P 20: Laser plasma and laser applications 2

Time: Thursday 14:00–16:00 Location: b302

Invited Talk P 20.1 Thu 14:00 b302

The interaction of lasers with material using pulse durations from fs to ns — •Georg Pretzler[1], Steffen Mittelmann[1], Jannis Oelmann[2], Julian Wegner[1], and Sebastijan Brezinsek[2] — [1]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf — [2]Forschungszentrum Jülich, Institut für Energie- und Klimaforschung – Plasmaphysik

We compare the interaction of lasers with different pulse durations with solid matter and focus on the effects induced in the target, like ionization, ablation, and crater formation. Experiments were performed with lasers of fs-, ps-, and ns-durations, yielding strongly differing results concerning plasma temperature, interaction depth, particle ejection and spectral line emission. The effects were analysed by the help of various types of simulations, and different energy transfer mechanisms proved to be dominant, dependent on the laser pulse duration. This allows connecting the well-known results with longer pulses to the ultra-short high-intensity regime, which might help for selecting the right laser parameters for applications. One example is discussed in the talk, namely laser induced breakdown spectroscopy (LIBS) for the diagnostics of the first wall in fusion devices, for which a series of experiments is presented using lasers with different pulse durations.

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Comparison of Laser Induced Breakdown Spectroscopy (LIBS) Results on Deuterium Loaded High Z Materials from Lasers of Different Pulse Durations — •Steffen Mittelmann[1], Jannis Oelmann[2], Dongye Zhao[2], Ding Wu[3], Arkadi Kreter[2], Sebastijan Brezinsek[2], Hongbin Ding[3], and Georg Pretzler[1] — [1]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf — [2]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik — [3]Key Laboratory of Material Modification by Laser, Ion and Electron Beams, Dalian University of Technology

Impurities in the wall material of upcoming fusion reactors can endanger the lifetime and quality of the confined plasma. To get an idea of deuterium or tritium retention at the wall the diagnostic Laser induced breakdown spectroscopy (LIBS) with possible in-situ application is used. This widely applied technique is executed by lasers with different pulse durations. In our institute we are operating a sub 10 fs Ti:Sa-laser that big advantage is the well-defined ablation area which leads to a high depth resolution. The results from LIBS experiments on tantalum exposed by deuterium in the linear plasma device PSI-2 with our laser system can be compared to ns- and ps-LIBS signals, which are shown here. An important aim of these studies is to reach a deeper understanding of the basic processes governing ablation, plasma formation and spectral emission in the different pulse duration regimes for finally deciding which type of laser pulses is the most promising for future fusion reactor wall analysis.

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Characterisation of plasma-facing surfaces by double-pulse LIBS with picosecond pulses — •Erik Wüst[1], Jannis Oelmann[1], Sebastijan Brezinsek[1], Christian Linsmeier[1], and Claus Schneider[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, 52425 Jülich — [2]Forschungszentrum Jülich GmbH, Peter-Grünberg-Institut, 52425 Jülich

Depth-resolved information about fuel retention and material mixing on plasma-facing components surfaces made out of Tungsten (W), Beryllium (Be) or Graphite (C) are required in order to understand plasma-surface interaction processes in long pulse plasma devices like ITER or W7-X. Laser-induced breakdown spectroscopy (LIBS) is here a promising candidate for the detection of hydrogen (H) isotopes, such as tritium which is critical from the point of safety.

The selection of W as plasma-facing material induces challenges regarding the detection of residual plasma fuel in the component due to overall low H isotope retention by implantation. One way to adapt to this by improving the detection limit of the technique is double-pulse LIBS (DP-LIBS) which uses a second laser pulse to further excite released H atoms in the plasma induced by the first pulse. This amplifies the H_α line intensity, which is used for H determination.

The perspective of DP-LIBS as a technique for H retention measurement is discussed and our approach to implement DP-LIBS with short pulses of a Nd:YAG laser ($\tau = 35$ ps, with wavelengths 1064 nm, 532 nm and 355 nm available simultaneously) is presented.

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Two-dimensional simulations of a water-confined ns-laser shock peening — •Vasily Pozdnyakov[1] and Jens Oberrath[2] — [1]Institute of Product and Process Innovation, Leuphana University Lüneburg, Germany — [2]South Westphalia University of Applied Science, Department of Electric Power Engineering, Modeling and Simulation, Soest, Germany

Due to continuously rising demands in microelectronics, aerospace and automotive productions, new surface improvement methods are required. Laser shock peening (LSP) is one of such enhancement techniques, which is considered to be a potential substitute to a conventional shot peening process due to a better performance and a wider application range. LSP deals with laser pulses with high intensities (over 1 GW/cm2) and short durations (ns-range), so all occurring physical phenomena are difficult to measure experimentally. Therefore, computer simulations of plasma formation and shock wave generation are required in order to optimize the process for industrial applications.

In this work, a two-dimensional simulation of a water-confined laser shock peening of aluminium with a circular laser focus is done. The radiation-hydrodynamics code MULTI2D [1] is used, which allows to identify temporal evolution of plasma and shock wave spatial distributions. The occurring processes are analyzed and compared for different peening parameters to get a physical insight into a pulsed laser-matter interaction. The results can be used for LSP optimization.

[1] R. Ramis, J. Meyer-ter-Vehn, and J. Ramírez, Comput. Phys. Commun. 180, 977-994 (2009)

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Efficiency of bi-circular High Harmonic Generation with a kHz Laser — •Zahra Chitgar[1], Roman Adam[2], and Paul Gibbon[1,3] — [1]Jülich Supercomputing Centre, Forschungszentrum Jülich, Germany — [2]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich GmbH, Germany — [3]Centre for Mathematical Plasma Astrophysics, KU Leuven, Belgium

Circularly-polarized (CP) extreme UV- and X-ray radiation is an essential tool for analyzing the magnetic properties of materials. Recently, CP high harmonic generation (HHG) has been demonstrated experimentally by focusing bi-chromatic (800 + 400nm wavelength), counter-rotating CP laser pulses into gas targets [Kfir, O. et al, Nat. Phot. (2015)], thus overcoming a long-standing limitation of HHG being only possible with linearly polarized light. The efficiency and brightness of such gas-based harmonics is ultimately restricted by the need to keep laser intensities below the ionization threshold, a limitation that can be overcome by using plasmas. Theoretical [Sharma, P. et al, Phys Plasmas (2018)] and numerical [Chen, Z. Phys Rev E (2018)] analysis have shown that a bi-circular laser driver can also work in under- and over dense plasmas with apparently the same selection rules as in gases, i.e. every third harmonic is suppressed and adjacent harmonics have opposite helicity. Here we demonstrate using both fluid and kinetic (PIC) modelling that bi-circular HHG has a comparable efficiency to the HHG source driven by linearly polarized laser light reflected from or transmitted through a thin ionized foil target with JuSPARC-VEGA laser parameters (40mJ, 25fs, 1kHz).

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Ultrafast Polarization of an Electron Beam in Intense Bi-chromatic Laser Pulses — •Daniel Seipt[1,2], Dario Del Sorbo[3], Christopher P. Ridgers[4], and Alec G. R. Thomas[2] — [1]Helmholtz-Institut Jena, Fröbelstieg 3, D-07743 Jena, Germany — [2]The Gérard Mourou Center for Ultrafast Optical Science, University of Michigan, Ann Arbor, MI-48109, USA — [3]High Energy Density Science Division, SLAC National Accelerator Laboratory, Menlo Park, CA-94025, USA — [4]York Plasma Institute, Department of Physics, University of York, York YO10 5DD, UK

Recent high-intensity laser-plasma experiments provided evidence for quantum radiation reaction effects due to hard photon emission. In this talk I will discuss the radiative spin-polarization of the electrons as a manifestation of quantum radiation reaction affecting the spin-dynamics. It is demonstrated that radiative polarization of high-energy electron beams can be achieved in collisions with PW class bichromatic laser pulses. We employ both a Boltzmann kinetic approach and a Monte-Carlo algorithm within the quasi-classical approximation of intense field QED to simulate the interaction. Aspects of spin dependent radiation reaction are addressed, where spin polarization leads to a measurable splitting of the energies of spin-up and spin-down electrons. Immediate consequences for extreme-intensity laser plasmas are discussed.

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X-ray assisted nuclear excitation by electron capture in plasmas generated by optical lasers — •Yuanbin Wu, Christoph H. Keitel, and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1,D-69117 Heidelberg, Germany

Nuclear excitation by electron capture (NEEC) is a resonant process in which electron recombination into an ion occurs with the simultaneous excitation of the nucleus. In this work we investigate theoretically x-ray assisted NEEC into inner-shell atomic holes in plasmas generated by strong optical lasers. This scenario involves intense x-ray radiation from an x-ray free electron laser (XFEL) to additionally produce inner-shell holes in the plasma ions, into which NEEC may occur. As a case study we consider the 4.85-keV transition starting from the 2.4 MeV ^{93m}Mo isomer that can release the stored excitation energy.

We find that, already at few hundred eV plasma temperature, the generation of inner-shell holes can allow optimal conditions for NEEC, otherwise reached for plasmas in thermodynamical equilibrium only at few keV [1]. The combination of XFELs and optical lasers is also advantageous as NEEC rates can be maximized at plasma temperatures where the photoexcitation rate remains low. Considering the combination of mJ-class optical laser and XFEL, the NEEC excitation number can reach ~ 1 depleted isomer per second and is competitive with scenarios recently envisaged at petawatt-class lasers [2].

[1] Y. Wu, C. H. Keitel, and A. Pálffy, arXiv:1910.05326.
[2] Y. Wu, J. Gunst, C. H. Keitel, and A. Pálffy, Phys. Rev. Lett. 120, 052504 (2018).