



Frontiers in Intense Laser-Matter Interactions Theory

Max Planck Institute of Quantum Optics
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Scientific report

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(Workshop chairmen)

Workshop objectives

Short abstract

The use of intense short laser pulses for fundamental physics experiments and in high potential applications raises new theoretical questions, both, in terms of fundamental understanding and methods. The workshop is devoted to these theoretical challenges with special attention to the new physics of nonlinear vacua, electron motion, and radiation at intensities of $10^{22}\text{W}/\text{cm}^2$ and beyond, the use of plasmonic enhancement for generating strong fields, the dynamics of photo-excitation and photo-emission.

Scientific summary

Short laser pulses drivers, their use for ultrafast spectroscopy of atoms, molecules, and solids, and their application to construct high-brilliance photon and particle sources all develop extremely rapidly. At the extreme field end (see ELI) the classical electronic motion will enter into the self-field interaction regime, the laser may probe vacuum non-linearities and ultimately approach vacuum breakup. Already at much lower intensities, present routine pulses can take atoms, molecules, and solids far from their ordinary field free state. Finally, lasers are used in various setups to build particle and photon sources with a host of applications ranging from the creation of ever shorter X-ray pulses, over compact particle accelerators, all the way to medical diagnostics and therapy. This workshop is devoted to new questions raised for theory and simulation by future intense laser sources and by current experiments. It is intended to offer a forum for communicating the most urgent questions from experiment to theory and in turn for highlighting new physics that will come into experimental reach in the near future. Ample room will be given to the discussion of current limitations and future possibilities of theory and simulations and extra effort will be put into attracting young researchers to these emerging questions. Among the topics, special emphasis will be on quantum vacuum itself, the free electron motion in the vacuum at intensities $10^{22}\text{W}/\text{cm}^2$ and beyond, ultra-fast field induced dynamics in atoms and molecules, field-enhancement by plasmonic effects, the effects of strong fields on few-electron systems and solids, and the control of laser generated particle and X-ray sources.

Fundamentals of high-field electrodynamics: Long-standing questions about vacuum nonlinearities, radiation reaction in electrodynamics and how to formulate appropriate equations in a non-perturbative way are just getting new attention, now in the light of high-intensity laser experiments.

They concern both classical and QED descriptions. They are not only of fundamental academic interest, but are expected to have major impact on experimental results of electron-positron generation, the acceleration of electrons and positrons, the emission of radiation and e.g. at lower intensities for applications to fast ignition of inertial confinement fusion. In this context ionization processes in high-Z atoms will get on the agenda too.

Ultrafast processes in atoms, molecules, and solids: Recent years have brought several new developments: with transient absorption spectroscopy a new tool for the observation of strong field or XUV induced ultrafast dynamics has emerged. Interpretation of the observations in presence of a strong IR field remains still to be explored. Extremely high precision measurements of strong-field photo-emission times have triggered a re-consideration of the ionization process. Measurements with time-resolution of a few attoseconds require re-consideration of seemingly simple processes like single-photon ionization, where the impact of intrinsic structure must be disentangled from post-ionization scattering and possible field-induced effects. New grounds are being explored with strong-field, ultrafast measurements at solid surfaces. Plasmonic fields may enhance weak sources with very high repetition rates to intensities that allow high harmonic generation.

Topics

- Laser based sources
 - Electron and ion acceleration
 - X-ray sources, including X-ray lasing
 - Attosecond sources
- Atoms, molecules, and solids
 - Ultrafast few-electron dynamics
 - Strong field ionization
 - Attosecond delays in photo-emission
- Extreme fields
 - Fundamentals of strong-field QED
 - Relativistic electron dynamics
 - Pair production and vacuum instability

Financial support

Generous support by Ludwig Maximilians University (LMU), the Munich Advanced Photonics Cluster (MAP), the Max Planck Institute of Quantum Optics (MPQ: lecture hall, conference secretary) in addition to the basic support by SILMI allowed us to fully cover the expensed by the majority of the participants.

Documentation

The workshop web-site is hosted at MPQ:
<http://www.mpq.mpg.de/APS/Frontiers2012/>.

No proceedings proper were produced, but the slides of the majority of the presentations are available all participants and anybody interested (needs to request password). So far, requests for access came mostly from non-official participants of the workshop.

Participant statistics

There were 31 oral presentations and 17 posters (two post-deadline, not listed in the program) presented by 48 participants from 17 different countries.

SILMI member states:	34
SILMI non-member states:	5
USA:	2
China:	2
Japan:	2
Russia:	2
Australia:	1
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Total:	48

In addition, the meeting was attended by students of the International Max Planck Research school “Advanced Photon Science” and local scientist (not listed in the official program) with a peak attendance of about 65 people.

Presentations and impact on the field

The workshop idea was to concentrate on topics in intense ultrafast fields where we felt that new theory questions are arising due to experimental developments. In particular, we believe that a few new topics were brought to greater attention of the strong field / ultrafast community, such as ultrafast

transients in phase transformation (Eugene Gamaly), large-scale simulation of laser-surface interactions (Kazuhiro Yabana), or the use of non-equilibrium Green's function methods in laser-solid interactions (Andrea Marini). As to sources, new techniques for controlling plasma acceleration within established schemes were suggested, e.g. by “two stage acceleration” (Sheng) or producing giant half-cycle pulses (Meyer-ter-Vehn). The recent achievement of X-ray lasing was reported in detail (Nina Rohringer).

In ultrafast dynamics, other than new topics mentioned above, approaches to describing and measuring ionization dynamics in detail (Olga Smirnova) and the elusive topic of time-delays in photo-ionization (Alfred Maquet) were discussed. With intermolecular Coulomb decay (Lenz Cederbaum) another topic that may deserve more attention from the ultrafast community was introduced.

Finally, the status of the fundamental description of extreme fields was reported with, e.g., new schemes for pair creation (Alexander Fedotov) and fundamentals of strong-field classical and quantum electrodynamics (Antonino di Piazza).

Apart from the progress reports in the sub-fields and the introduction of a few new topics, we believe that the moderate scale, and the relaxed workshop-type atmosphere have allowed official workshop participants and at times local audiences to come up-to-date in several hot topics of strong field physics in general.

Workshop program

-- Wed, Sep 19 --		
9:00-9:10	Joachain	Opening by the chairman of SILMI
9:10-9:40	Schroeder	Laser-plasma accelerators for high-energy physics and light source applications
9:40-10:10	Gamaly	Phase transformations produced inside a crystal
10:10-10:30	Psikal	Laser-driven proton acceleration enhancement by structured foils (simulations and experiments)
10:30-11:00 -- BREAK --		
11:00-11:30	Malka	Electron and X ray beams produced by laser plasma accelerators
11:30-12:00	Grech	High energy photon emission and its back-reaction effect in UHI laser-plasma interaction
12:00-14:00 -- LUNCH --		
14:00-14:30	Pukhov	Laser interaction with thin foils: new sources of radiation and fast particles
14:30-15:10	Sheng/Wang	Two-stage acceleration of protons from relativistic laser-solid interactions + Upper limit power for self-guided propagation of intense lasers in plasma
15:10-15:40	Silva	Novel simulation approaches for laser-plasma accelerators and fast ignition
15:40-16:00 -- BREAK --		
16:00-16:20	Meyer-ter-Vehn	Giant half-cycle attosecond pulse from ultrathin foils
16:20-16:50	Zepf	Coherent Emission from ultraintense laser thin foil interactions
-- DINNER --		
--THUR, Sept 20 --		
9:00-9:30	Rohringer	Amplified spontaneous x-ray emission in atomic and molecular gases
9:30-10:00	Tikhonchuk	Electron heating and acceleration in two plasmas colliding with sub-relativistic velocities
10:00-10:30	Goulielmakis	Elements of attosecond control of electrons
10:30-11:00 -- BREAK --		
11:00-11:30	Santra	Ultrafast processes in xenon
11:30-12:00	Yabana	Ab-initio description for the interaction of intense laser pulses with solids
12:00-14:00 -- LUNCH --		
14:00-14:30	Demekhin	Coherent Intense Laser Pulses Lead to Interference in the Time Domain: Dynamic Interference of Electron Waves
14:30-15:00	Madsen	Strong field ionization of molecules
15:00-15:30	Marini	Phonon-induced dynamics of electrons and excitons in solids driven out-of-equilibrium by strong laser pulses: an Ab-Initio approach
15:30-16:00 -- BREAK --		
16:00-16:30	Maquet	Attosecond delays in photoionization: A theoretical perspective
16:30-17:00	Smirnova	Attosecond multielectron dynamics in tunnel ionization
17:00-17:30	Cederbaum	Exploring Intermolecular Coulombic Decay by free electron lasers
-- DINNER --		

--FRI, Sept 21--		
9:00-9:30	Bauer	Coulomb-corrected quantum orbits in strong-field ionization
9:30-10:00	Seipt	Strong field QED processes in short laser pulses
10:00-10:30	Keitel	Electrons, ions and nuclei in extremely intense laser pulses
10:30-11:00 -- BREAK --		
11:00-11:30	Di Piazza	Testing strong-field CED and QED with intense laser fields
11:30-12:00	Marklund	Strong field QED effects in laser-matter interactions
12:00-14:00 -- LUNCH --		
14:00-14:30	Ilderton	Open problems and challenges in strong field QED
14:30-15:00	Fedotov	Pair creation by collision of intense laser pulse with high-frequency photon beam
15:00-15:30	Berenyi	Pair Production in Strong Fields: The Wigner function approach
15:30-16:00 -- BREAK --		
16:00-16:20	Raczka	Particle production effects in laser-matter interactions at ultra-high intensities
16:20-16:50	Narozhny	Vacuum instability in extreme laser fields
-- END 17:00 --		

-- POSTERS --	
Bamberg	The AMR domain
Boca/Florescu	Radiation Reaction Effects in Non-linear Thomson scattering
Deutschmann	FEL simulation
Dinu	Nonlinear Compton Scattering Probabilities
Elkina	Radiation reaction in laser irradiated plasma
King	Trident pair production in a constant-crossed field
Klier	Simulation of strong cascading and spontaneous vacuum decay
Kruchinin	Light induced currents in dielectrics and wide band gap semiconductors: quantum kinetic approach
Laasner	Band tail absorption saturation in CdWO ₄ with 100-fs laser pulses
Lupetti	High repetition rate attosecond sources by plasmonic enhancement
Majety	Ionic shake-up in the XUV ionization of molecules
Sato	Time-dependent density functional theory for ultrafast electron dynamics at solid surfaces
Siminos	Electron heating effect on self-induced transparency in relativistic intensity laser-plasma interaction
Zielinski	A new parallel code implementing t-SURFF: fully differential two-electron spectra at IR wavelength

Workshop chairs: Armin Scrinzi and Hartmut Ruhl
Workshop secretary: Monika Wild

Participants

Bamberg	Karl-Ulrich	LMU	Munich
Bauer	Dieter	University of Rostock	Rostock
Berenyi	Daniel	Eötvös Loránd University	Szeged
Boca	Madalina	University of Bucharest	Bucharest
Cederbaum	Lorenz	PCI, University of Heidelberg	Heidelberg
Demekhin	Phillipp	PCI, University of Heidelberg	Heidelberg
Deutschmann	Fabian	LMU	Munich
Di Piazza	Antonino	Max-Planck-Institut für Kernphysik	Heidelberg
Dinu	Victor	University of Bucharest	Bucharest
Elkina	Nina	LMU	Munich
Fedotov	Alexander	Nat. Nuc. Res. University MEPhI	Moscow
Florescu	Viorica	University of Bucharest	Bucharest
Gamaly	Eugene	Australian National University	Canberra
Goulielmakis	Eleferios	MPQ	Garching
Grech	Mickael	MPIPKS	Dresden
Ilderton	Antony	University of Umea	Umea
Joachain	Charles	U. Libre de Bruxelles	Brussels
Keitel	Christoph	Max-Planck-Institut für Kernphysik	Heidelberg
King	Ben	LMU	Munich
Klier	Constantin	LMU	Munich
Kruchinin	Stanslav	MPQ	Munich
Laasner	Raul	University of Tartu	Tartu
Lupetti	Mattia	LMU	Munich
Madsen	Lars	University of Aarhus	Aarhus
Majety	Vinay Pramod	LMU	Munich
Malka	Victor	LOA CNRS	Palaiseau
Maquet	Alfred	UPMC	Paris
Marini	Andrea	CNR	Rome
Marklund	Mattias	University of Umea	Umea
Meyer-ter-Vehn	Jürgen	MPQ	Munich
Narozhny	Nikolai	Nat. Nuc. Res. University MEPhI	Moscow
Psikal	Jan	Czech Tech. University	Prague
Pukhov	Alexander	University of Düsseldorf	Düsseldorf
Raczka	Piotr	University of Warsaw	Warsaw
Rohringer	Nina	CFEL	Hamburg
Santra	Robin	CFEL	Hamburg
Sato	Shunsuke	University of Tsukuba	Tsukuba
Schroeder	Carl	LBNL	Berkeley
Seipt	Daniel	HZDR	Dresden
Sheng/Wang	Zheng-Ming	Jiao Tong University	Shanghai
Silva	Luis	Instituto Superior Tecnico	Lisbon
Siminos	Evangelos	MPIPKS	Dresden
Smirnova	Olga	MBI	Berlin
Tikhonchuk	Vladimir	University of Bordeaux	Bordeaux
Wang	Wei-Min	Institute of Physics, CAS	Beijing
Yabana	Kazuhiro	University of Tsukuba	Tsukuba
Zepf	Matthew	Queen's University	Belfast
Zielinski	Alejandro	LMU	Munich