electron beams, the flux is increased by four orders of magnitude. The depolarization of electrons in the laser wakefield can be as low as 10 %. Depolarization of prepolarized electrons during laser acceleration is dominated by spin precession in strong magnetic field, which is absent or relatively weak in the accelerating phase of radially polarized laser. As a preparation of obtaining polarized electron beams in other acceleration regimes, superiority of radially polarized laser is investigated. In our investigation, generation of super-ponderomotive electrons are realized by an anti-dephasing acceleration with a laser pulse incident upon a wire target. Three-dimensional Particle-In-Cell simulations show a relativistic intense laser pulse can extract electrons from the wire and inject them into the accelerating field. Anti-dephasing, resulting from collective plasma effects, enhances the accelerated electron energy by two-orders of magnitude compared to the ponderomotive limit. It is demonstrated that ultra-short radially polarized pulses produce super-ponderomotive electrons more efficiently than pulses of the linear and circular polarization varieties.

Particle-in-cell simulation of propagation of intense proton beams in gas plasmas: role of hydrodynamic instabilities

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Beam-plasma instabilities play a significant role in the interaction of particles with matter. Here we demonstrate the formation and development of sausage instability and kink instability during beam-plasma interaction, which usually appear in Z-pinch inertial confinement fusion research. To analyse these instabilities, the transport of proton beams through plasmas with density of 1022 m-3 is simulated with a two dimensional (2D) particle-in-cell (PIC) code. The simulation reveals that the density of proton beams increases due to the focusing of beams, which is related to sausage instability. As the beam density raises, proton beams are forced to bend by the kink instability while propagating along plasma channels. We reveal how these two instabilities are formed. Moreover, the corresponding ways to stabilize the propagation of beams are discussed.

Formation of relativistic solitons in plasmas

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When a high-intensity laser pulse shoots into an underdense plasma, dispersion effects and nonlinearity appear. These effects lead to well-known nonlinear phenomena such as relativistic self-focusing and relativistic e.m. soliton generation.

Here, we summarize the features of relativistic solitons in plasma briefly. The solitons found in simulation are long-lived, and have low-frequency. They usually move toward the plasma-vacuum interface with an acceleration proportional to the gradient of the plasma density. The width of the solitons is of the order of the skin depth, and the electric field in the soliton is poloidal, while the magnetic field is toroidal.

We present a comprehensive numerical study of the dynamics of solitons, and aim to confirm the condition to form a relative soliton with tightly-focused ultra-short high-intensity laser pulse.

By varying the background plasma density and the amplitude of the laser pulse, significant differences are found in terms of energy transport and soliton formation. For laser pulses with low amplitude, solitons are formed in the wake of the laser pulse. For laser pulses with high amplitude, solitons are evolved from electron cavities which are formed by the ponderomotive forces at the plasma vacuum interface. Besides, the solitons, formed by higher amplitude laser pulse, have higher energy and lower energy efficiency.

Stopping of laser-accelerated ion beam in dense matter

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Knowledge about the energy loss of heavy ion in dense ionized matter is of great importance in fields such as inertial confinement fusion, fast ignition as well as intense heavy ion beam driven high energy density physics. Recently, we investigated the energy deposition of laser-accelerated ions in dense C-H-O plasmas. The energy loss of 3.4 MeV proton in TAC foam plasma was measured with a Thomson Parabola. It was found that the measured energy loss is far above the Beth prediction, and the beam intensity may play important roles in the stopping process.

Convective amplification of stimulated Raman rescattered modes in a pico-second laser plasma instability

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We present particle-in-cell (PIC) simulations for laser plasma instabilities (LPI) with the laser pulse duration of a few pico seconds. The simulation parameters are relevant to LPI experimental conditions on SG-II. It is found that when the incident laser intensity is well above its SRS threshold, the back-scattered light via SRS can also excite secondary SRS in the region below 0.11 critical density of incident laser. The daughter light wave via the secondary SRS can be amplified on its way propagating towards the higher density region in the bath of broadband lights generated through the primary backward SRS process. High intensity of incident laser broadens spectrum of daughter light yielded by primary backward SRS and increases the convective amplification of high-frequency part of daughter light via the secondary SRS significantly. This amplification process reduces the intensities of primary backward SRS lights thus may cause an underestimation of SRS level. Absolute modes of secondary SRS are also observed but they are not energetically important.

Enhancement of target normal sheath ion acceleration using a long wire-array attached plane target

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Ion acceleration using relativistic hundreds of femtoseconds laser pulse to irradiate a long wirearray attached plane target is studied using two-dimensional particle-in-cell simulation. It is found that the radial electric field of the laser can pull up plenty of of dense attosecond electron bunches from the preposed array structure. These electrons are synergistically accelerated by the longitudinal electric field from the transverse magnetic mode excited inside the hollow channels between the wires and the laser ponderomotive force. They show a conspicuous two-temperature spectrum structure with the temperature of these energetic electrons close to twice the ponderomotive potential energy. When penetrating through the attached plane substrate, a strong and wide sheath electric-field at the rear surface of the target is induced, leading to about 3 times improvement of both the maximum ion energy and laser-to-ions energy conversion efficiency. With the laser of intensity 1.37×10^{20} W/cm^2, duration 165 fs and energy 25.6 J, one can obtain 85 MeV protons and 31 MeV/u carbon ions, and the laser-to-ion energy conversion efficiency is 30% high. Besides, the influence of the laser polarization and wire-array size is also discussed.

Ultrarelativistic electron and positron beams polarization in single-shot interaction with an ultraintense laser pulse and the polarization determination

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Relativistic spin-polarized positron beams are indispensable for future electron-positron colliders to test modern high-energy physics theory with high precision. However, present techniques require very large scale facilities for those experiments. We put forward a novel efficient way for generating ultrarelativistic polarized positron and electron beams employing currently available laser fields and the polarization determination.

Absolute instability modes due to rescattering of stimulated Raman scattering in a large nonuniform plasma

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Absolute instability modes due to secondary scattering of stimulated Raman scattering (SRS) in a large nonuniform plasma are studied theoretically and numerically. The backscattered light of convective SRS can be considered as a pump light with a finite bandwidth. The different frequency components of the backscattered light can be coupled to develop absolute SRS instability near their quarter-critical densities via rescattering process. The absolute SRS mode develops a Langmuir wave with a high phase velocity of about 0.58c with c the light speed in vacuum. Given that most electrons are at low velocities in the linear stage, the absolute SRS mode grows with very weak Landau damping. When the interaction evolves into the nonlinear regime, the Langmuir wave can heat abundant electrons up to a few hundred keV via the SRS rescattering. Our theoretical model is validated by particle-in-cell simulations. The absolute instabilities may play a considerable role in the experiments of inertial confinement fusion.

New optical manipulation of relativistic vortex cutter

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A new relativistic vortex cutter [1] driven by the Laguerre–Gaussian (LG) mode is carried out for the first time in three-dimensional particle-in-cell simulations. Studies show that the electric fields periodically concentrate and emanate within every laser wavelength for the reflected CP LG_p^l (*p* = 0, *l* = 1, σ_z = -1) laser, which just works like a vortex cutter, resulting in a relativistic ultra-short collimated electron cluster with a constant period in space. A single particle model is given and verifies that the cluster formation has a close relation with the parameters of orbital angular momentum (*l*) and spin angular momentum (σ_z). Such relativistic vortex cutter can be potentially applied for the accelerator, generating high-flux particle and coherent radiation sources, and so on.

[1] Wang, et al. PRL 122,024801 (2019).

Magnetic field generation in plasma waves driven by co-propagating intense twisted lasers

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We present a new magnetic field generation mechanism in underdense plasmas driven by the beating of two, co-propagating, Laguerre-Gaussian (LG) orbital angular momentum (OAM) laser pulses with different frequencies and also different twist indices. Results of 3D particle-in-cell simulations show that the twisted ponderomotive force drives up an electron plasma wave with a helical rotating structure. For the case of 300 fs duration, 3.8×1017 W/cm2 peak laser intensity we observe magnetic field of up to 0.4 MG. We will also outline a theoretical model, based on cold electron fluid equations, that reproduces that pertinent features of the PIC simulations – including the axial magnetic field – in the appropriate limits and elucidates the mechanism and highlights its scaling with key parameters.To second order, there is a nonlinear rotating current leading to the onset of an intense, static axial magnetic field, which persists over a long time in the plasma (ps scale) after the laser pulses have passed by. Applications of this new method of magnetic field creation will be discussed.

Self-organized kilo-Tesla magnetic fields irradiated by kHz femtosecond laser pulses

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By using a millijoule kHz femtosecond laser pulse to irradiate a preformed expanding spherical plasma, we first identified fast-electron-mediated filamentary structures and accompanying self-organized magnetic-tube array with 2000 Tesla via time-resolved magneto-optical polarization rotation measurements. We reveal that these periodical filamentary structures predominantly originate from ejected energetic electron flows from the inner denser region of the spherical plasma, which will induce the electron Weibel instability and magnetic field organization and amplification in the expanding plasma in 2 picoseconds.

Laser plasma instabilities at large-angle oblique laser incidence

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Laser plasma instabilities (LPI) is a critical physical process in inertial confinement fusion(ICF). LPI can affect laser coupling efficiency and it may cause fuel preheating risk. When a laser is obliquely incident at a large angle with respect to the plasma density gradient, the turning-point density can be lowered to near its quarter-critical-density region where stimulated Raman scattering (SRS) and Two-plasmon decay (TPD) can be excited. We find that the LPI threshold is reduced because of field swelling near the turning-point region. Through fluid and particle simulations, we confirmed that TPD enhanced significantly with angle close to 60^{o}. PIC simulations show that significant amount of hot electrons can be produced by an obliquely incident laser whose intensity is lower than typical ICF laser intensities.

Stimulated Brillouin scattering behaviors in multi-ion species plasmas in high-temperature and high-density region

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The presence of multiple ion species can add additional branches to the IAW dispersion relation and change the Landau damping significantly. Different IAW modes excited by stimulated Brillouin scattering (SBS) and different SBS behaviors in several plasmas composed of ion species relevant to inertial confinement fusion (ICF) in the high-temperature and high-density region have been researched by Vlasov-Maxwell simulation. The slow mode in HeH or CH plasmas is the least damped mode and will be excited in SBS, while the fast mode in AuB plasmas is the least damped mode and will be excited in SBS. Due to strong Landau damping, the SBS in H or HeH plasmas is strong convective instability, while the SBS in AuB plasmas is absolute instability due to the weak Landau damping. However, although the SBS in CH plasmas is weak convective instability in the linear theory, the SBS will transform into absolute instability due to decreasing linear Landau damping by particle trapping. These results give a detail research of the IAW modes excitation and the properties of SBS in different species plasmas.

PIC-MCC simulation of high power microwave pulses discharge in air

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High power microwave pulses discharge in gases have drawn increasingly attention in a wide range of applications such as waveguide in radar systems, combustion ignition, microwave propulsion etc. Here we studied microwave pulses discharge in air at atmospheric pressure by a one dimensional particle model. A Particle In Cell (PIC) code is coupled with the Monte Carlo Collisional (MCC) technique to deal with the microwave propagation in air with consideration of collisional processes between electrons and air molecules.

We will give an introduction to the PIC-MCC model and discuss the gas breakdown, electron acceleration and other physics characteristics of microwave pulses discharge in air in our simulation results.

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