Working Group 1:

Laser-Plasma Wakefield Acceleration

Leader: Carl Schroeder, LBNL

Co-leader: Mike Helle, NRL

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Name of submitting author	Carlo Benedetti
Institution	Lawrence Berkeley National Laboratory
Email	cbenedetti@lbl.gov
Abstract Title	**Quasi-matched propagation of ultra-short, intense laser pulses in plasma channels**
Author/Affiliation listing	**C. Benedetti**, C. B. Schroeder, E. Esarey, and W. P. Leemans Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
Abstract	Propagation of short/intense laser pulses in a plasma channel is investigated. The nonlinear paraxial wave equation describing the laser propagation in the plasma is solved analytically and numerically. For any arbitrary temporal laser pulse profile and density profile in the channel, we determine the laser intensity distribution ensuring quasi-matched propagation

Summary

We address the problem of the matched propagation of a high intensity (a0 ~ 1) and/or high power (P ~ Pc) laser pulse traveling in a plasma channel with an arbitrary density profile. Matched propagation is relevant since, in the accelerating stage of an LPA, it is desirable that the laser driver generating the wake propagates over long distances with minimal variation in its properties to maintain the amplitude, shape and phase velocity of the associated wake as constant as possible. Variations in the wake properties may lead to additional particle injection (non dark-current-free structure) or degradation of beam quality. Starting from the paraxial wave equation, we derive an equation describing the evolution of the normalized-intensity-weighted second order transverse moment of the laser pulse at each longitudinal location along the laser beam. Imposing non-evolving second-order moment and assuming that at any given location along the laser pulse the intensity distribution in the transverse plane (slice) can be described by a Gaussian with a spot size that is, in general, slice-dependent, we obtain an equation characterizing the quasi-matched laser condition. For any arbitrary temporal laser pulse profile and any prescribed transverse (radial) density distribution in the plasma channel, we compute the intensity distribution, i.e., the functional dependence of the spot size on the longitudinal coordinate along the laser pulse, yielding a quasi-matched propagation. In the analysis all non-paraxial effects are neglected. A "conical" shaped intensity distribution is found to be the quasi-equilibrium solution in case of a laser pulse with a Gaussian temporal profile moving in a parabolic density channel. The generation of a laser pulse with such an intensity distribution may be difficult to realize experimentally. Therefore, approximate quasi-matched solutions, valid in the weakly-relativistic regime, are also investigated. In particular, for a prescribed Gaussian pulse with a constant spot size along the beam, propagating in a channel with a given (radial) density distribution, the optimal channel depth ensuring matching for the central region of the laser pulse, including self-focusing and plasma wave guiding effects, has been determined.

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Name of submitting author	Mr. Nicolas Bourgeois
Institution	University of Oxford
Email	n.bourgeois1@physics.ox.ac.uk
Abstract Title	**Transverse beam profile measurements of laser–accelerated electrons using coherent optical radiation.**
Author/Affiliation listing	**N. Bourgeois**, W. Rittershofer, S. Bajlekov, S. M. Hooker Clarendon laboratory, University of Oxford, UK M. Heigoldt, S-W. Chou, A. Popp, K. Khrennikov, S. Karsch Max-Planck-Institute für Quantenoptik, Germany
Abstract	In this talk we describe the use of coherent optical transition radiation (COTR) for measuring the transverse profile of laser-accelerated electron bunches. The electron beam profiles are reconstructed from COTR measurements and compared to scintillator-based beam profile measurement techniques.

Summary

Experimental measurements of COTR emitted from laser-accelerated electrons were carried out at the Max-Planck-Institute für Quantenoptik (MPQ) in Garching, Germany. In the experiments discussed here the target was a steady-state-flow gas cell and the optical transition radiation was produced by the ultra-short electron bunch crossing the surface of two thin metallic screens. The first screen was located just at the exit of the gas cell and the second screen was 0.5m downstream; each screen was imaged onto a CCD camera. This radiation was emitted coherently since the electron bunch length was shorter than the visible wavelengths detected. Previous experiments to measure the transverse profile of particle beams with OTR used the incoherent part of the spectrum. Coherent OTR was considered to be unsuitable for this application owing to the effects of interference of the radiation generated from different parts of the screen leading to a characteristic ring-shaped image, as previously observed for RF-accelerated electron beams [1]. We show here that it is nevertheless possible to reconstruct the transverse profile of the electron bunch from the measured near-field image of COTR. The transverse profiles reconstructed from COTR are compared to those measured directly – on the same shot – with Lanex screens and YAG crystals located close to the OTR screen. Finally we present single shot measurements of the beam profile and divergence deduced from the COTR produced at the two screens.

1. R. Akre et al., Phys. Rev. ST AB 11, 030703 (2008).

Name of submitting author	Dr. Min Chen
Institution	Lawrence Berkeley National Laboratory
Email	MinChen@lbl.gov
Abstract Title	**Electron injection and emittance control by transverse colliding pulses in a Laser-Plasma Accelerator**
Author/Affiliation listing	**M. Chen**, C.G.R. Geddes, E. Esarey, C.B. Schroeder, S.S. Bulanov, C. Benedetti, L.L. Yu, S. Rykovanov, W.P. Leemans Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA E. Cormier-Michel, D. Bruhwiler Tech-X Corporation, 5621 Arapahoe Ave, Suite A, Boulder, CO 80303, USA
Abstract	Electron injection and emittance control in laser plasma acceleration by transverse colliding pulses are studied. Simulations show beams with extremely small transverse emittance can be obtained by transverse standing wave injection. Transverse beat waves can also be used to create asymmetric electron injection.

Summary

By using transverse colliding pulses, electron injection and transverse emittance can be controlled in a laser plasma accelerator. For transverse pulses with same frequencies, a beam with extremely small emittance is obtained by putting the transverse standing wave position close to the density peak of a laser driven plasma wake. Electrons near the axis are accelerated longitudinally by the ponderomotive force of the transverse pulses and accelerated transversely by the beat wave, and later are injected into the second bucket of the wake. Ionization is used to increase the transverse injection area and the final injection charge. Simulations show transverse momentum spread can be as small as 0.04mec, which is orders of magnitude smaller than the normal optical injection schemes in laser plasma accelerators. For transverse pulses with different frequencies, transverse beat waves can be used to generate asymmetric injection, which can increase t he betatron radiation emission.

Supported by the U.S. Department of Energy under contract No. DE-AC02-05CH11231, by DOE NNSA DNN, DE-SC0004441 and DE-FC02-07ER41499, and by the COMPASS SciDAC project.

Computational resources of the National Energy Research Scientific Computing Center were used to perform the simulations. We acknowledge the assistance of the VORPAL development team.

Name of submitting author	Dr. Min Chen
Institution	Lawrence Berkeley National Laboratory
Email	MinChen@lbl.gov
Abstract Title	**Numerical modeling of laser tunneling ionization in explicit particle-in-cell codes**
Author/Affiliation listing	**M. Chen[1]**, E. Cormier-Michel[2], C.G.R. Geddes[1], D. Bruhwiler[2], L.L. Yu[1], E. Esarey[1], C.B. Schroeder[1], W.P. Leemans[1] 1Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA 2Tech-X Corporation, 5621 Arapahoe Ave, Suite A, Boulder, CO 80303, USA
Abstract	Methods for calculation of laser tunneling-ionization in explicit particle-in-cell codes used for modeling laser-plasma-interactions are compared against theoretical predictions. The effects of grid resolution and macro-particles numbers are examined. Implementation of the ionization algorithm in two particle-in-cell codes is compared for cases of ionization-based electron injection in a laser-plasma accelerator.
Summary	
Implementation of laser tunneling ionization rate formulae in explicit PIC codes has been examined. The originally published ionization rate formulae were reviewed, and corrections noted. It was shown, by comparison to theoretical predictions, that the DC form of the ionization rate provides improved accuracy. The effect of PIC numerical parameters, such as grid resolution and number of macro-particles per cell, on the calculated ionization probability was studied. It was found that the ionization probability is sensitive to the grid resolution, and increased number of macro-particles per cell can reduce the simulation noise. Modeling the ionization injection in a laser-plasma accelerator was used to benchmark the ionization algorithm implemented in two PIC codes. Supported by the U.S. Department of Energy under contract No. DE-AC02-05CH11231, DE-SC0004441 and DE-FC02-07ER41499, and by the COMPASS SciDAC project. Computational resources of the National Energy Research Scientific Computing Center were used to perform the simulations. We acknowledge the assistance of the VORPAL development team.	

Name of submitting author	Benjamin Cowan
Institution	Tech-X Corporation
Email	benc@txcorp.com
Abstract Title	**Improved particle statistics for laser-plasma self-injection simulations**
Author/Affiliation listing	**B. M. Cowan** (1), S. Y. Kalmykov (2), B. A. Shadwick (2), K. Bunkers (2), D. L. Bruhwiler (1), and D. P. Umstadter (2) (1) Tech-X Corporation (2) University of Nebraska, Lincoln
Abstract	We describe methods for improving the accuracy of injected particle beams by selectively enhancing the particle statistics in PIC simulations, using reduced model computations as a guide. We demonstrate convergence of key beam parameters in 2D, and show improved noise properties in 3D.

Summary

Laser-plasma acceleration (LPA) has seen remarkable progress in recent years, with production of quasi-monoenergetic electron bunches of ever-improving energy and quality. These beams are now being investigated for use in a number of applications, including light sources and high-energy colliders. As the range of applications has increased, so have the demands on beam quality and stability. Simulations play a key role in understanding the effect of initial conditions on injected beam parameters. A major challenge of simulation techniques is in obtaining accurate results that are free of numerical artifacts, while at the same time being computationally tractable. Here we present a method for improving the accuracy of simulated particle beams from the LPA self-injection process. We recently demonstrated the ability to compute the collection volume of an injection process -- the range of initial locations of injected particles [1, 2]. We find that the collection volume consists of an annular region around the propagation axis. By loading this region with higher particle statistics than in other locations, we can significantly increase the number of macroparticles in the injected beam. We show that this technique captures much finer detail of particle phase space than does uniform loading, and results in lower noise. We demonstrate convergence of key beam parameters in 2D, and present results of full 3D simulations. This technique in fact results in a lower comput ational burden, since it allows reducing particle statistics outside the collection volume. In addition, we present results of a novel technique in which particles can deform and split if they expand, effectively self-generating statistics. We find that this method yields a much lower phase space volume, as well as lower charge, than conventional PIC, and also reveals much finer structure of particle phase space.

[1] B. M. Cowan et al., "Computationally efficient methods for modeling laser wakefield acceleration in the blowout regime," accepted for publication in J. Plasma Phys. (2012)
[2] S. Y. Kalmykov et al., New J. Phys. 14, 033025 (2012)

Name of submitting author	Dr. Brigitte Cros
Institution	LPGP CNRS
Email	brigitte.cros@u-psud.fr
Abstract Title	**Electron beams and X-ray radiation generated by laser wakefield in capillary tubes**
Author/Affiliation listing	**B. Cros**[1], J. Ju[1], A. Döpp[1], K. Cassou[1], H. Ferrari [1,2], G. Maynard[1], G. Genoud[3], F. Wojda[3], M. Burza[3], K. Svensson[3], O. Lundh[3], A. Persson[3], C.G. Wahlström[3] 1:LPGP CNRS Université Paris Sud 11 UMR8578, Orsay, France 2: Consejo Nacional de Investigaciones Científicas y Técnicas CNEA, Bariloche, Argentina 3: LLC Department of Physics Lund University, Lund, Sweden
Abstract	Laser wakefield is generated inside capillary tubes in order to study inside a large domain of parameters the conditions for self-injection of plasma electrons and their acceleration. X-rays emitted by betatron radiation are a precise diagnostic of the electron acceleration process. Experiment results and simulation results are in good agreement.

Summary

Electron beams and betatron X-ray radiation generated by laser wakefield acceleration in long plasma targets are studied. The targets consist of hydrogen filled dielectric capillary tubes of diameter 150 to 200 microns and length 6 to 20 mm. Experimental results are compared to PIC simulations with CALDER-CIRC for input parameters close to the experimental ones. Electron beams are observed for peak laser intensities as low as 5 × 10^17 W/cm^2. It is found that the capillary collects energy outside the main peak of the focal spot and contributes to keep the beam self-focused over a distance longer than in a gas jet of similar density. This enables the pulse to evolve enough to reach the threshold for wavebreaking, and thus trap and accelerate electrons. No electrons were observed for capillaries of large diameter (250 μm), confirming that the capillary influences the interaction and does not have the same behavior as a gas cell. X-rays are used as a diagnostic of the interaction and, in particular, to estimate the position of the electrons trapping point inside the capillary. The X-ray fluence is enhanced in long plasmas at low density at an intensity of the order of 5 x 10^18 W/cm^2, due to the increase of the number and energy of the accelerated electrons in these conditions.

References: H.E. Ferrari, et al., Modeling of laser plasma acceleration in capillary tubes, Plasma Phys. Control. Fusion 53, 014005 (2011).

H. E. Ferrari, et al. Electron acceleration by laser wakefield and X-ray emission at moderate intensity and density in long plasmas, Phys. Plasmas 18, 083108 (2011).

G. Genoud, et al. Laser-plasma electron acceleration in dielectric capillary tubes, Appl Phys B, 105, 309 (2011). J. Ju, et al., Enhancement of X-rays generated by a guided laser wakefield accelerator inside capillary tubes, to be published in Applied Physics Letters (Accepted April 25, 2012).

Name of submitting author	Mr. Paul Cummings
Institution	University of Michigan, Center for Ultrafast Optical Sciences
Email	cummingp@umich.edu
Abstract Title	**A Computational Investigation of Synchrotron-Like Radiation Generation in LWFA Experiments**
Author/Affiliation listing	**Paul G. Cummings**, University of Michigan CUOS Alec G. R. Thomas, University of Michigan CUOS
Abstract	The generation of synchrotron radiation in LWFA experiments is investigated computationally. A novel computational model for explicitly simulating synchrotron radiation is derived and validated. Results from simulations run using this model within the PIC code OSIRIS 2.0 are presented.
Summary	
A promising application of laser-wake-field acceleration (LWFA) technology is as a tunable source of x-ray and gamma radiation, via synchrotron-like radiation. Such a source could have many potential applications, including microscale imaging of advanced composite materials. Simulating this radiation proves to be a non-trivial challenge, as an exact self-consistent solution involves a path integral over the radiating particles' entire trajectories. Consequently, a novel computational model which approximates this process using a monte-carlo algorithm to generate particle-like "macrophotons" was developed, and integrated into the well-known, robust particle-in-cell (PIC) code OSIRIS 2.0. Validation of this algorithm was performed using a separate, skeleton particle-tracking code; results from this validation will be presented. Additional validation results, resulting from integrating the algorithm into OSIRIS 2.0, will also be presented. Finally, preliminary results from simulations of recent LWFA experiments [1], which investigated the generation of synchrotron-like radiation, are presented and discussed. 1: Mangles, S. P. D., et al. "Controlling the spectrum of x-rays generated in a laser-plasma accelerator by tailoring the laser wavefront." Applied Physics Letters 95 (2009).	

Name of submitting author	Dr. Cameron Geddes
Institution	Lawrence Berkeley National Laboratory
Email	cgrgeddes@lbl.gov
Abstract Title	**Low-emittance electron bunches from a laser-plasma accelerator measured using single-shot X-ray spectroscopy**
Author/Affiliation listing	**C. G. R. Geddes**[1], G. R. Plateau[1], D. B. Thorn[2], M. Chen[1], C. Benedetti[1], E. Esarey[1], A. J. Gonsalves[1], N. H. Matlis[1], K. Nakamura[1], C. B. Schroeder[1], S. Shiraishi[1], T. Sokollik[1], J. van Tilborg[1], Cs. Toth[1], S. Trotsenko[3], T. S. Kim[1], M. Battaglia[1], Th. Stoehlker[2, 3], and W. P. Leemans[1] 1. Lawrence Berkeley National Laboratory, 94720 CA, USA 2. ExtreMe Matter Institute EMMI, D-64291 Darmstadt, Germany 3. Helmholtz-Institut Jena, D-07743 Jena, Germany
Abstract	High-resolution, single-shot X-ray spectroscopy measurements of betatron radiation are used to estimate the transverse emittance of electron bunches produced by a laser-plasma accelerator. Normalized transverse emittance was estimated to be as low as 0.1 mm mrad, consistent with simulations of self-trapping.

Summary

Single-shot spectroscopic measurements of betatron X-rays are reported, and used to infer the transverse bunch size of both broadband sub-100 MeV and low-energy-spread 0.5 GeV electron beams produced by a laser-plasma accelerator. The measurements use a semiconductor detector array, and spectra are obtained via single pixel absorption and cluster techniques. By matching the X-ray betatron spectra to analytical and numerical models of betatron radiation, the electron bunch radius inside the plasma is estimated to be ~0.1 micron. Combined with simultaneous electron spectrum and divergence measurements, the normalized transverse emittance is estimated to be as low as 0.1 mm mrad, consistent with three-dimensional particle-in-cell simulations. This emittance is lower than previously measured, important to applications of high gradient laser-plasma accelerators including Thomson gamma sources and eventual high-energy colliders.

This work was supported by the U.S. Dept. of Energy under Office of Science, Office of High Energy Physics Contract no. DE-AC02-05CH11231, by DOE NNSA NA-22, and NSF Grants PHY-0917687 and 0614001, and used computation at NERSC.

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Name of submitting author	Dr. Daniel Gordon
Institution	Naval Research Laboratory
Email	daniel.gordon@nrl.navy.mil
Abstract Title	**Ionization Physics and Laser Acceleration of Electrons**
Author/Affiliation listing	Antonio Ting, Michael Helle, Dmitri Kaganovich, Bahman Hafizi* Naval Research Laboratory, Washington, DC Icarus Research, Inc., Bethesda, MD
Abstract	Tunneling ionization is characterized using an ab initio quantum mechanical numerical model. Numerical ionization rates are compared with theoretical ones. The ionized phase space distribution is characterized by computing the Wigner transform of the simulated wave function. The implications for PIC simulations are discussed.

Summary

Laser acceleration of electrons is often most successful when the pre-pulse is small, so that the main pulse interacts with neutral gas. This suggests that the ionization process plays a role in electron trapping. Indeed, tunneling ionization is cited as playing a major role in various laser acceleration experiments [Moore et al., Phys. Rev. Lett. 82, 1688 (1999), Kaganovich et al., Phys. Rev. Lett. 100, 215002 (2008), Pollock et al., Phys. Rev. Lett. 107, 045001 (2011)]. An important tool for modeling laser acceleration of electrons is the Particle-in-Cell (PIC) code. When tunneling ionization is important, PIC codes are usually modified to spawn macro-particles at rest at a rate given by some simple tunneling theory, such as the ADK model [M.V. Ammosov et al., Sov. Phys. JETP 64, 1191 (1986)]. Such models are arrived at only after many approximations are made. It is of interest, therefore, to characterize the ionization process using a numerical model that makes very few approximations. For this purpose, we have developed a full-scale model for an atom in an arbitrary applied field that solves the exact non-relativistic time dependent Schroedinger equation. Since the output is the full electronic wave function, all parameters characterizing the ionized electrons can be determined. Of particular interest is the classical phase space distribution of the particles, which can be determined by evaluating the Wigner distribution in the quasi-classical region (far from the atom). We will compare the numerical ionization rates of hydrogen and helium with those derived from a variety of ionization theories. The phase space distribution of the ionized electrons will be given, and the implications for PIC simulations will be discussed.

This work is supported by the Naval Research Laboratory Base Program, the Department of Energy, and by NERSC

Name of submitting author	Julia Grebenyuk
Institution	DESY
Email address	jgreb@mail.desy.de
Abstract Title	**Simulations of laser-wakefield acceleration with external electron bunch injection for REGAE experiments at DESY**
Author/Affiliation listing	**Julia Grebenyuk** [1], Timon Mehrling [2], Eckhard Elsen [1], Klaus Floettman [1], and Jens Osterhoff [2] 1.DESY, Hamburg, Germany 2.University of Hamburg, Germany
Abstract	REGAE facility at DESY offers the unique possibility to study the external injection of pre-accelerated electron bunches from a conventional accelerator and their subsequent acceleration in plasma wakefields. Topics of particular interest are: emittance growth minimization, controlled betatron radiation emission, longitudinal bunch compression.

Summary

Short and highly intense laser pulses focused into a gas target, ionise the gas and may excite large amplitude, co-propagating plasma waves that support extreme electric fields (>10 GV/m) for acceleration of charged particles. These fields are orders of magnitude larger than in conventional radio-frequency accelerators. The REGAE facility at DESY offers the unique possibility to study the external injection of pre-accelerated electron bunches from a stable and fully controlled conventional accelerator, and their subsequent acceleration in plasma wakefields. REGAE (Relativistic Electron Gun for Atomic Exploration) provides 2-5 MeV velocity-bunched electron bunches of ~10 femtosecond length. A set of 2- and 3-dimensional numerical simulations was performed with the particle-in-cell code OSIRIS [1], showing a wide variety of effects which can be explored in the future at REGAE. External controlled injection allows to study effects which require precise information about the beam quality, position and momentum at the initial point of injection. One of the crucial topics for laser-plasma wakefield acceleration is the bunch emittance growth during the acceleration process. Controlled external injection is the most direct way to study the emittance evolution experimentally, and simulations were performed to investigate methods to reduce the growth. Injection with a transverse offset from the laser axis will cause the bunch to undergo betatron oscillations. External injection allows to manipulate the phase of injection, i.e. the parameters of the betatron oscillations such that the radiated betatron light is induced, which is currently investigated by means of simulations. Finally, injecting bunches at a defined phase of the wake will allow for the exploration of the longitudinal bunch compression in a wakefield during the acceleration process due to gradient of the electric field.

[1] Fonseca et al., LNCS 2331, 342 (2002)

Name of submitting author	Zhaohan He
Institution	University of Michigan Ann Arbor
Email	zhhe@umich.edu
Abstract Title	**High-Repetition-Rate Wakefield Electron Source Driven by Few-millijoule Ultrashort Laser Pulses**
Author/Affiliation listing	**Zhaohan He**, Bixue Hou, James H. Easter, Karl Krushelnick, John A. Nees, Alexander G. R. Thomas Center for Ultrafast Optical Science, University of Michigan, 2200 Bonisteel Blvd, Ann Arbor MI 48109-2099
Abstract	10 mJ ultrashort laser pulses acting on gas flow from capillary tubing nozzle generate stable 100 keV electron beams at a repetition rate of 500 Hz. Particle-in-cell simulations indicate that slow high amplitude plasma waves form and accelerate the electron beams.

Summary

We report on electron acceleration in an unexplored regime of plasma wakefield driven by few-millijoule femtosecond laser pulses (sub-TW) at high repetition rate (0.5 kHz). The high repetition rate enables better statistics and higher average particle flux, which were not accessible with typical <1 Hz repetition rate TW laser systems. Experiments were performed using the Lambda-Cubed laser at the University of Michigan. Collimated electron beams are produced with quasi-monoenergetic spectra up to approximately 150 keV. Two-dimensional numerical simulations using the particle-in-cell code OSIRIS show excellent agreement with the experimental results and suggest an acceleration mechanism in slow (non-relativistic) plasma waves on the density down ramp of a 100 μm scale gas target. Because of the relatively high charge (~10 fC) and potentially short temporal duration, such electron sources have the potential to be used for ultrafast electron microscopy and diffraction applications.

Name of submitting author	Dr. Arie Irman
Institution	Helmholtz Zentrum Dresden Rossendorf (HZDR), Germany
Email	a.irman@hzdr.de
Abstract Title	**Overview of laser-wakefield acceleration and Thomson backscattering experiments at HZDR**
Author/Affiliation listing	**A.Irman**[1]*, A. Jochmann[1], J.P. Couperus1, S. Trotsenko [2,3], M. Kuntzsch[1], U. Lehnert[1], A. Wagner[1], A. Köhler[1], A. Debus[1], H-P. Schlenvoigt[1], K.D. Ledingham[4], T. Cowan[1], R. Sauerbrey[1], U.Schramm[1] 1.Institute of Radiation Physics, Helmholtz Zentrum Dresden Rossendorf, Germany, 2.GSI, Damstadt, Germany, 3.Helmholtz Institute Jena, Jena, Germany, 4.University of Stratclyde, Glasgow, Scotland
Abstract	We present recent results from laser wakefield acceleration and Thomson backscattering experiments at HZDR, Germany. In LWFA experiment quasimonoenergetic electron bunches were produced with a central peak energy of 144 MeV in 400micron Helium gas jet. A laser Thomson backscattering source produced Xrays ranging from 5.5 KeV to 23.5 KeV.

Summary

We present recent results from laser wakefield acceleration and Thomson backscattering experiments at Helmholtz Zentrum Dresden Rossendorf. In laser wakefield acceleration experiments the laser and plasma parameters were chosen such that they match the condition for bubble generation and injection of electrons into the bubble structure and, thus, minimizing the required laser pulse evolution. We measured quasi-monoenergetic electron bunches with the central peak energy of 144 MeV after 400 µm acceleration distance in plasmas with a density of 2.2x10^(19) cm^(-3). We note that the monoenergetic feature was only observed at the optimum density. Varying the density by 5% is enough to broaden electron energy spectrum. Another important observation in this regime is that the generated electron beams showed a poor shot-to-shot reproducibility. This suggests that this approach is not really suitable if one aims on stable electron beam generati on. Ultrafast hard Xray pulses were produced via Thomson backscattering mechanism by colliding electron beams from the ELBE linear accelerator with laser beams delivered by the DRACO laser system. By tuning the electron beam energy the generated Xrays can be adjusted from 5.5 keV to 23.5 keV. The X-ray spectrum has a typical bandwidth of 1 keV (FWHM) collected within 5 mrad solid angle. In this initial experiment the total number of X-ray photons was estimated to be on the order of 10^(2) photons per shot within the observation solid angle. For applications, e.g., pump-probe experiments analyzing laser induced melting and recrystallization or temporal X-ray probing of warm dense matter, we aim to produce 10^(5) to 10^(6) photons per shot by optimizing the interaction cross section and using higher electron charge from the SRF photoinjector.

Name of submitting author	Dr. Dmitri Kaganovich
Institution	Naval Research Laboratory, Washington, DC
Email	dmitri.kaganovich@nrl.navy.mil
Abstract Title	**Laser Wakefield Electrons Injection and Acceleration in Gaseous Foils**
Author/Affiliation listing	Michael Helle, Daniel Gordon, and Antonio Ting Naval Research Laboratory, Washington, DC
Abstract	Thin, foil-like gaseous structures were created by laser-generated shock wave in gas jet. These gaseous foils have very sharp density gradients and were tested as stand alone electron injectors, as well as coupled to elongated, lower density gas jets for extended, high-energy electron acceleration.

Summary

Controlling the gas density gradient is important for electrons and protons acceleration, as well as for optical transition radiation generation. Thin, foil-like gaseous structure was created and tested as electron injector structure at the Naval Research Laboratory [1]. The foil was created by a laser-generated shock wave in gas jet [2]. The foil has sharp density gradients and total thickness of about 100 microns. This gaseous foil can be used as stand-alone electron injector or to be coupled to an additional acceleration structure like gas jet or capillary. We demonstrated stable injection of electrons from the gaseous foil, as well as successful coupling of the foil injector into a lower density gas jet. Simulations were used to understand and explain the experimental results.

[1] D. Kaganovich et al., Physics of Plasmas 18, 120701 (2011)
[2] D. Kaganovich et al., Applied Physics Letters 97, 191501 (2010)

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Name of submitting author	Dr. Serguei Kalmykov
Institution	University of Nebraska - Lincoln
Email	skalmykov2@unl.edu
Abstract Title	**Dark-current-free acceleration in the blowout regime using nonlinear plasma lens**
Author/Affiliation listing	**S. Y. Kalmykov**, B. A. Shadwick (University of Nebraska - Lincoln, USA), A. Beck, X. Davoine, and E. Lefebvre (CEA, DAM, DIF, France)
Abstract	A thin dense plasma slab ("lens"), placed before multi-cm-length, low-density plasma ("accelerator"), over-focuses an incident petawatt laser pulse, enforcing subsequent expansion of the laser-driven electron density bubble, self-injecting electrons over a brief period of time. Further stabilization and self-guiding of the pulse results in a dark-current-free acceleration.

Summary

Advent of short-pulse, petawatt lasers [1] opens a technological path to compact, multi-GeV laser wakefield acceleration in the blowout regime [2]. However, matching a PW pulse for stable self-guided propagation requires reducing plasma density to the level of 10^17 cm^-3 and increasing the laser spot radius to 60-80 microns, making evolution of the pulse and of the pulse-driven electron density bubble so slow as to exclude the possibility of self-injection. One solution to this problem is to employ the nonlinear focusing properties of dense plasmas [3,4]. We propose an experimentally feasible layout of a dark-current-free accelerator [4] using a thin (compared to the Rayleigh length) slab of dense plasma ("lens") placed before a long, rarefied plasma in which electrons are self-injected and accelerated ("accelerator"). The incident PW pulse (with the spot size close to the matched one for propagation in the accelerator) is over-focused by the plasma lens, and then diffracts in accelerator plasma as in vacuum, driving in its wake a rapidly expanding electron density bubble. The expanding bubble effectively traps initially quiescent electrons. As soon as laser diffraction saturates and self-guiding begins, the bubble transforms into a bucket of a weakly nonlinear non-broken plasma wave. Self-injection thus never resumes, and the structure remains free of dark current. A combination of reduced and full quasi-cylindrical PIC simulations for the parameters of Texas Petawatt laser [1] shows that the scheme promises trapping and acceleration of 1.3 nC charge to 2.6 GeV, with ~20 mm mrad normalized transverse emittance and ~2% relative energy spread [4]. This concept has been recently proven in the laboratory experiment with a 40 TW laser pulse, with the only modification: in accelerator plasma, the laser pulse was guided by the channel rather than self-guided [5].

[1] E.W. Gaul et al., Appl. Opt. 49 (2010) 1676-1681
[2] S.Y. Kalmykov et al., New J. Phys. 12 (2010) 045019
[3] C. Ren et al., Phys. Rev. E 63 (2001) 026411
[4] S.Y. Kalmykov et al., Plasma Phys. Control. Fusion 53(1) (2011) 014006
[5] A.J. Gonsalves et al., Nat. Phys. 7(11) (2011) 862–866

Name of submitting author	Dr. Serguei Kalmykov
Institution	University of Nebraska - Lincoln
Email	skalmykov2@unl.edu
Abstract Title	**Managing relativistic optical phenomena: An all-optical route to quasi-monoenergetic GeV electron beams generated with sub-100 TW laser pulses in mm-scale, high-density plasmas**
Author/Affiliation listing	**S. Y. Kalmykov**, B. A. Shadwick (University of Nebraska - Lincoln, USA); X. Davoine, A. Beck, and E. Lefebvre (CEA, DAM, DIF, France)
Abstract	Negative chirp of sub-100-TW driving laser pulse, in combination with a plasma density taper, prevents formation of an optical shock, reduces bubble expansion, and delays dephasing in blowout regime of LWFA, making possible to use the entire dephasing length to generate low-background, quasi-monoenergetic GeV electron beams from mm-scale dense plasmas.

Summary

Controlling evolution of the accelerating bucket - electron density bubble created by the ponderomotive force of short intense laser pulse - is of paramount importance for generating low-background, GeV-scale electron bunches [1,2]. Keeping this GeV-scale accelerator compact (using mm-scale plasmas and sub-100 TW laser systems) needs accelerating electrons until dephasing in high-density plasmas (above 5x10^18 cm^-3). These dense plasmas, however, rapidly transform an initially smooth driver into an optical shock (OS), destroying electron bunch quality [2,3]. Wake excitation red-shifts the laser pulse head, keeping the tail unshifted. Anomalous group velocity dispersion of plasma slows down the red-shifted head, compressing the pulse into a few-cycle-long relativistic shock, causing continuous expansion of the bubble, trapping copious numbers of unwanted electrons. Thus a poorly collimated, polychromatic energy tail is produced, completely do minating the electron spectrum at the dephasing limit [4]. To improve the situation, two approaches are instrumental. First, manipulations with the phase of the incident pulse (i.e. frequency chirp) may modify favorably the dynamics of pulse propagation. Using a broad-bandwidth (corresponding to a few-cycle transform-limited duration[5]), negatively chirped driver (viz. with blue-shifted leading edge) helps compensate for the nonlinear frequency red-shift, thus delaying OS formation[2]. To compensate the nonlinear frequency shift more precisely, the specific shape of the chirp may be extracted from reduced simulation models. Secondly, slowly increasing electron density in the direction of propagation further reduces bubble expansion and delays dephasing. Finally, using the plasma channel to suppress the diffraction of the pulse front further delays OS formation, reducing longitudinal deformations of the pulse to a minimum, making the quasi- monoenergetic bunch the dominant feature of the electron spectrum through dephasing. As a res ult, a 0.9-1 GeV electron beams with <5% energy spread and weak low-energy background can be generated with a negatively chirped 70 TW pulse from a 2 mm tapered plasma with the average density 6.5x10^18 cm^-3.

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Name of submitting author	Prof. Malte Kaluza C
Institution	Institute of Optics and Quantum Electronics, Jena
Email	Malte.Kaluza@uni-jena.de
Abstract Title	**Laser-driven electron acceleration with different target gases and generation of betatron radiation as a diagnostic for the electron bunch parameters**
Author/Affiliation listing	**M. C. Kaluza** [1,2,] M. Schnell[1] , A. Sävert[1], B. Landgraf [1,2], M. Reuter [1,2] , M. Nicolai[1],O. Jäckel [1,2] ,C. Peth [3], T. Thiele [3], O. Jansen [4], A. Pukhov [4] , O. Willi [3], S. P. D. Mangles [5], A. G. R. Thomas [6] , Z. He [6], C. Spielmann [1,2] 1 Institut für Optik und Quantenelektronik, Friedrich-Schiller Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany; 2 Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena, Germany; 3 Institut für Laser- und Plasmaphysik, Heinrich-Heine Universität Düsseldorf, 40225 Düsseldorf, Germany; 4 Institut für Theoretische Physik, Heinrich-Heine Universität Düsseldorf, 40225 Düsseldorf, Germany ;5 Department of Physics, Imperial College, London SW7 2AZ, United Kingdom; 6 Center for Ultrafast Optical Science (CUOS), University of Michigan, Ann Arbor, Michigan 48109, USA
Abstract	An analysis of the radiation emitted by electrons undergoing betatron oscillations during laser-wakefield acceleration has allowed us to determine the radiation source size and electron bunch diameter. Furthermore, experiments using different target gases show a strong influence on divergence, pointing stability, and bunch charge of the monoenergetic electrons.

Summary

Experimental results concerning the emission of x-ray radiation emitted by electrons undergoing betatron oscillations during the process of laser-driven wakefield acceleration are presented. The experiments have been carried out at the 40-TW laser system JETI at the Institute of Optics and Quantum Electronics at the University of Jena, Germany. From a careful analysis of the energy spectrum and the spatial distribution of the electromagnetic radiation emitted in the range of several keV, the size of the radiation source in the plasma could be deduced to be (1.8 ± 0.3) µm. Assuming a radiation pulse duration of at most the laser pulse duration, the peak brightness of the radiation source was 5´1021 photons per second per mrad2 per mm per 0.1% bandwidth. Furthermore, the transverse diameter of the oscillating electron bunch could be determined to be as small as (1.6 ± 0.3) µm. These results are compared to multi-dimensional pa rticle-in-cell simulations (PIC simulations) confirming our experimental findings [1]. Furthermore, new experimental results on laser-wakefield acceleration of electrons are shown. Here, the influence of different target gases (H2, D2, He) having different ionization potentials and charge-to-mass ratios has been investigated. A strong influence on the distribution and temperature of the preplasma formed by the leading edge of the laser pulse has been detected. As a consequence, this led to a significant improvement of the pointing stability, the total charge, and the relative energy spread of the generated quasi-monoenergetic electron pulses. The results can be explained to be a consequence of the preplasma temperature having different values for the various target gases. This temperature influences the injection of electrons into the plasma wave due to wave breaking. The experimental results have been compared to multi-dimensional PIC simulations confirming this hypothesis. [1] M. Schnell et al., Deducing the Electron-Beam Diameter in a Laser-Plasma Accelerator Using X-Ray Betatron Radiation, Physical Review Letters 108, 075001 (2012)

Name of submitting author	Prof. Stefan Karsch
Institution	LMU Munich & MPI for Quantum Optics
Email	stefan.karsch@mpq.mpg.de
Abstract Title	**Electron acceleration and radiation generation at Munich - an overview**
Author/Affiliation listing	Wenz, Johannes, LMU Munich & MPI for Quantum Optics ;Khrennikov, Konstantin, LMU Munich & MPI for Quantum Optics ;Popp, Antonia, LMU Munich & MPI for Quantum Optics ;Chou, Shao-Wei, LMU Munich & MPI for Quantum Optics ;Heigoldt, Matthias, LMU Munich & MPI for Quantum Optics ;Nathaniel Kajumba, LMU Munich & MPI for Quantum Optics ;Alexander Buck, MPI for Quantum Optics ;Jiancai Xu, MPI for Quantum Optics; Laszlo Veisz, MPI for Quantum Optics ;Andreas Maier, LMU Munich & MPI for Quantum Optics; Christian Werle, LMU Munich & MPI for Quantum Optics ;Sebastian Raith, LMU Munich & MPI for Quantum Optics ;Rafael Weingartner, LMU Munich & MPI for Quantum Optics ;Florian Grüner, DESY Hamburg ;Bourgeois, Nicholas, University of Oxford ;Bajlekov, Svetjoslav, University of Oxford ;Hooker, Simon, University of Oxford
Abstract	We will give an overview on recent activities in Munich concerning the experimental investigation of various electron acceleration regimes and their application to X-ray generation. In particular, we will present the current status of quasi-monochromatic Thomson-backscattered hard X-rays and betatron phase-contrast tomography.
Summary	
We will present results from the 2010-2012 experimental campaign with MPQ's ATLAS laser facility before its recent shutdown. In electron acceleration we focused on optimizing self-injected beams through variation of electron density, acceleration length, laser parameters and trace gas amount, as well as on shock front injection in as gas jet. Various self-injected, high-charge (>100 pC) acceleration regimes in the 300-600 MeV energy band will be discussed. Using shock-front injection, background-free beams with 100 pC at 50 MeV were created in a reliable way. In addition, we will present data on longitudinal emittance of the electron beams, showing a single sub-10fs bunch for short interactions and the self-injection of a second bunch in the second wakefield period for long acceleration distances. Using the wakefield accelerator as a betatron source for X-ray photons of up to 10 keV, we recorded high signal-to-noise images of an insect in a single shot, allowing to reconstruct a first high-resolution phase-contrast tomogram from approx. 1000 laser shots. Finally, we collided a part of the ATLAS laser beam with the shock-front accelerated, narrow-band electron beam to generate Thomson-backscattered X-rays with a tunable, quasi-monoenergetic spectrum between 5 and 30 keV.	

Name of submitting author	Mr. Karl Krushelnick
Institution	University of Michigan
Email	kmkr@umich.edu
Abstract Title	**Plasma dynamics in laser wakefield accelerators**
Author/Affiliation listing	**K. Krushelnick**, W. Schumaker, C. McGuffey, M. Vargas, V. Chvykov, F. Dollar, G. Kalintchenko, V. Yanovsky, A. Maksimchuk, A.G.R. Thomas (University of Michigan)
Abstract	Recent experimental results using the HERCULES laser system at the University of Michigan will be discussed. We will describe measurements of the dynamics of ions and the electron beams from laser wakefield accelerator experiments at powers up to 200 TW using probing and scattering diagnostics.
Summary	
Recent experimental results using the HERCULES laser system at the University of Michigan will be discussed. We will describe measurements of the dynamics of ions and the electron beams from laser wakefield accelerator experiments at powers up to 200 TW. These results include: 1) spatially resolved Raman scattering measurements 2) measurements of electron beam filamentation 3) measurements of ion dynamics and laser channeling during the interaction 4) effects of self-generated magnetic fields Comparisons with simulations will also be discussed as well as some potential applications for these beams.	

Name of submitting author	Mahadevan Krishnan
Institution	Alameda Applied Sciences Corporation
Email	krishnan@aasc.net
Abstract Title	**Tailored supersonic gas jet targets for wakefield acceleration**
Author/Affiliation listing	**Mahadevan Krishnan**, Kristi Wilson Elliott, Robert Madden and Brian Bures, AASC, San Leandro, CA, USA; Phillip Coleman, Evergreen Sciences, Philomath., OR, USA, C.G.R. Geddes, A.J. Gonsalves and W.P. Leemans, LBNL, Berkeley, CA, USA.
Abstract	A supersonic gas valve that opens in <100µs, closes in <400µs and drives supersonic nozzles at pressures beyond 1000psia and >10Hz rep-rates has been built and tested for Laser Plasma Accelerator applications. Performance of the valve and ongoing work to characterize tailored gas jets are presented.

Summary

The emerging field of laser-plasma acceleration (LPA) has demonstrated electron accelerators with unprecedented electric field gradients . Supersonic, highly collimated gas jets and gas-filled capillary discharge waveguides are two primary targets of choice for LPA, that have been used to accelerate beams up to 1 GeV [1,2]. A fast opening and closing gas valve is essential both as a gas jet target and to tailor density profiles in capillary targets [3]. AASC has (under a DOE SBIR grant) developed a fast valve that opens in <100µs, closes in <400µs and can run (in cooled mode) at ~10Hz rep-rates at pressures as high as 1000psia [4]. The valve with a single supersonic nozzle has been tested at LOASIS/LBNL and has also been delivered to the U. of Nebraska LPA program. A version will soon be delivered to Imperial College for use in LPA research. The design and operation of the valve with single nozzles is described.

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Name of submitting author	Dr. Sergey Kuzikov V.
Institution	Institute of Applied Physics, Russian Academy of Sciences
Email	kuzikov@appl.sci-nnov.ru
Abstract Title	**RF Undulator for Compact X-Ray SASE Source of Variable Wavelength***
Author/Affiliation listing	**S.V. Kuzikov** / Institute of Applied Physics, 46 Ulyanov St., Nizhny Novgorod, Russia and Omega-P, Inc., New Haven, CT, USA Y. Jiang / Yale University, New Haven, CT, USA A.A. Vikharev, J.L. Hirshfield /Yale University, New Haven, CT, USA and Omega-P, Inc., New Haven, CT, USA T.C. Marshall / Columbia University, New York, NY and Omega-P, Inc., New Haven, CT, USA
Abstract	A room-temperature RF undulator to produce ~1 nm wavelength radiation using relatively low energy electrons is considered. The necessary short electron bunches with energy in the range 0.1-1 GeV could be produced by a conventional linac, or using a compact petawatt laser injecting pulses into plasma bubbles.

Summary

The design features of RF undulator include an effective undulator period of 0.45 cm, an undulator parameter of K = 0.4, and an effective field length of 50 cm. These parameters could be realized using a multi-MW RF power amplifier to drive the undulator (e.g., the 34 GHz pulsed magnicon at Yale or a 30 GHz gyroklystron at IAP). Design of an undulator is based on the use of long high-Q cavities. Two designs were considered that avoid problems with a co-propagating wave destroying beam optics and spectra of scattered radiation: a dual-mode cylindrical cavity [TE01 (counter propagating) - TE02 (co-propagating)] with an off-axis electron beam; and a TM11 mode near cut off cavity with an on-axis beam. Both designs provide low surface fields, low pulse heating effects and require 10-30 MW power. Usually an injection of the electron bunches in an undulator should be synchronized with a phase of RF radiation. In our designs field distributions with s mooth tapers on ends allow to avoid problems with synchronization. Short (10's of fs) electron bunches could be produced using petawatt laser pulsed injection into plasma bubbles, as has already been demonstrated [1].

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Name of submitting author	Jiansheng Liu
Institution	State Key Laboratory of High Field Laser Physics, Shanghai Institute of Optics and Fine Mechanics
Email	michaeljs_liu@mail.siom.ac.cn
Abstract Title	**Cascaded Laser Wakefield Accelerators**
Author/Affiliation listing	**J. S. Liu**, W. T. Wang, H. Y. Lu, C. Wang, A. H. Deng, W. T. Li, Y. Tian, H. Zhang, R. X. Li, Z. Z. Xu Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences
Abstract	We investigated the control of electron injection in the cascaded laser wakefield accelerators, optimization of seeding phase and the self-guided propagation of laser pulses between the two accelerators. The maximum acceleration gradient with energy spread narrowing was obtained when the seeding phase and the laser pulse propagation were optimized.
Summary	

Past few years have witnessed the major breakthroughs in the field of electron-acceleration based on the laser wakefield accelerator (LWFA) concept [1-4]. Cascaded LWFAs offer great potentials to produce controllable multi-GeV monoenergetic electron beams. By designing two segments of gas cells filled with He/O_2 mixture and pure He gas flows respectively, we separated the electron injection from the succeeding acceleration stage and successfully realized an all-optical cascaded LWFA experimentally [5]. The first-stage LWFA which contained 1-mm-thick He/O_2 mixture was operated as an electron ejector assisted by ionization-induced injection. The energy, energy spread, and charge of the generated electron beams in the electron injector can be adjusted by changing the input laser intensity and the plasma density [6]. The second-stage LWFA, which contained pure He gas with relatively low density, was operated as the acceleration stage. The advantage of using ionization-induced-injection scheme is to decrease the required laser intensity and plasma densities for electron trapping in the electron injector. Therefore, the matching between the two-segment plasmas can be easily satisfied. By optimizing the seeding phase and the self-guiding of the laser pulse in the second LWFA to obtain the maximum acceleration gradient, electrons with Maxwellian spectrum generated from the electron injector with relatively high plasma density were successfully seeded into the second 3-mm-long low-density LWFA and post accelerated to be a quasi-monoenergetic electron beam with energy of 0.8 GeV, corresponding to an acceleration gradient of 187 GV/m in the second LWFA. Additionally, two segments of plasmas with different densities, which are operated as the electron injector and accelerator, respectively, are designed to realize a cascaded LWFA with gradient injection [7]. Particle-in-cell simulations indicate that the further acceleration of the electrons in the second-stage accelerator relies on the injection and acceleration in the electron injector. It is found that electrons trapped in the second wakefield period in the electron injector can be seeded into the next stage with an optimized phase for efficient acceleration and reducing in the relative energy spread. And finally a 700 MeV electron beam with a relative rms energy spread about 0.6% was obtained after a 5.5-mm-long acceleration in a dark-current free cascaded laser wakefield accelerator. References [1] T. Tajima & J. M. Dawson, Phys. Rev. Lett. 43, 267 (1979). [2] S. P. D. Mangles et al., Nature 431, 535 (2004). [3] C. G. R. Geddes et al., Nature 431, 538 (2004). [4] J. Faure et al., Nature 431, 541 (2004). [5] J. S. Liu, et al., Phys. Rev. Lett. 107, 035001 (2011). [6] C. Q. Xia, et al., Phys. Plasmas 18, 113101 (2011). [7] A. H. Deng, et al., Phys. Plasmas 19, 023105 (2012).

Name of submitting author	Dr. Nelson Lopes
Institution	Instituto Superior Tecnico
Email	nelson.lopes@ist.utl.pt
Abstract Title	**High-energy electron beams produced by a laser wakefield accelerator**
Author/Affiliation listing	**N. C. Lopes**, C. Russo, R. A. Bendoyro, J. Jiang, J. M. Dias, N. Lemos, J. Vieira, L. O. Silva, Grupo de Lasers e Plasmas, IPFN, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001, Lisboa, Portugal M. Bloom, J. Cole, S. Kneip, S. P. D. Mangles, Z. Najmudin, Blackett Laboratory, Imperial College London, SW7 2AZ, UK D. R. Symes, P. Foster, R. Pattathil, S. Hawkes, C. Hooker, B. Parry, O. Chekhlov, Y. Tang, Central laser Facility, STFC, Rutherford Appleton Laboratory, Didcot OX11 0QX, UK
Abstract	Electron bunches with sub GeV energies were obtained from the interaction of a 4-10 J laser pulse with hydrogen contained in a 4 cm long structured gas cell. The pre-formation of a plasma channel inside the gas cell allowed for a 1.5 GeV energy gain signature.
Summary	
A laser-wakefield acceleration (LWFA) experiment was performed at Astra-Gemini laser Facility using structured gas cells. In this experiment laser pulses with energies in the range 4-10 J were propagated in 2-4 cm long gas cells filled with hydrogen resulting in electron bunches with sub-GeV energies. It was possible to pre-form a plasma channel in the gas cell optical axis using a a high-voltage (100 kV) high-current (2kA) discharge between two hollow electrodes limiting the gas cell. The internal structure of the gas cell sets the initial plasma position and size and allows an almost free radial expansion resulting in a plasma channel. The plasma channel radial density profile was measured by interferometry as close to parabolic. The propagation of the laser pulse in this plasma channel resulted in a significant enhancement of the energy gain to above 1.5 GeV with low divergence and energy spread.	

Name of submitting author	Prof. Wei Lu
Institution	Tsinghua University of Beijing, China / UCLA
Email	weilu@tsinghua.edu.cn
Abstract Title	**Recent Progress of Laser Plasma Physics and Advanced Accelerator Research at L2PA of Tsinghua University**
Author/Affiliation listing	**Wei Lu** / Tsinghua University of Beijing, UCLA Jianfei Hua / Tsinghua University of Beijing Lixin Yan / Tsinghua University of Beijing Yingchao Du / Tsinghua University of Beijing Wenhui Huang / Tsinghua University of Beijing Chuanxiang Tang/ Tsinghua University of Beijing Xinlu Xu / Tsinghua University of Beijing, UCLA Chaojie Zhang / Tsinghua University of Beijing Fei Li / Tsinghua University of Beijing Yang Wan / Tsinghua University of Beijing Yipeng Wu/ Tsinghua University of Beijing Meng Luo / Tsinghua Univeristy of Beijing Jian Ma / Tsinghua University of Beijing Warren B. Mori / UCLA Chan Joshi / UCLA
Abstract	A new group named L2PA has recently been formed at Tsinghua University of Beijng to study laser plasma physics and advanced accelerator technology. This talk will briefly introduce the recent research activities of L2PA, including progresses made on theory, simulation and experiments.

Summary

A new group named L2PA has recently been formed at Tsinghua University of Beijng to study laser plasma physics and advanced accelerator technology. L2PA is the acronym of Laboratory of Laser Plasma Physics and Advanced Accelerator Technology. This talk will briefly introduce the recent research activities of L2PA, including progresses made on theory, simulations and experiments. On the experiments part, some details of a Thomson scattering X-ray facility equipped with a 20TW short pulse laser and a synchronized 45MeV electron LINAC will be present, together with recent experimental results on Thomson X-ray generation and laser plasma experiments. On theory and simulation part, two recent works will be discussed in details: one is on how to utilize an ultrashort electron pulse to diagnosis the electromagnetic structure of wakefield; another one is on theoretical understanding and simulations of special phase space dynamics of plasma photo-cat hode (laser ionization injection in electron beam driven nonlinear wakefield).

Name of submitting author	Stuart Mangles
Institution	Imperial College London
Email address	stuart.mangles@imperial.ac.uk
Abstract Title	**Hard X-Rays and High-Energy Electrons From a Laser Plasma Accelerator**
Author/Affiliation listing	**Stuart P. D. Mangles**, Michael Bloom, Matthew J. V. Streeter, Andreas Döpp, Stefan Kneip, Hirotaka Nakamura, Zulfikar Najmudin The Blackett Laboratory, Imperial College London, London SW7 2AZ, UK Rodolfo Bendoyro, Jiasheng Jiang, Nelson Lopes, GoLP/Inst. Plasmas e Fusão Nuclear, Laboratório Associado, Instituto Superior Técnico, Lisbon, 1049-001, Portugal James Holloway, Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK Dan R. Symes Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Science and Innovation Campus, Didcot, Oxfordshire, OX11 0QX, UK
Abstract	Using 250 TW laser pulses from the Astra Gemini Laser we demonstrate the production of high-energy (> 1 GeV) electron beams and bright, hard x-rays (10-100 keV) using a self-injecting, self-guiding laser wakefield accelerator. Measurements of the 3D momentum trajectory of the beam provide insight into the x-ray generation mechanism.
Summary	
We present results from a self-injection, self-guided laser wakefield experiment performed using the 250 TW Astra Gemini Laser at the Rutherford Appleton Laboratory. Using centimeter scale gas jets operating at plasma densities slightly above the self-injection threshold for the laser parameters we are able to produce electron beams of very high energy – up to 1.5 GeV. The electron beam energies were measured using a two-screen electron spectrometer operating without a slit. This set-up allowed measurements of the electron beam energy simultaneously with measurements of the x-rays produced by the betatron oscillations of the beam. Very bright x-rays were observed which emanate from a few-micron sized source and are well characterized by a synchrotron spectrum with a critical energy as high as 30 keV. The electron beam's betatron oscillations were also observed directly on the spectrometer. Using the two screen set-up we are able to reconstruct the three dimensional momentum trajectory of the beam and so gain insight on the x-ray generation mechanism.	

Name of submitting author	Dr. Nicholas Matlis
Institution	Lawrence Berkeley National Lab
Email	nhmatlis@lbl.gov
Abstract Title	**Spectral Multiplexing for Single-shot Ultrafast Tomographic Imaging**
Author/Affiliation listing	1. **Nicholas H. Matlis**: Lawrence Berkeley National Lab 2. Andrew Axley: Lawrence Berkeley National Lab 3. Wim P. Leemans: Lawrence Berkeley National Lab
Abstract	We demonstrate single-shot, ultrafast computed-tomography reconstructions of laser-induced plasmas using a new technique, spectral multiplexing. Interferometric projection data was acquired over a continuous range of angles simultaneously, permitting unambiguous plasma-density determinations. High-precision, picosecond-resolved, position and morphology measurements of a heterogeneous plasma object are presented.

Summary

Computed Tomography has revolutionized imaging in science, medicine and technology by using projection measurements at multiple angles to enable resolution of embedded structure. Traditionally, multi-angle measurements are accomplished by performing scans of either the object or the measurement device, which for dynamically-varying objects, must be completed faster than the time-scale over which the object changes. For ultrafast phenomena, which vary on picosecond timescales or faster and which may vary significantly on a shot-by-shot basis, single-shot acquisition is required. Here we introduce a technique, Spectrally Multiplexed Tomography (SMT), which uses a single beam to provide ultrafast, single-shot tomographic imaging of two spatial dimensions with a continuous range of angles, and apply it to measure 2D electron-density cross-sections of laser-induced plasma filaments with high precision. Characterization of these electron-density pro files is of critical importance for the tuning and development of many high-intensity-laser applications such as laser-plasma accelerators [1], for which the density of the plasma target sensitively determines the performance and stability. Traditional diagnostics, which probe the plasma from a single direction, require profile-symmetry assumptions and inversion algorithms for reconstruction of the density distribution [2], resulting in errors for non-symmetric plasmas. Tomographic probing allows profiling of arbitrarily-shaped plasmas, improving the density measurement. SMT, with its high temporal and spatial resolution and its very simple implementation opens the door to shot-by-shot tomographic profiling of ultrafast transient targets.

This work was supported by the Director, Office of Science, Office of High Energy Physics, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

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Name of submitting author	Dr. Eisuke Miura
Institution	National Institute of Advanced Industrial Science and Technology (AIST)
Email	e-miura@aist.go.jp
Abstract Title	**X-ray generation via laser Compton scattering using quasi-monoenergetic electron beam driven by laser-plasma acceleration**
Author/Affiliation listing	**Eisuke Miura**(1), Satoshi Ishii(2), Kenji Tanaka(2), Shun Kashiwaya(2), Ryunosuke Kuroda(1), Hiroyuki Toyokawa(1) (1) National Institute of Advanced Industrial Science and Technology (AIST) (2) Tokyo University of Science
Abstract	A well-collimated X-ray beam with a divergence angle of approximately 5 mrad is generated via laser Compton scattering using a quasi-monoenergetic electron beam driven by laser-plasma acceleration. The number of X-ray photons with an energy of around 65 keV is estimated to be 2x10^7 per pulse.

Summary

In laser-plasma acceleration (LPA), a femtosecond electron pulse can be generated, because the wavelength of the accelerating field is the order of 10 μm. A compact electron accelerator will be realized using the extremely high accelerating field of more than 100 GV/m. The unique characteristics of LPA enable us to produce compact all-optical ultrashort X-ray sources. X-ray generation using an electron beam driven by LPA has been conducted [1-3]. One type of such X-ray sources is a laser Compton scattering (LCS) X-ray source, which is produced by scattering a femtosecond laser pulse off a high-energy electron beam. In this paper, we report the first demonstration of X-ray generation via LCS using a quasi-monoenergetic electron beam driven by LPA. X-rays were generated by scattering a femtosecond laser pulse (800 nm, 140 mJ, 100 fs) off a quasi-monoenergetic electron beam containing 70 pC electrons in the monoenergetic peak with an energy of 60 MeV produced by focusing an intense laser pulse (800 nm, 700 mJ, 40 fs) on a helium gas jet. A well-collimated X-ray beam was produced, and the divergence angles were 4.2 and 6.2 mrad in the vertical and horizontal directions, respectively. The number of X-ray photons was estimated to be 2x10^7 per pulse. The characteristics of X-rays were investigated using a Monte-Carlo simulation code. The spectrum of X-rays emitted within the scattered angle of 5 mrad had a quasi-monochromatic structure with a peak at 65 keV. The number of X-ray photons was 2.4x10^7, which was in a good agreement with the experimental result. The allowance delay between the two laser pulses for X-ray generation was approximately 100 fs, and was nearly equal to the duration of the laser pulse scattered by the electron pulse. This suggests that both the electron and the X-ray pulse durations are shorter than 100 fs.

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Name of submitting author	Mr. Inhyuk Nam
Institution	Graduate Program of Photonics and Applied Physics, Gwangju Institute of Science and Technology (GIST), Gwangju 500-712, Korea
Email	inhyuknam@gmail.com
Abstract Title	**Hard X-ray generation from betatron oscillations of a wakefield-accelerated electron beam by asymmetric laser pulses**
Author/Affiliation listing	Min Sup Hur/ School of Electrical and Computer Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan, 689-798, Korea Han Sup Uhm/ Electrophysics Department, Kwangwoon University, Seoul 139-701, Korea Nasr A. M. Hafz/ Shanghai Jiao Tong University, Physics Department, Shanghai 200240, China Hyyong Suk/ Graduate Program of Photonics and Applied Physics, Gwangju Institute of Science and Technology (GIST), Gwangju 500-712, Korea
Abstract	We investigated the hard x-ray generation from the electron beam's betatron oscillations by temporally-asymmetric laser pulses in laser wakefield acceleration via two-dimensional (2D) particle-in-cell simulations (PIC).

Summary

The ultrashort laser pulses having sharp rising and slow falling time scales is used to increase amplitude of transverse oscillation to produce the light with high photon energy from a few to several tens of keV. In this situation, the accelerated electron beam interacts directly with the tail of the laser field in the ion cavity and undergoes transverse oscillations due to a phase-slip with the laser field. This oscillation can be matched with the betatron oscillation frequency due to the focusing force of the ions, which can lead to the large transverse oscillation amplitude due to the resonance between them. Furthermore, in this case the electron beam can be also micro-bunched at the laser wavelength, which may provide the possibility for generation of a coherent synchrotron radiation.

Reference:

[1] Inhyuk Nam, et el., "Controlling the Betatron Oscillations of a Wakefield-Accelerated Electron Beam by Temporally-Asymmetric Laser Pulses", Phys. Plasmas 18, 043107 (2011)

Name of submitting author	Dr. Jens Osterhoff
Institution	University of Hamburg
Email	jens.osterhoff@desy.de
Abstract Title	**Prospects of Plasma-Based Particle Acceleration at DESY**
Author/Affiliation listing	**J. Osterhoff** (a), R. Brinkmann (b), E. Elsen (b), K. Flöttmann (b), B. Foster (a,b), F. Grüner (a), B. Schmidt (b), H. Schlarb (b), F. Stephan (b) (a) University of Hamburg, 22761 Hamburg, Germany (b) Deutsches Elektronen-Synchrotron DESY, 22607 Hamburg, Germany
Abstract	A synergetic combination of established conventional and novel particle-acceleration concepts offers an attractive pathway to study many of the mechanisms occurring in plasma-based accelerators. Here, we present plans to harness and enhance existing radio-frequency facilities at Deutsches Elektronen-Synchrotron DESY for plasma-wakefield acceleration experiments.

Summary

The field of particle acceleration in plasma wakes has seen remarkable progress in recent years. Accelerating gradients of more than 10 GV/m can now be readily achieved using either ultra-short intense laser pulses or particle beams as wake drivers. The demonstration of the first GeV electron beams and a general trend towards improved reproducibility, beam quality and control over the involved plasma processes has led to plasma-acceleration techniques beginning to draw considerable interest in the traditional accelerator community. As a consequence, DESY, Germany's leading accelerator center, and the University of Hamburg have established a research program for plasma-based novel acceleration techniques with the goal of exploiting the synergetic combination of conventional and new accelerator concepts. Specific examples of the areas to be investigated include the external injection of pre-accelerated electron bunches from the radio-frequency accelerators REGAE (at ~5 MeV) and FLASH (at ~1.2 GeV) into high-intensity laser-driven wakefields in plasma. The interaction of phase-space-tailored beams with plasma waves will facilitate a variety of interesting and highly relevant studies, such as detection of electron-beam-emittance evolution [1], extreme bunch compression, the controlled emission of betatron radiation, and staging of accelerating units. In addition, FLASH and the Photo Injector Test Facility PITZ (at ~25 MeV) with their advanced beam-shaping capabilities will allow for a number of beam-driven plasma wakefield experiments. Some of these studies build on the recent demonstration of temporally triangular beams [2] and investigate different schemes to obtain transformer ratios beyond two. In addition, the superconducting FLASH accelerator will potentially enable the exploration of MHz repetition rates for beam-driven acceleration, a highly relevant topic for future particle-physics applications. All of these activities are planned within the framework of the newly formed LAOLA collaboration.

References: [1] T. Mehrling et al., submitted (2012) [2] P. Piot et al., Phys. Rev. Lett. 108, 034801 (2012)

Name of submitting author	Dr Chih-Hao Pai
Institution	The University of Texas at Austin
Email	rick.pai0327@gmail.com
Abstract Title	**Compact tunable x-ray sources based on Compton backscatter from laser wakefield accelerators**
Author/Affiliation listing	**Chih-Hao Pai**, Hai-En Tsai and M. C. Downer
Abstract	We propose compact, tunable x-ray generation by Compton backscatter from laser-wakefield accelerators. The globally-optimized terawatt-laser-driven wakefield accelerator can routinely generate 100-MeV, monoenergetic electrons with high quality, suitable for producing ~200-keV x-ray pulse by Compton scatter. Controlled-injection will also be incorporated in our setup, enhancing tunability and stability of this source.

Summary

Production of bright, coherent, femtosecond hard x-ray pulses by Compton backscatter from compact TW-laser-driven wakefield accelerator (LWFA) beams can open a range of ultrafast x-ray science to university laboratories [1], but because of low conversion efficiency requires careful optimization of charge, energy, energy spread, collimation and repeatability of the electron beam [2]. In a separate student poster, we report global optimization of tabletop LWFA performance by systematically varying duration and focus of the drive laser pulse, and density, profile and thickness of the gas jet in detail. Quasi-monoenergetic ~100 MeV electron beam can be routinely generated with high-quality: <10% energy spread, 100 pC charge, <4 mrad divergence and <10 mrad pointing fluctuation with ~100% reproducibility. Here, I will propose in detail how to incorporate a probe pulse to implement Compton backscatter based on our laser and electron parameters. Experimental design and calculations of x-ray conversion efficiency will be presented in detail. Calculations based on Ref. [2] show that > 10^6 hard (200 keV) x-ray photons/pulse can be generated from the optimized LWFA beam. In the past, colliding-pulse injection technique has been demonstrated to able to tune the electron beam energy and enhance its stability [3]. Further, I will propose in detail how to implement controlled injection technique in our experiment setup by adding one colliding pulse to tune the output electron beam energy and enhance its repeatability as well, thereby enhance the tunability and stability of this compact x-ray source.

[1] Hartemann et al., Phys. Rev. ST-AB 10, 011301 (2007).
[2] Esarey et al., Phys. Rev. E 48 3003 (1993). [3] Faure et al., Nature 444, 737 (2006).

Name of submitting author	Mr. Bradley Pollock
Institution	Lawrence Livermore National Laboratory
Email	pollock6@llnl.gov
Abstract Title	**High Power Laser Self-Guiding in Mixed Gases**
Author/Affiliation listing	**B.B. Pollock**(1), J.E. Ralph(1), M. Beckler(2), A. Kemp(1), S.H. Glenzer(1) 1. Lawrence Livermore National Laboratory, Livermore CA 2. University of the Pacific, Stockton CA
Abstract	We present experimental results of laser self-guiding over a distance of 4 mm using a 100 TW Ti:Sapphire laser in He/N2 mixtures over the range of 0-100% N2 by partial pressure. Self-guiding is also observed in He/Ar mixtures with Ar concentrations up 10% for electron densities 0f 5-10x10^18 cm^-3.
Summary	
Laser Wakefield Accelerators rely on self-guiding of short-pulse, high-power lasers to drive relativistix plasma waves over centimeter-scale distances. The plasma is generally comprised of fully ionized He in order to reduce the effects of ionization-induced defocusing at the head of the laser pulse. However, the addition of higher-Z gases to the He background has been shown to aid in the trapping of electrons in the wakefield at low densities. We present experimental results of laser self-guiding in a gas cell over a distance of 4 mm using a nominally 100 TW Ti:Sapphire laser in He/N2 mixtures over the range of 0-100% N2 by partial pressure. Self-guiding is also observed in He/Ar mixtures with Ar concentrations as high as 10% for electron densities 0f 5-10x10^18 cm^-3. Measurements of the relative laser pulse transmission, exit spot size and imaged spectrum will be presented.	

Name of submitting author	Dr. Antonia Popp
Institution	Ludwig-Maximilians-University, Munich
Email	antonia.popp@physik.uni-muenchen.de
Abstract Title	**Acceleration Dynamics in Laser-Driven Wakefields**
Author/Affiliation listing	**A. Popp[1]**, R. Weingartner[1], S.-W. Chou[1], M. Heigoldt[1], K. Khrennikov[1], J. Wenz[1], F. Krausz [1,2] and S. Karsch [1,2] 1. Ludwig-Maximilans-University Munich, Am Coulombwall 1, 2. MPI of Quantum Optics, Hans-Kopfermann-Str. 1 85748 Garching, Germany
Abstract	A statistically significant experimental study of the dynamics of electron acceleration in laser-driven wakefields is presented. The evolution of electron bunch properties along the acceleration distance is observed at different electron densities. Basic parameters (e.g. dephasing length) and the limiting factors for different regimes were compared to theory.

Summary

In the presented experiments the dynamics during the acceleration of electrons in a laser-driven wakefield is studied by means of a length-variable gas cell. The electron bunches that were accelerated by the 25 fs, 1.8 Joules pulses of the ATLAS-laser, could be extracted and analyzed after different acceleration distances between 2mm and 14 mm. As the bunches from the steady-state flow gas-cell exhibit high stability and reproducibility this measurement could be conducted with significant statistics. >From the evolution of the energy spectrum important acceleration parameters could be deduced directly, such as the dephasing length (4.9 mm @ 6.4. 1018 cm-3) and the corresponding longitudinal electric field (160 GV/m). Both values are in good agreement with theory Scanning the gas-cell length at different electron densities also reveals the factors that limit the acceleration under the respective conditions, such as laser energy depletion or insufficient self-guiding. These results are also consistent with a scan of the electron density at a fixed gas cell length. While plasma-length scans have been performed by other groups this is the first comprehensive scan that covers a wide range of lengths, even beyond the dephasing length, thus allowing for a reliable determination of acceleration parameters. Only with this knowledge the gas target length and electron density can be optimized for given laser parameters. In addition, the evolution of several additional electron bunch parameters could be quantified. Especially, the change in emittance (0.2 p mm mrad) and bunch duration (~5 fs) could be determined with elaborate single-shot diagnostics. With increasing acceleration distance the transition to a beam-driven regime could be identified.

Name of submitting author	Nathan Powers
Institution	University of Nebraska-Lincoln
Email	nathandpowers@gmail.com
Abstract Title	**Characterization of laser wakefield accelerated electron beams by inverse-Compton cross-correlation**
Author/Affiliation listing	**N. D. Powers**1, S. Chen[1], C. M. Maharjan[1], I. Ghebregziabher[1], C. Liu[1], G. Golovin[1], S. Banerjee[1], J. Zhang[1], N. Cunningham[1†], A. Moorti[1+], S. Clarke[2], S. Pozzi[2], and D. P. Umstadter[1] 1. Department of Physics and Astronomy, University of Nebraska, Lincoln. 2. Department of Nuclear Engineering & Radiological Sciences, University of Michigan, Ann Arbor. † Current address: Physics Department, Nebraska Wesleyan University, Lincoln, NE 68504 (USA). + Current address: Raja Ramanna Centre for Advanced Technology, Indore 452013, India.
Abstract	We characterize the emittance and source size of a laser wakefield accelerated e-beam by means of a cross-correlation technique, in which a laser pulse is inverse-Compton scattered from the electron bunch near the exit of the accelerator.

Summary

Characterization of laser wakefield accelerated (LWFA) electron beams is important for understanding the acceleration process, and for applications. Several groups have demonstrated inverse-Compton scattering (ICS) as a technique to determine the focused e-beam characteristics from conventional accelerators [1-5]. ICS is useful in non-destructively determining the e-beam charge, spectrum, duration, source size and normalized emittance. We measured the LWFA e-beam normalized emittance by means of ICS. The energy dependent divergence of the e-beam was measured experimentally by imaging the e-beam profile. The e-beam source size was inferred from the divergence and its measured size at the ICS interaction point. Measurements were in line with previously predicted and measured results.

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[3] I. Sakai et al., Physical Review Special Topics - Accelerators and Beams 6, 091001 (2003).
[4] H. Kotaki et al., Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 455, 166 (2000).
[5] W. P. Leemans et al., Physical Review Letters 77, 4182 (1996).

Name of submitting author	Mr. Wolf Rittershofer
Institution	University of Oxford
Email	Wolf.Rittershofer@physics.ox.ac.uk
Abstract Title	**Tapered plasma channels to phase-lock accelerating and focussing forces in laser-plasma accelerators for enhanced energy gain.**
Author/Affiliation listing	**W. Rittershofer**, N. Bourgeois, J. Cowley and S. M. Hooker; University of Oxford C. B. Schroeder, E. Esarey, W. P. Leemans; Lawrence Berkely Lab F. J. Grüner; Ludwig Maximilians University, Munich
Abstract	Tapered plasma channels or longitudinal plasma density variations allow for enhanced energy gain in a laser-plasma accelerator. Tapered channels are considered for controlling dephasing of a beam with respect to a weakly relativistic plasma wave. Analytic expressions and first steps towards an experiment facilitating a tapering plasma channel are presented.

Summary

Techniques for increasing the energy gain per stage of laser-driven plasma accelerators are of great interest. One way of achieving this is to control the dephasing of a beam with respect to a plasma wave driven by a weakly relativistic, short-pulse laser. [1-3]. Algebraic expressions are presented for the taper, or longitudinal plasma density variation, required to maintain a beam at a constant phase in the longitudinal and/or transverse fields of the plasma wave. The energy gain of an accelerated electron in a tapered laser-plasma accelerator is calculated, and the laser pulse length required to optimize the energy gain is shown. The performance of a linearly-tapered plasma channel – which might be easier to achieve in practice – is compared with the ideally-tapered channels. The first steps towards realizing a tapering plasma channel are presented. This includes the results of CFD simulations to predict the electron density in a gas-filled capillary wave guide.

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3. T. Katsouleas, Phys. Rev. A 33, 2056 (1986)

Name of submitting author	Dr. Lucas Schaper
Institution	University of Hamburg
Email	lucas.schaper@desy.de
Abstract Title	**High Sensitivity Gas-Density Profilometry for Plasma Acceleration Targets**
Author/Affiliation listing	**Lucas Schaper**, Tobias Kleinwächter, Jan-Patrick Schwinkendorf, Jens Osterhoff / Institute for Experimental Physics, University of Hamburg, 22761 Hamburg, Germany
Abstract	Density-profile controlled targets are important for control over plasma-wakefield acceleration processes. Our approach towards design, fabrication and characterization meeting density and density-fluctuation requirements will be illustrated. For target characterization, we utilize gas-density profilometry via Raman scattering and pressure calibration with longitudinal interferometry, which in combination allow for absolute density mapping.

Summary

Knowledge and tailoring of density profiles with high accuracy in longitudinal and transverse direction has been identified to be one of the key points for achieving controllable, stable and reproducible acceleration conditions in plasma wakefield accelerators [1]. In particular, requirements of next generation plasma-wakefield concepts operating at plasma densities around 1017 cm-3 pose significant challenges with respect to target fabrication and reliable diagnostics. In order to approach this problem we combine the aspects of target simulation with fabrication and characterization. The target concepts are based on capillaries with multiple gas in- and outlets in which resulting density profiles are simulated with the fluid code OpenFOAM [2]. Capillary shapes proving successful in simulations are then engraved into sapphire plates via femtosecond laser machining. Subsequently, the resulting density profiles at variable inlet pressures are measured and benchmarked against the simulation utilizing a combination of diagnostic methods. Longitudinal density-profile information is obtained via Raman scattering [3] while absolute pressure calibration is achieved via longitudinal interferometry, which results in high sensitivity and thus characterization capabilities at low gas densities down to the 1017 cm-3 range. Such target densities are desirable for use in upcoming wakefield-acceleration experiments at Petawatt-class laser installations and in hybrid accelerators proposed to be investigated at the FLASH and REGAE facilities at DESY, Hamburg, Germany.

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[2] H. Jasak; Int. J. Nac. Archit. Oc. Engng 1, 89-94 (2009)
[3] T. Weineisen et al; Phys. Rev. ST Accel. Beams 14, 050705 (2011)

Name of submitting author	Carl Schroeder
Institution	LBNL
Email	cbschroeder@lbl.gov
Abstract Title	**Operational plasma density and laser parameters for future colliders based on laser-plasma accelerators**
Author/Affiliation listing	**C. B. Schroeder**, E. Esarey, W. P. Leemans Lawrence Berkeley National Laboratory
Abstract	Beam-beam interaction constraints modify the plasma density scalings for a linear collider based on laser-plasma accelerators. Operating at low plasma density increases beamstrahlung. Optimal plasma density and the required laser parameters are presented for collider operation in the quantum beamstrahlung regime. The impact of laser technology is discussed.
Summary	
In this talk, the basic plasma density and laser wavelength scaling laws for a collider based on laser-plasma accelerators [Schroeder et al., PR ST-AB 2010] will be presented. Under the assumptions of fixed final focusing to the interaction point, fixed efficiency of the energy conversion, and a fixed center-of-mass energy and luminosity required for high-energy physics experiments, these scaling laws indicated that the total required power for the collider scales as the square-root of plasma density. The operational plasma density determines the required drive laser parameters (duration, laser energy, peak and average power, etc.). Although the power scaling indicates lower plasma densities are favorable for reduced total collider power requirements, additional constraints may modify this basic scaling. In this talk I will present how the additional constraint, imposed by experimental high-energy physics, of fixed beamstrahlung induced beam energy loss and photon emission strongly modifies the basic plasma density scalings. Beamstrahlung effects are manifest when operating at sufficiently low plasma density. In particular, the scalings for the required power imply that it is no longer advantageous to operate at low density as opposed to more moderate densities (with higher accelerating gradients and smaller laser systems). If round beams are used in a multi-bunch train format with fixed beam loading, and the collider is constrained by beamstrahlung, then the required collider power is independent of plasma density [Schroeder et al., PR ST-AB (in press)]. The influence of laser technology on the optimal plasma density operating regime for a laser-plasma-accelerator-based collider will also be discussed. Work supported by Office of High Energy Physics, of the US DOE, Contract No. DE-AC02-05CH11231.	

Name	Will Schumaker
Institution	University of Michigan
Email	wschumak@umich.edu
Abstract Title	**Betatron Radiation Generation up to 200TW**
Author/Affiliation Listing	**W. Schumaker**, C. McGuffey, M. Vargas, V. Chvykov, F. Dollar, G. Kalintchenko, V. Yanovsky, A. Maksimchuk, A.G.R. Thomas, and K. Krushelnick (University of Michigan) S. Kneip (Imperial College London)
Abstract	Recent experimental results of laser wakefield acceleration of electrons and their consequent betatron radiation using the Hercules laser up to 200TW are presented. Single-hit spectroscopy data are presented as a spectral composition diagnostic. Data from K-alpha generated using the identical setup are presented to give yield and source size comparisons.
Summary	
Highly nonlinear plasma waves driven by ultra-intense short-pulse lasers can trap large numbers of electrons (~100s pC charge) from the plasma and accelerate them in quasi-monoenergetic bunches to upwards of ~GeV energy over a few cm. The self-trapping process and plasma wave structure force the trapped electrons to undergo transverse oscillatory motion within the plasma channel structure, resulting in short wavelength betatron radiation in the keV x-ray regime. These x-ray beams are presumed to retain the short-pulse characteristic of the electron beam, resulting in high peak flux, making the source a candidate for ultrafast temporally resolved imaging applications. Presented here are experimental studies of the scalings of fluence upon laser power, gas jet length, and electron beam parameters. The spectrum was directly measured by single hit spectroscopy to be broad and smooth with peak photon energy exceeding 10 keV. Additional measurements indicate that the beam source size can be as small as 1 micron and that the radiation exhibits spatial coherence. These two key characteristics are demonstrated by directly comparing source size and yield from copper K-alpha measurements with the identical laser parameters and experimental geometry.	

Name of submitting author	Prof B. A. Shadwick
Institution	University of Nebraska - Lincoln
Email	shadwick@unl.edu
Abstract Title	**A Reduction of the Vlasov-Maxwell System Using Phase-Space Blobs**
Author/Affiliation listing	**B. A. Shadwick**, Department of Physics and Astronomy, University of Nebraska - Lincoln Frank M. Lee, Department of Physics, The University of Texas at Austin
Abstract	We develop a new computational approach to the Vlasov-Maxwell equation, representing the distribution by a superposition of extended phase-space "blobs." The primary advance of this technique over traditional particle methods is the near elimination of macro-particle "noise." Furthermore, the distribution function can be readily reconstructed at any instant.
Summary	

We develop a new computational approach to solving the Vlasov-Maxwell equation by representing the distribution function by a supper-position of finite-extent phase-space "blobs." Each blob evolves as a warm beamlet [1] driven by the collective plasma fields. The underlying approximation treats each blob as a different plasma species and, as such, makes a counting error, which we expect to be reflected in the system entropy. This approach results in a non-canonical Hamiltonian model, inheriting various properties of the original system. The primary advance of this technique over traditional Lagrangian particle methods is the near elimination of macro-particle ``noise." Since we are evolving elements of phase-space, the distribution function can be readily reconstructed at any instant. We discuss the performance and convergence of this model using a variety of standard examples.

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Supported by the U.S. DoE under Contract DE-FG02-08ER55000

Name of submitting author	Professor Zheng-Ming Sheng
Institution	Shanghai Jiao Tong University
Email	zmsheng@sjtu.edu.cn
Abstract Title	**Ultrafast XUV Emission from Laser Wakefields in Underdense Plasma**
Author/Affiliation listing	Y. Liu, **Z.M. Sheng**, J. Zheng, F.Y. Li, J. Zhang Key Laboratory for Laser Plasmas (Ministry of Education) and Department of Physics, Shanghai Jiao Tong University, Shanghai 200240, China X. L. Xu, W. Lu Department of Engineering Physics, Tsinghua University, Beijing 100084, China W. B. Mori Department of Physics and Astronomy and Department of Electrical Engineering, University of California, Los Angeles, CA 90095-1547, USA C. S. Liu East-West Space Science Center, University of Maryland, College Park, MD, USA
Abstract	The laser wakefields driven in underdense plasma are promising ultrafast bright X-ray sources, either from laser-driven electron beams through betatron radiation, undulator emission, and Compton scattering, or from a nonlinear laser wakefield itself. In this work, we propose a new mechanism of ultrafast coherent XUV emission with ultra-broadband.
Summary	
There has been significant interest over the last 10 years on the generation of ultrafast bright X-rays from laser-plasma interaction either from the interaction of ultrashort intense laser pulse with solid or gas targets. Various schemes have been proposed such as high harmonics generation, nonlinear Thomson scattering, betatron radiation, reflection of laser pulses from flying mirrors and etc. In particular, X and gamma-ray emission from laser-driven electron beams through betatron radiation, undulator emission, and Compton scattering has been observed recently. In this work, we propose a new mechanism of coherent ultrafast XUV emission, which has a duration of few femoseconds with ultra-broadband in the spectrum continuing from zero to a few tens of the laser frequency. It is produced in a laser wakefield driven in the highly nonlinear regime or the wave-breaking regime in underdense plasma. The emission is caused by a transverse current sheet co-moving with the laser pulse. This current sheet is produced by an electron density spike in the wakefield together with the transverse kinetic momentum of electrons left behind the laser pulse. This residual momentum appears when the laser pulse undergoes strong self-modulation and subsequent pulse steepening at the front. The emission can be produced with laser pulse parameters currently available according to our 2D and 3D particle-in-cell simulations. The present scheme provides a simple method to produce single bright ultrashort XUV pulses for ultrafast applications.	

Name of submitting author	Satomi Shiraishi
Institution	Lawrence Berkeley National Laboratory
Email	sshiraishi@lbl.gov
Abstract Title	**Analysis of Optical Spectra for Laser-Plasma Accelerators**
Author/Affiliation listing	**S. Shiraishi**, C. Benedetti, A. J. Gonsalves, K. Nakamura, B. Shaw, T. Sokollik, J. van Tilborg, R. Mittal, C. G. R. Geddes, C. B. Schroeder, C. Toth, E. Esarey, and W. P. Leemans / Lawrence Berkeley National Laboratory
Abstract	We present analysis of optical spectra as a non-destructive diagnostic of laser-plasma interactions in a LPA. Experimental data and simulation results are studied to gain insight in pump depletion and the wake excitations. These measurements allow us to characterize coupling of laser energy into plasmas for efficient acceleration.

Summary

Laser diffraction and pump depletion [1] represent two fundamental limitations to the acceleration lengths of laser-plasma accelerators (LPAs). In vacuum, a laser undergoes Rayleigh diffraction and rapidly loses intensity. The diffraction effect can be mitigated using a hydrogen-filled capillary discharge waveguide to optically guide the laser [2]. However, the laser pulse can oscillate transversely if it does not match the guiding condition for the waveguide density channel. This mismatched guiding leads to inefficient coupling of laser energy into the plasma. We present an experimental study of these effects and our efforts to optimize coupling using driving laser mode, spectra, and wavefront measurements. The second limitation is pump depletion, the loss of energy by the laser pulse driving a wakefield. As the laser pulse excites plasma waves, the spectrum is red-shifted and modulated [3]. We present optical spectral analysis that extracts the amplitude of the wake excitation by comparing experimental data with simulation. The spectral analysis is a non-destructive diagnostic of laser energy depletion and accelerating gradient. These measurements will be critical in staged LPAs. Measurement of laser energy depletion helps us determine an optimal length for each LPA module. Measuring the amplitudes of excited waves allows us to estimate the potential energy gain from the module for an externally injected electron beam. These studies contribute to improved control of LPAs and greater reliability.

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This work is supported by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231 and the National Science Foundation.

Name of submitting author	Dr. Thomas Sokollik
Institution	LBNL
Email	TSokollik@lbl.gov
Abstract Title	**Staged Laser Plasma Accelerators**
Author/Affiliation listing	**T. Sokollik**, S. Shiraishi, A. Gonsalves, K. Nakamura, J. van Tilborg, B. Shaw, E. Esarey, C. B. Schroeder, C. Beedetti, C. Toth and W. Leemans
Abstract	We will present the current status of the LOASIS staged laser plasma accelerator using two laser pulses to drive two acceleration modules.

Summary

Laser driven electron accelerators or Laser Plasma Accelerators (LPA)[1] are in the focus of a worldwide research where many aspects of the acceleration concept are currently under investigation. The overall goal is to build a stable, tunable electron accelerator, which can be the foundation of a new generation of accelerators. One important milestone to reach this goal is to demonstrate the scalability of LPAs. Staged laser plasma accelerators are one approach where several acceleration modules are combined and each of them is driven by a ‘fresh’ laser pulse [2]. We will present the latest experimental results from the LOASIS staged laser plasma beamline.

References:

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[2] W. Leemans and E. Esarey, Phys. Today, 62, 44 (2009).

Acknowledgment: This work is supported by US DOE Contract No. DE-AC02-05CH11231 and the National Science Foundation.

Name of submitting author	Dr. Arnd Specka
Institution	Ecole Polytechnique (LLR) - CNRS/IN2P3
Email	specka@llr.in2p3.fr
Abstract Title	**Acceleration of electrons and ions at the CILEX 10PW laser facility**
Author/Affiliation listing	**Arnd Specka**, Ecole Polytechnique (LLR) - CNRS/IN2P3 (Author list to be completed)
Abstract	The Interdisciplinary Center for Extreme Light (CILEX) near Paris (France) will start to operate in 2015. It's flagship laser APOLLON (10PW, 15fs) will address frontier topics in ultrahigh intensity plasma physics as ion and electron acceleration and photon generation at intensities ranging up to 10^22 W/cm2 (a0>100).

Summary

The Interdisciplinary Center for Extreme Light (CILEX) near Paris (France) will start to operate in 2015. It's flagship laser APOLLON (10PW, 15fs) will address frontier topics in ultrahigh intensity plasma physics as ion and electron acceleration and photon generation at intensities ranging up to 1022Wcm-2 (a0>100). >From 2015 on, the Interdisciplinary Center for Extreme Light (CILEX) will address an ambitious scientific program in an unexplored range of intensities such as l acceleration of electrons and ions , and X-ray photon creation in different schemes. Its main instrument, the APOLLON laser (TiSapphire) will deliver 15 fs pulses with 10PW maximum peak power on target at a rate of one per minute thus giving access to intensities up to 1022Wcm-2 (a0>100). It will reach a very high temporal contrast through the use of a double plasma mirror. In addition to this main pulse, independent secondary beams will allow for pump-probe experiments and multi-stage LWFA. The pulse durations of the secondary beams will be adjustable independently in a range from 15fs to 1 ps in order to match a wide range of plasma wavelengths. The laser will serve two independent, fully radiation protected experimental areas, of which one is dedicated to ion acceleration and laser-matter interaction at highes power densities, whereas the other will be dedicated to LWFA acceleration. Photon creation experiments will be performed in either of these experimental areas depending on the needed experimental setup. The CILEX facility will also host two smaller 100TW class lasers in independent areas for research on connected topics at higher shot repetition rates and preparation of experiments on APOLLON. It is foreseen that the facility will be open to the national and international community. The characteristics of the facility and the detailed scientific programme of CILEX will be described.

Name of submitting author	Dr. Hyyong Suk
Institution	Gwangju Institute of Science and Technology
Email	hysuk@gist.ac.kr
Abstract Title	**Tapered-capillary plasma source development for laser wakefield acceleration**
Author/Affiliation listing	**Hyyong Suk**, Dong-Gyu Jang, Min-Seok Kim, and Inhyuk Nam/Gwangju Institute of Science and Technology
Abstract	We developed a tapered capillary plasma source for laser wakefield acceleration experiments, which can suppress the dephasing problem. The capillary plasma source was tested and it turns out to be suitable for laser wakefield acceleration experiments. In this presentation, some details of the test results are shown.
Summary	
The dephasing problem is one of the main energy saturation mechanisms in laser wakefield acceleration. To avoid the dephasing problem, we developed a tapered capillary plasma source, in which the plasma density gradually increases along the laser pulse propagation direction. As a result, the accelerated electrons remain continously in the acceleration phase, leading to an enhanced accelaration energy. Recently we developed a hydrogen-filled capillary source with the density tapering feature and tested its operation characteristis by changing the injected gas density, the applied high voltage, etc. Our test results show that it is suitable for laser wakefield acceleration experiments. In this presentation, details of the test results are given.	

Name of submitting author	Jeroen Van Tilborg
Institution	Lawrence Berkeley National Laboratory
Email	JvanTilborg@lbl.gov
Abstract Title	**Observation of long range coherent OTR from LPA electron beams**
Author/Affiliation listing	**Jeroen van Tilborg**, Chen Lin, Kei Nakamura, Anthony Gonsalves, Nicholas Matlis, Thomas Sokollik, Satomi Shiraishi, Carl Schroeder, Carlo Benedetti, Eric Esarey, and Wim Leemans. LAWRENCE BERKELEY NATIONAL LABORATORY
Abstract	Simulations show that laser plasma accelerated e-beams have correlated energy distribution. Measurements of coherent optical transition radiation are presented for broad-energy-spread beams with laser-induced density and momentum modulations. The long-range (meter-scale) observation of COTR indicates that the slice energy spread is below the percent level to preserve the modulations.

Summary

Laser plasma accelerators have been known to produce femtosecond electron beams of energy spread ranging from 100% to a few percent, with the latter value limited by detector resolution. To date, such energy distribution measurements have been performed in an integrated manner, integrating the electron distribution over the entire e-beam. Simulations indicate that the measured energy spread can be dominated by a correlated spread, with the slice spread significantly lower. Slice energy spread measurements with femtosecond resolution have traditionally been outside the capability of available diagnostics. Here we report the observation of coherent optical transition radiation (COTR) from electron bunches that have propagated for up to 4 m from the exit of the laser plasma accelerator (Lin et al. Phys. Rev. Lett. 108, 094801 [2012]). Transition radiation images, produced by electrons passing through two separate foils (located from the LPA at 2.3 m and 3.8 m) were recorded with a high resolution imaging system. Transition radiation in the visible wavelength regime was measured at signal levels of more than two orders of magnitude greater than expected from incoherent emission. The enhancement results from coherent effects due to the presence of longitudinal and transverse e-beam microstructure. The observations indicate that such structure on the electron beams persisted over meter-scale propagation distances. This persistence implies an upper limit for the slice energy spread on the sub-percent level. Furthermore, for a selection of shots the coherent enhancement from the 3.8- m foil was higher than the closer 2.3-m one, consistent with dynamic changes of the bunch structure due to beam velocity bunching. Experimental results and modeling efforts will be presented.

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Name of submitting author	Dr. Laszlo Veisz
Institution	Max-Planck-Institut für Quantenoptik, Garching, Germany
Email	laszlo.veisz@mpq.mpg.de
Abstract Title	**Diagnostics of electron beams and plasma waves in laser-plasma accelerators**
Author/Affiliation listing	**L. Veisz** (1), A. Buck (1,2), M. Nicolai (3), K. Schmid (1,2), C. M. S. Sears (1), A. Sävert (3), J. M. Mikhailova (1), J. Xu (1), F. Krausz (1,2), M. C. Kaluza (3,4) 1:Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany 2:Ludwig-Maximilians-Universität München, Am Coulombwall 1, 85748 Garching, Germany 3:Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität, 07743 Jena, Germany 4:Helmholtz-Institute Jena, Helmholtzweg 4, 07743 Jena, Germany
Abstract	A short overview of the determination of important characteristics of laser-driven electron bunches as well as accelerating plasma waves will be given. At the end of the paper an emphasis will be placed on state-of-the-art techniques providing temporal information about laser plasma acceleration.

Summary

In the last decade laser wakefield acceleration (LWFA), a laser-driven electron acceleration scheme in underdense plasmas, supporting extreme large accelerating gradients and few-fs electron bunch durations generated high-quality electron beams with significantly different properties than conventional RF accelerators. This fact necessitates the modification of conventional characterization techniques or even the development of completely new methods to routinely measure the unique electron properties. Probably, the biggest change in LWFA compared to conventional approaches is the electron accelerating structure itself, which is an electron plasma wave. The distinguished properties of the electrons originate from this plasma wave, whose characterization is a real challenge due to its few-(10)-micrometer size and local speed of light propagation velocity. A brief summary will be given about the relevant electron beam properties and their characterization techniques including electron spectrum, charge, divergence & beam profile, transverse normalized emittance, and temporal structure and duration. Furthermore, relevant plasma wave properties as plasma period, length, electron bunch position in the plasma wave, amplitude, accelerating field and their measurement possibilities will be also discussed. Emphasis will be placed also on the importance of using few-optical-cycle-long laser pulses to measure the most challenging peculiarities including direct temporal characterization of laser wakefield acceleration [1].

[1] A. Buck et al. “Real-time observation of laser-driven electron acceleration”, Nature Physics 7, 543–548 (2011).

Name of submitting author	Dr. Jorge Vieira
Institution	Instituto Superior Técnico
Email	jorge.vieira@ist.utl.pt
Abstract Title	**Magnetic field assisted self-injection for LWFA and PWFA**
Author/Affiliation listing	**J. Vieira** V. B. Pathak J. Martins GoLP/Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Portugal W. B. Mori Department of Physics and Astronomy, University of California, Los Angeles, USA L. O. Silva GoLP/Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Portugal
Abstract	We show numerically and analytically that static and spatially localized magnetic fields can relax self-trapping thresholds in the LWFA or PWFA, leading to off-axis self-injected bunches in narrow angular regions. The self-injected bunches then execute synchronized betatron oscillations. This scheme also enables radiation generation in the undulator regime.

Summary

The working principles of plasma-based accelerators (PBA) are firmly established. Thus, one of the upcoming challenges consists in using this technology in medical, industrial, or scientific applications. This requires the generation of tailored electron bunches with well-defined bunch charge, energy spread, and transverse properties. Several controlled injection techniques have been explored in order to control features of PBA generated electron bunches. New concepts have then emerged resorting to counter- and cross-propagating laser pulses in LWFAs [1], to short plasma down-ramps [2], and to evolving bubbles [3]. In addition, ionization induced trapping [4 has also been investigated. These methods provide mechanisms to adjust the charge and the energy of self-injected bunches. In this work [5] we resort to static transverse magnetic fields to trigger and to control the self-injection in PBA. We show that magnetic fields can relax the trapping thresholds in the LWFA or PWFA. The trapping occurs off-axis, in a narrow angular region, thus leading to synchronized betatron oscillation. This could improve the quality of x-ray emission by the magnetically injected electrons. The direction of the magnetic field controls the azimuthal position where trapping occurs. The scaling law for the magnetic field induced injection is determined with the appropriate Hamiltonian, and illustrated with particle-in-cell (PIC) simulations in OSIRIS [6]. For the next generation PBAs aiming at producing multi-10 GeV electron bunches in controlled injection scenarios, our scheme requires external magnetic fields as low as 5 T. Radiation post-processing simulations [7] show that betatron radiation can be emitted in the undulator regime.

[1] J. Faure et al, Nature 444, 737 (2006); X. Davoine et al, PRL 102, 065001 (2009); H. Kotaki et al, PRL 103, 194803 (2009). [2] C. G. R. Geddes et al, PRL 100, 215004 (2008). [3] S. Kalmykov et al, PRL 103, 135004 (2009). [4] A. Pak et al, PRL 104, 025003 (2010); E. Oz et al, PRL 98, 084801 (2007). [5] J. Vieira et al PRL 106 225001 (2011). [6] R. A. Fonseca et al, Lect. Notes Comp. Sci. vol. 2331/2002, (Springer Berlin / Heidelberg,(2002). [7] J. Martins et al Procc. SPIE 73590V (2009).

Name of submitting author	Ms. Marija Vranic
Institution	Instituto Superior Tecnico, Portugal
Email	marija.vranic@ist.utl.pt
Abstract Title	**All-optical radiation reaction configuration at I~10^21 W/cm2**
Author/Affiliation listing	**M. Vranic[1]**, J.L. Martins[1], J. Vieira[1], R. A. Fonseca[1,2], L.O. Silva[1] 1. GoLP/IPFN, Instituto Superior Técnico, Lisbon, Portugal 2. DCTI, ISCTE, Lisbon University Institute, Portugal
Abstract	A theoretical and numerical (3D full-scale PIC) study confirming the possibility to observe classical radiation reaction effects at intensities as low as I~10^21W/cm2, and quantum effects at I~4x10^21 W/cm2 in an all-optical configuration is presented, resorting to LWFA accelerated electron bunches colliding with tightly focused intense laser pulses.

Summary

Radiation reaction is a topic under a strong debate with implications both from the fundamental and the applications point of view. The threshold for the radiation reaction dominated regime, as well as the threshold for the quantum effects have caused many scientific discussions, still awaiting for experimental confirmation since state-of-the-art laser technology does not deliver intensities high enough for observing the phenomena with the conventional configurations. In the view of near-future laser technology advancements, radiation reaction is expected to play a significant role in laser-matter interactions, and the understanding of classical radiation reaction, as well as its transition to the quantum radiation reaction regime becomes critical. We present a theoretical and numerical study of the experimental conditions that would provide an answer to some of these questions in an all-optical configuration with laser systems available today (i.e. I~10^21 W/cm2), resorting to a head-on collision between laser pulses and electron beams generated in a laser wakefield accelerator (LWFA). The analytical calculations predict that the effects of radiation reaction can be observed with present-day laser technology. The interaction is followed by ultra-intense gamma-ray backscattered radiation. One-GeV electron beams, already generated experimentally in LWFA configurations, can suffer energy losses up to 40% when colliding with a 10^21W/cm2 laser, also available today. The gamma-ray photons produced in this configuration will have energy of the order of 10 MeV. The analytical predictions were confirmed by 3D full scale particle-in-cell (PIC) simulations over a wide range of parameters encompassing current and near future lase r technology. The radiation reaction was included in Osiris 2.0 PIC code via the Landau&Lifshitz model. For the various configurations we considered, the theoretical expectations on the energy loss are in excellent agreement with the simulation results. Our results show that the radiation reaction signatures will be experimentally observable both on the electron phase-space and on the emitted radiation frequency spectra.

Name of submitting author	Mr. Paul Andreas Walker
Institution	Oxford University, Atomic and Laser Physics Department
Email	a.walker1@physics.ox.ac.uk
Abstract Title	**Electron Acceleration in Capillary Discharge Waveguide at Astra-Gemini**
Author/Affiliation listing	**P.A.Walker**, N.Bourgeois, W.Rittershofer, J.Cowley, S.M. Hooker Oxford University, Atomic and Laser Physics Dept. UK N.Kajumba, A.R.Maier, J.Wenz, C.Werle, S.Karsch, F.Gruener Max-Planck-Institut fuer Quantenoptik Munich, Germany D.Symes, R.Pattathil, S.Hawkes, O.Chekhlov, C.Hooker, V.Marshall, B.Parry, Y.Tang Central Laser Facility, Didcot, UK
Abstract	Results of a recent experiment on laser plasma acceleration driven in the plasma channel formed by a capillary discharge waveguide are presented. Electron beams with energies up to 900 MeV were observed with good repeatability. Spectral and Grenouille measurements of the transmitted laser pulse and simulations will be presented.

Summary

The results of experimental laser-driven plasma acceleration in plasma channels, performed with the Astra-Gemini laser at Rutherford Appleton Laboratory will be described. In this work the laser beam was apodized to achieve a symmetric focal spot size of 42 um and an on target pulse energy of approximately 4 J. The laser pulses were focused at the entrance to the plasma channel formed in a gas-filled capillary discharge waveguide of 33 mm length and 300 um diameter. The laser pulses transmitted by the plasma channel were reflected from an optical wedge and directed to a visible spectrometer and a Grenouille. Electron beams generated within the plasma channel passed through a hole in the wedge and thence to a two-screen electron spectrometer [1] comprising two 1 Tesla, 400 mm by 150mm magnets and two 1 meter long scintillating screens between which was placed an array of lead bars. Electron beams with energies up to 900 MeV and rms divergence of 3.5 mrad were observed with good repeatability for plasma densities of 2 x 10^18 cm^-3. The variation of the peak electron energy with the axial density was recorded and found to agree well with theory [2]. Spectral and Grenouille measurements of the laser pulses transmitted through the plasma channel were recorded simultaneously with electron beam parameters. These measurements of the laser pulse show pulse shortening consistent with simple models [3]. Numerical simulations of these experiments will be presented.

[1] C. E. Clayton et al., Phys. Rev. Lett. 105, 105003 (2010)
[2] Lu et al. Physical Review Special Topics - Acc. and Beams 10, 061301 (2007)
[3] Schreiber et al. Phys. Rev. Lett. 105, 235003 (2010)

Name of submitting author	Dr. Xiaoming Wang
Institution	The University of Texas at Austin
Email	xwang3543@gmail.com
Abstract Title	**Physics of electron acceleration beyond 1 GeV at the Texas Petawatt Laser**
Author/Affiliation listing	**Xiaoming Wang**, S. Austin Yi, Rafal Zgadzaj, Neil Fazel, Watson Henderson, Yen-Yu Chang, Rick Korzekwa, Vladimir Khudik, Gennady Shvets, Hai-En Tsai, Chih-Hao Pai, Zhengyan Li, Erhard Gaul, Mikael Martinez, Hernan Quevedo, Ted Borger, Michael Spinks, Mike Donovan, Aaron Bernstein, Gillis Dyer, Todd Ditmire and Mike Downer/Department of physics, University of Texas at Austin
Abstract	We accelerate electrons up to 2 GeV in a He plasma (3 to 5e17 cm^-3) driven by the Texas Petawatt Laser. Beam energy, energy spread, charge and divergence vary strongly with laser pulse parameters and nitrogen doping. We survey the results and discuss the physics underlying these variations.

Summary

We will first survey recent laser-plasma accelerator (LPA) experiments, reported in more detail in a student poster by N. Fazel, in which 150 fs, 150 J pulses from the Texas Petawatt Laser were focused loosely (f/40) into a uniform, 7cm-long He plasma of density 1 < n_e < 5e17 cm^-3 doped uniformly with 0-5% nitrogen. In pure undoped He plasma, we observed self-injected acceleration of electrons up to ~350 MeV with n_e = 1e17 cm^-3 [1], 10× lower than previous self-injected LPAs. With N_2 doping, K-shell ionization of dopant atoms supplied electrons [2], which were accelerated to ≥ 1GeV. The duration, focal spot quality and location of the drive pulse varied from shot to shot, causing dramatic variation in the energy, energy spread, charge and divergence of the GeV electron beam. Quasi-continuous electron energy distributions with maximum energy up to 2 GeV and ~nC charge were observed on some shots. Quasi-monoenergetic ~10 pC bunches up to 1.2 GeV central energy, with <0.25 mrad FWHM divergence, and no detectable low energy dark current were observed on others. We will then discuss the physics underlying these variations, supported by PIC simulations. Quasi-monoenergetic, low-charge bunches result when electron injection is localized near the plasma entrance. This occurs when the incident pulse relativistically over-self-focuses to intensity above the nitrogen K-shell ionization threshold, thereby injecting electrons, before self-guiding at lower intensity, thereby terminating injection. This simple approach to injection localization, if controlled, can avoid the complication of engineering 2-stage gas targets [3] or synchronizing auxiliary injection pulses [4]. Quasi-continuous, high-charge bunches are produced when injection occurs continuously, as a result of guiding the drive pulse above the K-shell ionization threshold. Mechanisms limiting acceleration to 2 GeV will also be discussed.

[1] X. Wang et al., J. Plasma Phys., in press (2012).
[2] Pak et al., Phys. Rev. Lett. 104, 025003 (2011); McGuffey et al., ibid. 104, 025004 (2011).
[3] Pollock et al., Phys. Rev. Lett. 107, 045001 (2011); Liu et al., ibid. 107, 035001 (2011); Gonsalves et al., Nat. Phys. 7, 862 (2011).
[4] Faure et al., Nature 444, 737 (2006).

Name of submitting author	Johannes Wenz
Institution	Ludwig-Maximilians-University Munich
Email	johannes.wenz@mpq.mpg.de
Abstract Title	**Quantitative X-Ray Phase-Contrast Tomography from a compact, spatially coherent Betatron source produced by Laser Wakefield Acceleration**
Author/Affiliation listing	**J.Wenz[1,2]**, S. Schleede[3], K. Khrennikov[1], M. Bech[3], M. Heigoldt[1], F. Pfeiffer[3], F. Krausz[1,2] and S. Karsch[1,2] 1. Ludwig-Maximilans-University Munich, Am Coulombwall 1, 2. MPI of Quantum Optics, Hans-Kopfermann-Str. 1 3. Technische Universität München, James Franck-Straße 1, 85748 Garching, Germany
Abstract	We present for the first time a quantitative phase contrast X-ray tomogram of a biological specimen recorded with a laser driven betatron source. To this end we have characterized the source size and photon spectrum, and optimized them for phase contrast imaging.

Summary

Laser-wakefield acceleration of electrons has paved the way to a novel source of bright, partially spatial coherent synchrotron-like radiation using table-top laser systems. The fundamental mechanism behind the so-called betatron radiation is the wiggling of the electrons in the radial electrostatic plasma fields during the acceleration process. The small source size inherent to this concept permits its use for producing phase contrast images by the free propagation method. Such images taken from different perspectives combined with the computed tomography technique are able to provide detailed information about the specimen. In the presented measurement the Betatron radiation was used for tomographic imaging and characterization of the electron acceleration process. We address the important properties of this spatially coherent source such as its size and the photon spectrum. A single phase contrast image has a resolution of 5 µm which is limited by the detector pixel size . This is sufficient to resolve small structures like hairs and antennae of small insects. Furthermore we present the first quantitative phase-contrast tomogram of a fly. Due to the stability and reproducibility of the source we were able to record 1500 laser shots necessary for the precise reconstruction of the insect. We see a bright future for this kind of sources due to their excellent qualities in resolving power and contrast. Both are needed for biomedical diagnostics and material sciences. The intrinsically short pulse duration of a few femtoseconds could also be exploited for time resolved investigations.

Name of submitting author	Sung Jun Yoon
Institution	University of Maryland, College Park
Email	sungjunyoon@gmail.com
Abstract Title	**Quasi-Phase Matched Acceleration of Electrons in a Corrugated Plasma Channel**
Author/Affiliation listing	**S. J. Yoon[1]**, J. P. Palastro[1], D. Gordon[2], T. M. Antonsen[1], and H. M. Milchberg[1] 1Institute for Research in Electronics and Applied Physics, University of Maryland, College Park, Maryland 20740 2Naval Research Laboratory, Washington DC 20375
Abstract	Acceleration of electrons directly by a phase-matched laser field in a corrugated plasma waveguide is demonstrated with self-consistent Particle-In-Cell simulations. We examine the beam dynamics during the acceleration process. By implementing a density ramp in a corrugated plasma waveguide, the trapping energy for acceleration is reduced significantly.

Summary

A laser pulse propagating in a corrugated plasma channel [1] is composed of spatial harmonics whose phase velocities can be subluminal. The phase velocity of a spatial harmonics can be matched to the speed of a relativistic electrons resulting in direct acceleration by the laser field and linear energy gain over the interaction length. Here we examine the fully self-consistent interaction of the laser pulse and electron beam using particle-in-cell (PIC) simulations. For low electron beam densities, we find that the ponderomotive force of the laser pulse pushes plasma channel electrons towards the propagation axis, which deflect the beam electrons. When the beam density is high, the space charge force of the beam drives the channel electrons off axis, providing collimation of the beam. The simulated acceleration gradients were were ~110MeV/cm for a0 = 0.25 and ~50MeV/cm for a0 = 0.1, matching well with analytic predictions [2]. Simulations also corroborated that a threshold energy exists for the trapping and linear energy gain of electrons in a spatial harmonic. In addition, we consider a ramped density profile for lowering the threshold energy for trapping in a subluminal spatial harmonic. By using a density ramp, the trapping energy for a normalized vector potential of a0 = 0.1 is reduced from a relativistic factor γ0 = 170 to γ0 = 20.

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[2] J. P. Palastro, T. M. Antonsen, S. Morshed, A. G. York, H. M. Milchberg, Phys. Rev. E 77, 036405 (2008)

Name of submitting author	Wenxi Zhu
Institution	IREAP, University of Maryland at College Park
Email	wenxijasmine@gmail.com
Abstract Title	**Studies of Spectral Modification and Limitations of the Modified Paraxial Equations in the Laser Wakefield Simulations**
Author/Affiliation listing	**Wenxi Zhu**, John Palastro, Thomas Antonsen
Abstract	Spectral shift, energy depletion, and action conservation of nonlinear laser pulses were examined using the modified paraxial equation (MPE) implemented in WAKE. For large red shifts, the numerical damping and slowing down of the group velocity result in action decay. Modifications to the WAKE numerical algorithm have improved the performance.
Summary	
Spectral broadening of intense laser pulses propagating in plasma in the regime where the pulse energy is strongly depleted and spectral shifts are large has been studied using WAKE, a two-dimensional, quasi-static simulation code. For the parameters considered there was complete cavitation of the plasma, large wavenumber shifts, equal or greater than 50% of the laser central wavenumber, and depletion of a similar fraction of the laser pulse energy. The first part of the investigation was devoted to analysis of the laser field propagation algorithm in WAKE, which solves the modified paraxial equation (MPE) using forward differencing in the laser frame time coordinate. Studies indicated that higher order differencing could reduce artificial numerical damping in the wave equation that occurs when the wave envelope acquires fine structure due to large wavenumber shifts. Implementing a more accurate (four point) fitting scheme to evaluate the temporal derivative, remarkably reduced numerical damping for a given resolution in space and time, and greatly enhanced simulation efficiency. The MPE gives an inaccurate group velocity when wavenumber shifts are comparable to the central wavenumber. Implementing a full wave equation (FWE) solver is promising in this situation. Finally, we have investigated the effect of tapering the density profile on the efficiency of energy extraction from and the spectral shift of the laser pulse.	

Name of submitting author	Calvin Zulick
Institution	University of Michigan
Email	czulick@umich.edu
Abstract Title	**Electron Acceleration from Intense Laser Interactions with Under Dense Targets**
Author/Affiliation listing	**C. Zulick**(1), L. Willingale(1), H. Chen(3), J. Cobble(4), R.S. Craxton(2), A. Maksimchuk(1), P. M. Nilson(2), P.A. Norreys(5), T.C. Sangster(2), R.H.H. Scott(5), C. Stoeckl(2), A. G. R. Thomas(1), K. Krushelnick(1) (1) Center for Ultrafast Optical Science, University of Michigan (2) University of Rochester-Laboratory for Laser Energetics (3) Larence Livermore National Laboratory (4) Los Alamos National Laboratory (5) STFC, Rutherford Appleton Laboratory
Abstract	Experiments performed on the Omega EP laser facility have investigated the acceleration of electrons from under dense plasmas created by exploding plasma plumes and foam targets. OSIRIS two-dimensional particle-in-cell codes are being performed to investigate the electron acceleration mechanism within the channel.

Summary

The acceleration of electrons from under dense plasmas (1E18 < ne < 1E20) in the high intensity picosecond regime is likely due to direct laser acceleration. Plasmas with density ranges of interest are formed by heating solid density foils with a long-pulse beam 2.5 ns prior to the arrival of the main pulse [1, 2]. High energy electron spectra have been measured and compared for a range of target densities and laser parameters. Pulse energies of 55 – 300 J were used in 1 ps pulses and up to 750 J in 8.4 ps pulses. Proton radiography has been used to image the formation of the channel and modulations of the channel wall. OSIRIS two-dimensional particle-in-cell simulations have been performed which show the channel wall modulations result from the formation of surface waves which may play a role in the injection of electrons into the channel [4]. This initiates a two-stage acceleration processes which allows subsequent acceleration of the electrons through direct laser acceleration mechanisms including resonant betatron acceleration [5].

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[2] L. Willingale et al., IEEE Transactions on Plasma Science, 39, 2616(2011)
[3] L. Willingale et al., Physics of Plasmas, 18, 056706 (2011)
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[5] A. Pukhov et al. Physics of Plasmas, 6, 7 (1999)