



第一届强场量子电动力学新视野研讨会

The 1st workshop on New Opportunities of Strong-Field Quantum Electrodynamics

会议手册

Conference Manual

主办单位:中国工程物理研究院研究生院

Host: Graduate School of China Academy of Engineering Physics

合办单位:北京大学物理学院 上海交通大学物理与天文学院

Co-hosts: School of Physics, Peking University

School of Physics and Astronomy, Shanghai Jiao Tong University

时间:2024年8月19日至8月23日

Time: August 19-23, 2024

中国 · 北京
Beijing, China

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会议介绍

量子电动力学 (QED) 理论是描述光与物质相互作用的基础理论。随着强激光技术的发展, 相应的物理过程表现出越来越强的非线性, 使得科学家们开始聚焦于 QED 理论在极端条件下的应用。相应的研究不仅有助于推动理论物理、等离子体物理、粒子物理和天体物理等前沿领域的发展, 而且有望探索超出标准模型之外的新物理。

“第一届强场量子电动力学新视野研讨会”由中国工程物理研究院研究生院主办, 北京大学和上海交通大学联合举办。本次会议将聚焦:

专题一 强场 QED 理论及其适用性

专题二 强场 QED 数值模拟方法

专题三 强激光环境或天体环境中的强场 QED 效应

专题四 利用强场 QED 效应产生新型光源和粒子源

专题五 强场 QED 领域的未来发展

旨在深入探讨超强激光激发的强场量子电动力学领域的最新进展及未来的发展方向。

特别提醒: 请报告人在报告前一天将 PPT 发送至会议邮箱 neosfqed@gscaep.ac.cn, 或携带 U 盘使用会场电脑播放报告材料, 报告材料只支持 PPT 及 PDF 格式文件。

Conference Introduction

Quantum Electrodynamics (QED) theory is the fundamental theory describing the interaction between light and matter. With the development of high-intensity laser technology, the corresponding QED processes exhibit increasingly strong nonlinearity, prompting scientists to focus on the application of QED theory under extreme conditions. Such research not only helps to advance the frontier of theoretical physics, plasma physics, particle physics, and astrophysics, but also holds the promise of exploring new physics beyond the Standard Model.

The topic includes:

- 1. Strong-field QED theory and its applications**
- 2. Numerical methods for strong-field QED**
- 3. Strong-field QED phenomena in intense laser or astrophysical environments**
- 4. Next generation of light/particle source based on Strong-field QED effects**
- 5. The future of strong field physics**

会议须知

一、会议时间及注册安排

8月19日 10:00–18:00 会议注册报到

如您在8月19日 10:00至18:00之间抵达酒店，请您先至会议中心办理会议报到手续，再至度假酒店前台办理入住。如您在当日18:00之后抵达，请您直接办理入住，并在8月20日 8:00–9:00至会议中心办理会议报到。

8月20日–23日 每日 9:00–17:00 专题报告

8月24日 离会

二、会议地点及用餐安排

北京·春晖园温泉度假酒店 顺义区高泗路于庄段37号

会议室：会议中心二层 会议12厅

自助餐厅：会议中心二层 画廊餐厅

早餐时间：06:30–09:00

午餐时间：11:30–13:30

晚餐时间：17:30–19:30

请您在签到处领取餐券和参会证，会议期间凭餐券用餐。

三、联系方式

会议联系人：吕清正 15201291048

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BEI JING CHUNHUIYUAN RESORT GENERAL LAYOUT

北京春晖园温泉度假酒店 平面示意图



Conference Guidelines

1. Conference Schedule and Registration

August 19 10:00 AM - 6:00 PM: Conference Registration

If you arrive at the hotel between 10:00 and 18:00 on August 19, please first go to the Conference Center to complete the Workshop check-in procedures, and then proceed to the resort hotel front desk to check in. If you arrive after 18:00 on the same day, please check in directly at the hotel and complete the Workshop check-in at the Conference Center between 08:00 and 09:00 on August 20.

August 20-23 9:00 AM - 5:10 PM: Thematic Presentations

August 24 Conference Departure

2. Conference Venue and Dining Arrangements

Location: Chunhuiyuan Hot Spring Resort, 37 Yuzhuang Section, Gaosi Road, Shunyi District, Beijing

Meeting Room: Conference Center, 2nd Floor, Room 12

Buffet Restaurant: Conference Center, 2nd Floor, Gallery Restaurant

Breakfast: 6:30 AM - 9:00 AM

Lunch: 11:30 AM - 1:30 PM

Dinner: 5:30 PM - 7:30 PM

Please collect your meal vouchers and conference badge at the sign-in desk. Meal vouchers are required during the conference for dining.



3. Contact Information

Conference Contact:

Qingzheng Lyu, +86 152 0129 1048

Event Coordination Contact:

Mei Zheqing, +86 132 6317 1528

Conference Email: neosfqed@gscaep.ac.cn

Special Reminder: Please send your PPT to the conference email at neosfqed@gscaep.ac.cn the day before your presentation, or bring a USB drive to use the conference computer to present your materials. The presentation materials are only supported in PPT or PDF format.

Summary Agenda

August 19th	
Time	Event
10:00–18:00	Conference Registration
18:00–19:30	Reception
August 20th	
Time	Topic
9:00–9:20	Opening Ceremony
9:20–10:40	Plenary Talks
10:40–11:10	Group Photo
11:10–12:10	Invited Talks
12:10–14:00	Lunch
14:00–15:30	Invited Talks
15:30–15:50	Break
15:50–17:00	Invited Talks & Oral Talks
17:30–19:30	Dinner
August 21st	
Time	Topic
9:00–10:20	Plenary Talks
10:20–10:40	Break
10:40–12:10	Invited Talks
12:10–14:00	Lunch
14:00–15:30	Invited Talks
15:30–15:50	Break
15:50–17:00	Poster Session
17:30–19:30	Dinner

August 22nd	
Time	Topic
9:00–10:20	Plenary Talks
10:20–10:40	Break
10:40–12:10	Invited Talks
12:10–14:00	Lunch
14:00–15:30	Invited Talks
15:30–15:50	Break
15:50–17:00	Invited Talks & Oral Talks
17:30–19:30	Dinner
August 23rd	
Time	Topic
9:00–10:20	Plenary Talks
10:20–10:40	Break
10:40–12:10	Invited Talks
12:10–14:00	Lunch
14:00–15:30	Invited Talks
15:30–15:50	Break
15:50–16:50	Oral Talks
17:30–19:30	Dinner

Conference Schedule

August 19th			
Time	Event		
10:00–18:00	Conference Registration		
18:00–19:30	Welcome Reception		
August 20th			
Time	Topic	Speaker	Chairperson
9:00–9:20	Welcome Address	TBA	Qingzheng Lyu
9:20–10:00	Photon–photon scattering and Axion–like particle generation	Baifei Shen	Matteo Tamburini
10:00–10:40	TBA	Bin Qiao	
10:40–11:10	Group Photo and Break		
11:10–11:40	Linear Breit–Wheeler process driven by compact lasers	Jinqing Yu	Tongpu Yu
11:40–12:10	Photon–photon and photon–nuclear interactions in heavy ion ultraperipheral collisions	Shi Pu	
12:10–14:00	Lunch		

August 20th			
Time	Topic	Speaker	Chairperson
14:00–14:30	Coherency revisited: Collective effects in nonlinear Thomson scattering	Stefan Weber	Jinqing Yu
14:30–15:00	Numerical Investigation of Polarization Dynamics in Strong-Field QED	Yanfei Li	
15:00–15:30	Quantum Mechanisms of Particle Acceleration through Nonlinear Compton Scattering and Nonlinear Breit-Wheeler Process in Coherent Photon Dominated Regime	Bo Zhang	
15:30–15:50	Break		
15:50–16:20	Strong-field QED research in China University of Mining and Technology, Beijing	Miao Jiang	Wenpeng Wang
16:20–16:40	Vortex particle scattering in strong laser fields	Mamutjan Ababekri	
16:40–17:00	Generation of Quantum Vortex Electrons with Intense Laser Pulses	Zhigang Bu	
17:30–19:30	Dinner		

August 21st			
Time	Topic	Speaker	Chairperson
9:00–9:40	From one to many particles: Coherent emission and radiation reaction	Matteo Tamburini	Yutong Li
9:40–10:20	Strong Electromagnetic Fields and electron–positron pairs in Physics and Astrophysics	She–Sheng Xue	
10:20–10:40	Break		
10:40–11:10	Electric permittivity of the vacuum in a strong electric field	Hidetoshi Taya	Yanjun Gu
11:10–11:40	Copious $e^+e^-/\mu^+\mu^-$ Pairs Generation by Ultra–Intense Lasers	Tongpu Yu	
11:40–12:10	Bright Betatron X–ray Source Developed at SIOM Using Laser Wakefield Acceleration	Song Li	
12:10–14:00	Lunch		
14:00–14:30	Ultrarelativistic spin–polarized plasma	Zheng Gong	Liangliang Ji
14:30–15:00	Manipulating the quantum vacuum to control the electron–positron creation	Dandan Su	
15:00–15:30	Vacuum propulsion	Yusong Cao	
15:30–15:50	Break		
15:50–17:00	Poster Session		
17:30–19:30	Dinner		

August 22nd			
Time	Topic	Speaker	Chairperson
9:00–9:40	Nonlinear QED effects and brilliant gamma-ray emission induced by plasma acceleration	Zhengming Sheng	Sergey Bulanov
9:40–10:20	Strong field QED driven ultrarelativistic particle sources with large angular momenta	Jianxing Li	
10:20–10:40	Break		
10:40–11:10	Attosecond, ultrabright, and collimated γ -photon driven by relativistic spatiotemporal optical vortex lasers	Wenpeng Wang	Jianxing Li
11:10–11:40	Towards High-Level Precision and Statistics in High-Field QED Experiments	Conor McAnespie	
11:40–12:10	Study of beam-driven strong-field QED	Xinglong Zhu	
12:10–14:00	Lunch		
14:00–14:30	Extreme field physics and the 10/100 PW lasers at SIOM	Liangliang Ji	Gianluca Sarri
14:30–15:00	The measurements of QED vacuum excitation from RHIC-STAR	Wangmei Zha	
15:00–15:30	Fermionic signal of vacuum polarization in strong laser fields	Yueyue Chen	
15:30–15:50	Break		
15:50–16:20	From collisional to collisionless QED plasmas	Huaihang Song	Wenchao Yan
16:20–16:40	Momentum spiral on pair production in rotating fields	Lina Hu	
16:40–17:00	Electron Self-Polarization in a Quantum-Radiation-Dominated Beam-Plasma Interaction	Kun Xue	
17:30–19:30	Dinner		

August 23rd			
Time	Topic	Speaker	Chairperson
9:00–9:40	From Nonlinear Optics of Quantum Vacuum to Relativistic Catoptics	Sergey Bulanov	She–Sheng Xue
9:40–10:20	High–field QED in the laboratory: current status and near–term opportunities	Gianluca Sarri	
10:20–10:40	Break		
10:40–11:10	Stable electron acceleration via LWFA for robust table–top XUV–FEL	YanJun Gu	Hidetoshi Taya
11:10–11:40	Opportunities in the strong field QED based on the large scientific facilities	Wenchao Yan	
11:40–12:10	Generation of highly spin–polarized energetic electrons via intense laser–irradiated overdense targets	Xiaofei Shen	
12:10–14:00	Lunch		
14:00–14:30	Highly nonlinear light–nucleus interaction	Xu Wang	Zheng Gong
14:30–15:00	Tunneling time in strong field ionization	Michael Klaiber	
15:00–15:30	Monoenergetic proton beam acceleration and depolarization in the PW lasers	Meng Wen	
15:30–15:50	Break		
15:50–16:10	On the spin–quantization–axis selection for the spin polarization modeling during laser–electron collision	Xiangyan An	Xiaofei Shen
16:10–16:30	Breit–Wheeler Process Dressed in Intense Laser Field	Shiyu Liu	
16:30–16:50	Enhancement of pair production in oscillated overlapped fields	Adiljan Sawut	
17:30–19:30	Dinner		

Plenary Talk Introduction

August 20th 9:20-10:00

Photon-photon scattering and Axion-like particle generation

Baifei Shen^{1,2}

1. Shanghai Normal University, China

2. Shanghai Institute of Optics and Fine Mechanics, CAS, China

Abstract:

Based on the ultra intense 100 PW optical laser and hard XFEL at SHINE in Shanghai, China, possible QED experiments in vacuum are considered. For photon-photon scattering, we consider the changes of polarization, energy, and transverse momentum of the probe XFEL due to the QED effects [1-6]. The experiment for vacuum birefringence is designed for SHINE considering the effects of vacuum degree and focusing lens. The pump laser of flying focus is suggested to be used to enhance the vacuum birefringence. To avoid the strong signal in the forward direction, we consider the vacuum wave mixing with resonance at an angle away from the forward direction and vacuum diffraction of the probe XFEL from the intense optical laser where multi XFEL modes are used to enhance the signal. We also consider the axion-like particle generation in laser-plasma interaction. By detecting the change of polarization of the XFEL, we may know the generation of axion-like particles [7].



References:

1. Baifei Shen et al., Photon-photon scattering in a plasma channel, *Physics of plasmas*, 10(4570), 2003.
2. Baifei Shen et al., Exploring vacuum birefringence based on a 100 Pw laser and an x-ray free electron laser beam, *Plasma Phys. Control. Fusion*, 60(044002), 2018.
3. Dirui Xu, Baifei Shen et al. XFEL beamline design for vacuum birefringence experiment, *Nuclear inst. and Methods in Physics Research, A* 982 (164553). 2020.
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6. Bufan Jin and Baifei Shen, Enhancement of vacuum birefringence with pump laser of flying focus, *PHYSICAL REVIEW A* (accepted), 2023.
7. Shan Huang, Baifei Shen et al., Axion-like particle generation in laser-plasma interaction, *Phys. Scr.* 97 (105303), 2022.

August 20th 10:00-10:40

TBA

Bin Qiao

Peking University

August 21th 9:00-9:40

From one to many particles: Coherent emission and radiation reaction

Matteo Tamburini

Max Planck Institute for Nuclear Physics

Abstract:

The trajectories of relativistic particles in an intense electromagnetic field can be described by the Landau-Lifshitz equation, where the effect of radiation emission is accounted for via a self-force, and interparticle fields are often neglected as an approximation. Yet, the inclusion of interparticle fields is necessary to ensure energy-momentum conservation, particularly during coherent emission. By simulating a neutral, relativistic bunch of electrons and positrons colliding with a laser pulse, we show that the inclusion of interparticle fields can significantly affect the particle dynamics, and can result in sustained coherent emission and the rapid formation of microbunches over a few micrometers distances, six orders of magnitude shorter than the typical length of an undulator in a free-electron laser.



August 21th 9:40-10:20

Strong Electromagnetic Fields and electron-positron pairs in Physics and Astrophysics

She-Sheng Xue

ICRANet, Rome University, INFN

Abstract:

I present a theoretical discussion on the dynamical issue of electron-positron pair productions in strong static or alternating fields and high-energy photon collisions in Quantum Electrodynamics (QED). I come into the question of semi-classical and adiabatic approximation approaches to the calculation issue. I suspect an effective field theory of quantum electromagnetic dynamics realises in a strong coupling regime. I advocate a fully nonperturbative computation approach to the strong-coupling QED. I briefly mention the recently observed signal of electron-positron annihilations in astrophysics and other relevant experimental and observational issues.

August 22th 9:00-9:40

Nonlinear QED effects and brilliant gamma-ray emission induced by plasma acceleration

Zheng-Ming Sheng

School of Physics and Astronomy, Shanghai Jiao Tong University

Tsung-Dao Lee Institute, Shanghai Jiao Tong University

Abstract:

The technology progresses in the generation of ultra-intense lasers and brilliant electron beams provide unique opportunities for the experimental investigations of nonlinear QED effects and their applications. In this talk, I will present our recent theoretical and numerical studies on the nonlinear QED and their applications in brilliant gamma-ray emission and positron generation driven by intense lasers and high energy electron beams. Numerical simulation (particle-in-cell) codes are developed to investigate the involved highly nonlinear physics, such as radiation damping, gamma-ray photon emission, pair production via linear and nonlinear Breit-Wheeler processes, and beam polarization via the Sokolov-Ternov effect. The propagation of multi-PW intense lasers in plasma is investigated with some QED effects included. Several schemes are discussed for the production of GeV gamma-rays with unprecedented brilliance via laser wakefield acceleration of electrons with multi-PW lasers in underdense plasma and via the interaction of high energy electron beams with solid targets.



References:

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- [2] W. M. Wang, Z.-M. Sheng, T. Wilson, Y.T. Li, and J. Zhang, Phys. Rev. E 101, 011201(R) (2020).
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- [5] X.L. Zhu, T.P. Yu, M. Chen, S.M. Weng, Z.M. Sheng, New J. Phys. 20, 083013 (2018).
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- [10] X.L. Zhu et al., New J. Phys. 25 093016 (2023).
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- [12] X.L. Zhu et al., Phys. Rev. Lett. 132, (2024).
- [13] T.P. Yu et al., Rev. Mod. Plasma Phys. 8, 24 (2024).
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August 22th 9:40-10:20

Strong field QED driven ultrarelativistic particle sources with large angular momenta

Jian-Xing Li

Xi'an Jiaotong University, China

Abstract:

Ultrarelativistic particle sources with large angular momenta have significant applications in many fields. In this talk, we will introduce the generation mechanisms of those particle sources by employing strong field QED effects, e.g., nonlinear Compton scattering and nonlinear Breit-Wheeler process. And, the angular momentum transferring mechanisms therein will also be revealed. Besides, we will further introduce some applications of vortex particles in nuclear reaction.



August 23th 9:00-9:40

From Nonlinear Optics of Quantum Vacuum to Relativistic Catoptrics

Sergei Bulanov

ELI-ERIC, ELI BEAMLINES, Za Radnicí 835, Dolní Břežany, 25241, Czech Republic

Abstract:

Here we present an overview of the latest results obtained by the ELI-BL team and colleagues on problems related to strong field quantum electrodynamics. The talk starts with a discussion of nonlinear optics of the quantum vacuum, where the dependence of the vacuum refractive index on the electromagnetic field amplitude and photon energy leads to the generation of high-order harmonics, solitons and synergistic Compton-Cherenkov radiation. We then discuss an approach to the extremely efficient generation of gamma-ray flashes using the nonlinear Compton scattering mechanism in the interaction of a multi-petawatt laser with a high-density target. Multi-petawatt lasers interacting with low-density plasma targets are expected to accelerate electrons via the LWFA mechanism to energies where radiation corrections are not negligible in electron-laser collisions. The role of these effects increases dramatically as the electromagnetic field amplitude approaches the limits of the critical QED field. The use of relativistic catoptrics will allow us to approach the critical QED field.

August 23th 9:40-10:20

High-field QED in the laboratory: current status and near-term opportunities

G. Sarri

School of Mathematics and Physics, Queen's University Belfast, BT71NN, Belfast UK

Abstract:

The fast-paced advance in the high-power laser technology has recently allowed reaching focussed intensities exceeding 10^{21} Wcm^{-2} , with realistic plans to reach $> 10^{23} \text{ Wcm}^{-2}$ in near-term largescale laser facilities worldwide. While these intensities are still orders of magnitude lower than those needed to produce an electron-positron pair from the vacuum, this limitation can be overcome by focussing the laser pulse onto an ultra-relativistic electron beam. In this case, the electric field in the rest frame of the electron is relativistically boosted by its Lorentz factor. As an example, a 1 GeV electron beam interacting with a laser focussed intensity of 10^{21} Wcm^{-2} will experience, in its own rest frame, an electric field of the order of 20% of the Schwinger field. GeV-scale electron beams suitable for these experiments can be provided either by laser-wakefield or radio-frequency accelerations.

At these unique field intensities, a plethora of exotic processes can be triggered and studied, including highly non-linear Compton scattering, quantum radiation reaction, Breit-Wheeler pair production, and elastic photon-photon scattering. Detailed experimental characterisation of these phenomena will not only advance our fundamental understanding of this branch of fundamental physics but will also be instrumental for

astrophysics, cosmology, and plasma physics. An international collaboration led by UK scientists has recently performed the first experiments in this area at the Rutherford Appleton Laboratory, unveiling quantum signatures of radiation reaction [1,2] and commissioning the first laser-driven photon-photon collider [3]. Several other campaigns at different world-class physics laboratories, including the E-320 experiment at SLAC [4], the LUXE experiment at the Eu-XFEL [5], and experiments at the Extreme Light Infrastructure and the Astra-Gemini laser, are currently in their preparation stage and aim at pushing our experimental capabilities even beyond the Schwinger field.

In this talk, an overview of the current status and near-term opportunities in this area of physics will be given, with a particular focus on novel diagnostics [6,7], analysis methods [8,9], and challenges in high-power laser design and handling.

References:

- [1] K Poder, M Tamburini, G Sarri et al., Phys. Rev. X 8, 031004 (2018)
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- [3] B. Kettle et al., New J. Phys. 23,115006 (2021)
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Conference Notes



Conference Notes

Conference Notes

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