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STRUCTURING FREE-STANDING FOILS FOR LASER-DRIVEN PARTICLE ACCELERATION EXPERIMENTS

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The recent development of petawatt-class laser systems sets a focus on the development of ultra-thin free-standing targets to access enhanced particle acceleration schemes vital for future applications, such as, medical and laser-driven nuclear physics. Specific strategies are required to improve the laser-to-particle energy conversion efficiency and increase the maximum particle energy. One of the promising approaches is based on the target design optimization; either by tuning key parameters which will strongly affect the laser-matter interaction process (e.g., material, composition, density, thickness, lateral dimensions, and shape) or by using micro/nanostructures on the target surface. At ELI-NP, considerable efforts are dedicated to extend the target capabilities beyond simple planar target design and develop complex targets with tailored properties suitable for high-power laser-plasma interaction experiments, as well as for studies with gamma and positrons beams. The paper provides an overview of the manufacturing capabilities currently available within ELI-NP Targets Laboratory for providing users with certain types of solid targets, specifically micro/nanostructured gold and copper foils and microns thick, porous anodized alumina. Also, optimization studies of alternative patterns (micro/nanodots) on silicon substrate are presented for future implementation on metallic free-standing thin foils.

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A CRYOGENIC HYDROGEN RIBBON FOR LASER DRIVEN PROTON ACCELERATION AT HZ-LEVEL REPETITION RATE

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The publication reports on recent progress in deploying a continuous solid hydrogen ribbon as a debris-free and renewable laser-driven source of pure proton beams generated by a 30-fs laser with ~1-J laser energy focused on target at relativistic intensities of ~1019 W/cm2 and repetition rate of 0.1 Hz. The stability of the ribbon position versus the laser interaction point and maximum repetition rate was tested up to 3.3 Hz. The acceleration of protons with cut-off energies up to 1.5 MeV is demonstrated using a 100-μm thick hydrogen ribbon as proof-of-principle capability of the relatively thick target delivery system. The laser-target geometry presented demonstrates an experimental technique that can potentially enables the operation of a laser–plasma source at Hz-level repetition rate.

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ANGULAR-RESOLVED THOMSON PARABOLA SPECTROMETER FOR LASER-DRIVEN ION ACCELERATORS

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This article reports the development, construction, and experimental test of an angle-resolved Thomson parabola (TP) spectrometer for laser-accelerated multi-MeV ion beams in order to distinguish between ionic species with different charge-to-mass ratio. High repetition rate (HHR) compatibility is guaranteed by the use of a microchannel plate (MCP) as active particle detector. The angular resolving power, which is achieved due to an array of entrance pinholes, can be simply adjusted by modifying the geometry of the experiment and/or the pinhole array itself. The analysis procedure allows for different ion traces to cross on the detector plane, which greatly enhances the flexibility and capabilities of the detector. A full characterization of the TP magnetic field is implemented into a relativistic code developed for the trajectory calculation of each pinhole beamlet. We describe the first test of the spectrometer at the 1PW1PW VEGA 3 laser facility at CLPU, Salamanca (Spain), where up to 15MeV15MeV protons and carbon ions from a 3μm laser-irradiated Al foil are detected.

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FABRICATION OF MICROMETRE-SIZED PERIODIC GRATINGS IN FREE-STANDING METALLIC FOILS FOR LASER-PLASMA EXPERIMENTS

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Engineered targets are expected to play a key role in future high-power laser experiments calling for joined, extensive knowledge in materials properties, engineering techniques and plasma physics. In this work, we propose a novel patterning procedure of self-supported 10 μm thick Au and Cu foils for obtaining micrometre-sized periodic gratings as targets for high-power laser applications. Accessible techniques were considered, by using cold rolling, electron-beam lithography and the Ar-ion milling process. The developed patterning procedure allows efficient control of the grating and foil surface on large area. Targets consisting of patterned regions of 450 μm × 450 μm, with 2 μm periodic gratings, were prepared on 25 mm × 25 mm Au and Cu free-standing foils, and preliminary investigations of the micro-targets interacting with an ultrashort, relativistic laser pulse were performed. These test experiments demonstrated that, in certain conditions, the micro-gratings show enhanced laser energy absorption and higher efficiency in accelerating charge particle beams compared with planar thin foils of similar thickness.

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LARGE AREA ION BEAM SPUTTERED DIELECTRIC ULTRAFAST MIRRORS FOR PETAWATT LASER BEAMLINES

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The latest advances in petawatt laser technology within the ELI Beamlines project have stimulated the development of large surface area dielectrically coated mirrors meeting all demanding requirements for guiding the compressed 30 J, 25 fs HAPLS laser beam at 10 Hz repetition rate and a center wavelength of 810 nm entirely in vacuum. We describe the production and evaluation of Ta2O5/HfO2/SiO2 ion beam sputtered coated (440 × 290 × 75) mm3 beam transport mirrors. No crazing was observed after thirty vacuum-air cycles. A laser induced damage threshold of 0.76 J/cm2 (fluence on mirror surface) was achieved and maintained at high shot rates.

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TIME-OF-FLIGHT METHODOLOGIES WITH LARGE-AREA DIAMOND DETECTORS FOR THE EFFECTIVELY CHARACTERIZATION OF TENS MEV PROTONS

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A novel detector based on a polycrystalline diamond sensor is here employed in an advanced time-of-flight scheme for the characterization of energetic ions accelerated during laser-matter interactions. The optimization of the detector and of the advanced TOF methodology allow to obtain signals characterized by high signal-to-noise ratio and high dynamic range even in the most challenging experimental environments, where the interaction of high-intensity laser pulses with matter leads to effective ion acceleration, but also to the generation of strong Electromagnetic Pulses (EMPs) with intensities up to the MV/m order. These are known to be a serious threat for the fielded diagnostic systems. In this paper we report on the measurement performed with the PW-class laser system Vega 3 at CLPU (~30 J energy, ~1021 W/cm2 intensity, ~30 fs pulses) irradiating solid targets, where both tens of MeV ions and intense EMP fields were generated. The data were analyzed to retrieve a calibrated proton spectrum and in particular we focus on the analysis of the most energetic portion (E > 5.8 MeV) of the spectrum showing a procedure to deal with the intrinsic lower sensitivity of the detector in the mentioned spectral-range.

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PROTON STOPPING MEASUREMENTS AT LOW VELOCITY IN WARM DENSE CARBON

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Ion stopping in warm dense matter is a process of fundamental importance for the understanding of the properties of dense plasmas, the realization and the interpretation of experiments involving ion-beam-heated warm dense matter samples, and for inertial confinement fusion research. The theoretical description of the ion stopping power in warm dense matter is difficult notably due to electron coupling and degeneracy, and measurements are still largely missing. In particular, the low-velocity stopping range, that features the largest modelling uncertainties, remains virtually unexplored. Here, we report proton energy-loss measurements in warm dense plasma at unprecedented low projectile velocities. Our energy-loss data, combined with a precise target characterization based on plasma-emission measurements using two independent spectroscopy diagnostics, demonstrate a significant deviation of the stopping power from classical models in this regime. In particular, we show that our results are in closest agreement with recent first-principles simulations based on time-dependent density functional theory.

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COMPRESSING HIGH ENERGY LASERS THROUGH OPTICAL POLYMER FILMS

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The thin-film post-compression technique has the ability to reduce the pulse duration in PW-class lasers, increasing the peak power. Here, the nonlinear response of an increasingly available optical thermoplastic demonstrates enhanced spectral broadening, with corresponding shorter pulse duration compared to fused silica glass. The thermoplastic can be used close to its damage threshold when refreshed using a roller mechanism, and the total amount of material can be varied by folding the film. As a proof-of-principle demonstration scalable to 10-PW, a roller mechanism capable of up to 6 passes through a sub-millimeter thermoplastic film is used in vacuum to produce two-fold post-compression of the pulse. The compact design makes it an ideal method to further boost ultrahigh laser pulse intensities with benefits to many areas, including driving high energy acceleration.

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NANOSCALE CONTROL OF STRUCTURE AND COMPOSITION FOR NANOCRYSTALLINE FE THIN FILMS GROWN BY OBLIQUE ANGLE RF SPUTTERING

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The use of Fe films as multi-element targets in space radiation experiments with high-intensity ultrashort laser pulses requires a surface structure that can enhance the laser energy absorption on target, as well as a low concentration and uniform distribution of light element contaminants within the films. In this paper, (110) preferred orientation nanocrystalline Fe thin films with controlled morphology and composition were grown on (100)-oriented Si substrates by oblique angle RF magnetron sputtering, at room temperature. The evolution of films key-parameters, crucial for space-like radiation experiments with organic material, such as nanostructure, morphology, topography, and elemental composition with varying RF source power, deposition pressure, and target to substrate distance is thoroughly discussed. A selection of complementary techniques was used in order to better understand this interdependence, namely X-ray Diffraction, Atomic Force Microscopy, Scanning and Transmission Electron Microscopy, Energy Dispersive X-ray Spectroscopy and Non-Rutherford Backscattering Spectroscopy. The films featured a nanocrystalline, tilted nanocolumn structure, with crystallite size in the (110)-growth direction in the 15–25 nm range, average island size in the 20–50 nm range, and the degree of polycrystallinity determined mainly by the shortest target-to-substrate distance (10 cm) and highest deposition pressure (10–2 mbar Ar). Oxygen concentration (as impurity) into the bulk of the films as low as 1 at. %, with uniform depth distribution, was achieved for the lowest deposition pressures of (1–3) × 10–3 mbar Ar, combined with highest used values for the RF source power of 125–150 W. The results show that the growth process of the Fe thin film is strongly dependent mainly on the deposition pressure, with the film morphology influenced by nucleation and growth kinetics. Due to better control of film topography and uniform distribution of oxygen, such films can be successfully used as free-standing targets for high repetition rate experiments with high power lasers to produce Fe ion beams with a broad energy spectrum.

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THE ELIMAIA LASER–PLASMA ION ACCELERATOR: TECHNOLOGICAL COMMISSIONING AND PERSPECTIVES

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The article reports on the technological commissioning of the Laser–Plasma Ion Accelerator section of the ELIMAIA user beamline at the ELI Beamlines facility in the Czech Republic. The high-peak, high-average power L3-HAPLS laser system was used with an energy of ~10 J and pulse duration of ~30 fs on target, both in single-pulse and high repetition-rate (~0.5 Hz) mode. The laser pulse was tightly focused to reach ultrahigh intensity on target (~1021 W/cm2) and sustain such laser-plasma interaction regime during high repetition-rate operations. The laser beam, ion beam, and laser-plasma emission were monitored on a shot-to-shot basis, and online data analysis at 0.5 Hz was demonstrated through the full set of used diag-

nostics (e.g., far and near field, laser temporal diagnostics, X- and gamma-ray detectors, Thomson Parabola ion spectrometer, time-of-flight ion detectors, plasma imaging, etc.). The capability and reliability of the ELIMAIA Ion Accelerator was successfully demonstrated at a repetition rate of 0.5 Hz for several hundreds of consecutive laser shots.

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TWO-XUV-PHOTON DOUBLE IONIZATION OF NEON

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Two-XUV-photon double ionization of Ne, induced by an intense few-pulse attosecond train with a ~4 fs envelope duration is investigated experimentally and theoretically. The experiment is performed at ELI-ALPS (Extreme Light Infrastructure Attosecond Light Pulse Source) utilizing the recently constructed 10 Hz gas phase high-order harmonic generation SYLOS GHHG-COMPACT beamline. A total pulse energy up to ~1 μJ generated in argon in conjunction with high-reflectivity optics in the XUV region allowed the observation of the doubly charged state of Ne induced by 40 eV central XUV-photon energies. The interaction of the intense attosecond pulse train with Ne is also theoretically studied via second-order time-dependent perturbation theory equations of motion. The results of this work, combined with the feasibility of conducting XUV-pump–XUV-probe experiments, constitute a powerful tool for many potential applications. Those include attosecond pulse metrology as well as time-resolved investigations of the dynamics underlying direct and sequential double ionization and their electron correlation effects.

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TOF ANALYSIS OF IONS ACCELERATED AT HIGH REPETITION RATE FROM LASER-INDUCED PLASMA

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The generation, detection, and quantification of high-energy proton spectra that are produced from laser-target interaction methodologies is a field of increasingly growing popularity over the last 20 years. Generation methods such as target normal sheath acceleration or similar allow for collimated laminar ion beams to be produced in a compact environment through the use of short-burst terawatt lasers and are a growing field of investment. This project details the development and refinement of a python-based code to analyze time-of-flight ion spectroscopy data, with the intent to pinpoint the maximum proton energy within the incident beam to as reliable and accurate a value as possible within a feasible processing time. TOF data for 2.2 × 1016 W/cm2 intensity laser shots incident on a 2 mm Cu target that were gathered from the PERLA 1 kHz laser at the HiLASE center were used as training and testing data with the implementation of basic machine learning techniques to train these methods to the data being used. These datasets were used to ensure more widely applicable functionality, and accurate calculation to within 1% accuracy of an assumed correct value was seen to be consistently achievable for these datasets. This wider functionality indicates a high level of accuracy for previously unseen TOF datasets, regardless of signal/noise levels or dataset size, allowing for free use of the code in the wider field.

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DUAL STAGE APPROACH TO LASER-DRIVEN HELICAL COIL PROTON ACCELERATION

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Helical coil accelerators are a recent development in laser-driven ion production, acting on the intrinsically wide divergence and broadband energy spectrum of laser-accelerated protons to deliver ultra-low divergence and quasi-monoenergetic beams. The modularity of helical coil accelerators also provides the attractive prospective of multi-staging. Here we show, on a proof-of-principle basis, a two-stage configuration which allows optical tuning of the energy of the selected proton beamlet. Experimental data, corroborated by particle tracing simulations, highlights the importance of controlling precisely the beam injection. Efficient post-acceleration of the protons with an energy gain up to ~16 MeV (~8 MeV per stage, at an average rate of ~1 GeV m−1) was achieved at an optimal time delay, which allows synchronisation of the selected protons with the accelerating longitudinal electric fields to be maintained through both stages.

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MEASURING SPATIO-TEMPORAL COUPLINGS USING MODAL SPATIO-SPECTRAL WAVEFRONT RETRIEVAL

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Knowledge of spatio-temporal couplings such as pulse-front tilt or curvature is important to determine the focused intensity of high-power lasers. Common techniques to diagnose these couplings are either qualitative or require hundreds of measurements. Here we present both a new algorithm for retrieving spatio-temporal couplings, as well as novel experimental implementations. Our method is based on the expression of the spatio-spectral phase in terms of a Zernike-Taylor basis, allowing us to directly quantify the coefficients for common spatio-temporal couplings. We take advantage of this method to perform quantitative measurements using a simple experimental setup, consisting of different bandpass filters in front of a Shack-Hartmann wavefront sensor. This fast acquisition of laser couplings using narrowband filters, abbreviated FALCON, is easy and cheap to implement in existing facilities. To this end, we present a measurement of spatio-temporal couplings at the ATLAS-3000 petawatt laser using our technique.

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SPECTRALLY TUNABLE ULTRASHORT MONOCHROMATIZED EXTREME ULTRAVIOLET PULSES AT 100 KHZ

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We present the experimental realization of spectrally tunable, ultrashort, quasi-monochromatic extreme ultraviolet (XUV) pulses generated at 100 kHz repetition rate in a user-oriented gas high harmonic generation beamline of the Extreme Light Infrastructure—Attosecond Light Pulse Source facility. Versatile spectral and temporal shaping of the XUV pulses is accomplished with a double-grating, time-delay compensated monochromator accommodating the two composing stages in a novel, asymmetrical geometry. This configuration supports the achievement of high monochromatic XUV flux (2.8 ± 0.9 × 1010 photons/s at 39.7 eV selected with 700 meV full width at half maximum bandwidth) combined with ultrashort pulse duration (4.0 ± 0.2 fs using 12.1 ± 0.6 fs driving pulses) and small spot size (sub-100 μm). Focusability, spectral bandwidth, and overall photon flux of the produced radiation were investigated, covering a wide range of instrumental configurations. Moreover, complete temporal (intensity and phase) characterization of the few-femtosecond monochromatic XUV pulses—a goal that is difficult to achieve by conventional re construction techniques—has been realized using a ptychographic algorithm on experimentally recorded XUV-infrared pump-probe traces. The presented results contribute to in situ, time-resolved experiments, accessing direct information on the electronic structure dynamics of novel target materials.

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CONTROLLED TRANSITION TO DIFFERENT PROTON ACCELERATION REGIMES: NEAR-CRITICAL-DENSITY PLASMAS DRIVEN BY CIRCULARLY POLARIZED FEW-CYCLE PULSES

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A controlled transition between two different ion acceleration mechanisms would pave the way to achieving different ion energies and spectral features within the same experimental set up, depending on the region of operation. Based on numerical simulations conducted over a wide range of experimentally achievable parameter space, reported here is a comprehensive investigation of the different facets of ion acceleration by relativistically intense circularly polarized laser pulses interacting with thin near-critical-density plasma targets. The results show that the plasma thickness, exponential density gradient, and laser frequency chirp can be controlled to switch the interaction from the transparent operating regime to the opaque one, thereby enabling the choice of a Maxwellian-like ion energy distribution with a cutoff energy in the relativistically transparent regime or a quasi-monoenergetic spectrum in the opaque regime. Next, it is established that a multispecies target configuration can be used effectively for optimal generation of quasi-monoenergetic ion bunches of a desired species. Finally, the feasibility is demonstrated for generating monoenergetic proton beams with energy peak at E≈20–40 MeV and a narrow energy spread of ΔE/E≈18%–28.6% confined within a divergence angle of ~175 mrad at a reasonable laser peak intensity of I0 ~ 5.4 × 1020 W/cm2.

Matter Radiat. Extremes 8, 054001 (2023)
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TUNABLE ULTRAFAST THERMIONIC EMISSION FROM FEMTOSECOND-LASER HOT SPOT ON A METAL SURFACE BY CONTROL OF LASER POLARIZATION AND ANGLE OF INCIDENCE: A NUMERICAL INVESTIGATION

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Ultrafast laser induced thermionic emission from metal surfaces has several applications. Here, we investigate the role of laser polarization and angle of incidence on the ultrafast thermionic emission process from laser driven gold coated glass surface. The spatio-temporal evolution of electron and lattice temperatures are obtained using an improved three-dimensional (3D) two-temperature model (TTM) which takes into account the 3D laser pulse profile focused obliquely onto the surface. The associated thermionic emission features are described through the modified Richardson-Dushman equation, including dynamic space-charge effects and are included self-consistently in our numerical approach. We show that temperature-dependent reflectivity influences laser energy absorption. The resulting peak electron temperature on the metal surface monotonically increases with the angle of incidence for the P polarization, while for the S polarization it shows the opposite trend. We observe that thermionic emission duration shows a strong dependence on the angle of incidence and contrasting polarization dependent behavior. The duration of the thermionic current shows strong correlation to the intrinsic electron-lattice thermalization time, in a fluence regime well below the damage threshold of gold. The observations and insights have important consequences in designing ultrafast thermionic emitters using a metal based architecture.
Applied Surface Science

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IMPULSE

TIME-RESOLVED INVESTIGATION OF A HIGH-REPETITION-RATE GAS-JET TARGET FOR HIGH-HARMONIC GENERATION

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High-repetition-rate gas targets constitute an essential component in intense laser matter interaction studies. The technology becomes challenging as the repetition rate approaches the kilohertz regime. In this regime, cantilever-based gas valves are employed, which can open and close in tens of microseconds, resulting in a unique kind of gas characteristics in both the spatial and temporal domain. Here we characterize piezo cantilever-based kilohertz pulsed gas valves in the low density regime, where it provides sufficient peak gas density for high-harmonic generation while releasing a significantly smaller amount of gas reducing the vacuum load within the interaction chamber, suitable for high-vacuum applications. In order to obtain reliable information of the gas density in the target jet, space-time resolved characterization is performed. The gas-jet system is validated by conducting interferometric gas density estimations and high-harmonic generation measurements at the Extreme Light Infrastructure Attosecond Light Pulse Source facility. Our results demonstrate that while employing such targets for optimal high-harmonic generation, the high intensity interaction should be confined to a suitable time window, after the cantilever opening. The measured gas density evolution correlates well with the integrated high-harmonic flux and state-of-the-art three-dimensional simulation results, establishing the importance of such metrology.

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ENERGETIC, TUNABLE, HIGHLY ELLIPTICALLY POLARIZED HIGHER HARMONICS GENERATED BY INTENSE TWO-COLOR COUNTER-ROTATING LASER FIELDS

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In this work, authors demonstrate experimentally the efficient generation and tunability of energetic highly elliptical high harmonics in Ar gas, driven by intense two-color counter-rotating laser electric fields. A bichromatic beam tailored by a Mach-Zehnder-Less for Threefold Optical Virginia spiderwort (MAZEL-TOV) apparatus generates high-order harmonic generation (HHG), where the output spectrum of the highly elliptical HHG radiation can be tuned for an energy range of ΔE≈150 meV in the spectral range of ~20 eV with energy per pulse E_{XUV}≈400 nJ at the source. Furthermore, we employ time-dependent density-functional simulations to probe the dependence of the harmonic ellipticity and the strength of the attosecond pulses on the driving-field parameters and demonstrate the robustness of the HHG with the bichromatic field. We

show how, by properly tuning the central frequency of the second harmonic, the central frequency of the extreme ultraviolet (XUV) high-harmonic radiation is continuously tuned. The demonstrated energy values largely exceed the output energy from many other laser-driven attosecond sources reported so far and prove to be sufficient for inducing nonlinear processes in an atomic system. We envisage that such tunable energetic highly elliptical HHG spectra can remove the facility restrictions from requirements of few-cycle driving pulses for isolated circular attosecond-pulse generation.

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PARAMETRIC AMPLIFICATION AS A SINGLE-SHOT TIME-RESOLVED OFF-HARMONIC PROBE FOR LASER-MATTER INTERACTIONS

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An optical probing of laser–plasma interactions can provide time-resolved measurements of plasma density; however, single-shot and multi-frame probing capabilities generally rely on complex setups with limited flexibility. We have demonstrated a new method for temporal resolution of the rapid dynamics (~170~170 fs) of plasma evolution within a single laser shot based on the generation of several consecutive probe pulses from a single beta barium borate-based optical parametric amplifier using a fraction of the driver pulse with the possibility to adjust the central wavelengths and delays of particular pulses by optical delay lines. The flexibility and scalability of the proposed experimental technique are presented and discussed.

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NOVEL APPROACH TO TNSA ENHANCEMENT USING MULTI-LAYERED TARGETS—A NUMERICAL STUDY

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In the context of ion acceleration driven by ultra-high contrast lasers using thin foils, there is a clear trend towards increasing ion energy when the target thickness is reduced. However when the target is too thin and the prepulse strength is not negligible, this trend is reversed due to degradation of the target mainly caused by prepulse-induced shocks, among other effects (thermal plasma expansion, early onset of transparency, etc). In this paper, we propose and motivate the use of multi-layered targets for the purpose of enhancing the target normal sheath acceleration mechanism by means of attenuating the shock waves inside the target. It is demonstrated through hydrodynamic simulations that multi-layered targets, composed of alternating layers of plastic and gold, can significantly delay the time of shock wave breakout, reducing the shock energy that breaks out of the target and shortening the plasma scale-length. This approach paves the way for enhanced laser-driven ion acceleration using thinner targets even for relatively low contrast lasers.

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PROTON BRAGG CURVE AND ENERGY RECONSTRUCTION USING AN ONLINE SCINTILLATOR STACK DETECTOR

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Real-time measurement and characterization of laser-driven proton beams have become crucial with the advent of high-repetition-rate laser acceleration. Common passive diagnostics such as radiochromic film (RCF) are not suitable for real-time operation due to time-consuming post-processing; therefore, a novel approach is needed. Various scintillator-based detectors have recently gained interest as real-time substitutes to RCF—thanks to their fast response for a wide range of dose deposition rates. This work introduces a compact, scalable, and cost-effective scintillator-based device for proton beam measurements in real-time suitable for the laser–plasma environment. An advanced signal processing technique was implemented based on detailed Monte Carlo simulations, enabling an accurate unfolding of the proton energy and the depth–dose deposition curve. The quenching effect was accounted for based on Birks' law with the help of the Monte Carlo simulations. The detector was tested in a proof-of-principle experiment at a conventional cyclotron accelerating protons up to 35 MeV of energy. The signal comparison with a standard RCF stack was also performed during the test of the device, showing an excellent agreement between the two diagnostics. Such devices would be suitable for both conventional and laser-driven proton beam characterization.

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EXPERIMENTAL DEMONSTRATION OF ULTRAHIGH SENSITIVITY TALBOT-LAU INTERFEROMETER FOR LOW DOSE MAMMOGRAPHY

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Even though the techniques used for breast cancer identification have advanced over the years, current mammography based on x-rays absorption, the 'gold standard' screening test at present, still has some shortcomings as concerns sensitivity and specificity to early-stage cancers, due to poor differentiation between tumor and normal tissues, especially in the case of the dense breasts. We investigate a possible additional technique for breast cancer detection with higher sensitivity and low dose, x-ray phase-contrast or refraction-based imaging with ultrahigh angular sensitivity grating interferometers, having several meters length. Approach. Towards this goal, we built and tested on a mammography phantom, a table-top laboratory setup based on a 5.7 m long Talbot-Lau interferometer with angular sensitivity better than 1 μrad. We used a high-power x-ray tungsten anode tube with a 400 μm focal spot, operated at 40 kVp and 15 mA with a 2 mm aluminum filter. Main results. The results reported in our paper confirm the ultrahigh sensitivity and dose economy possible with our setup. The visibility of objects simulating cancerous formations

is strongly increased in the refraction images over the attenuation ones, even at a low dose of 0.32 mGy. Notably, the smallest fiber of 400 μm diameter and calcifications specs of 160 μm in diameter are detected, even though the spatial resolution at the object of our magnification M ~ 2 setup with a 400 μm source spot is only ~250 μm. Significance. Our experiments on a mammography phantom illustrate the capabilities of the proposed technique and can open the way toward low-dose interferometric mammography.

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TARGET CHARACTERISTICS USED IN LASER-PLASMA ACCELERATION OF PROTONS BASED ON THE TNSA MECHANISM

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The target normal sheath acceleration is a robust mechanism for proton and ion acceleration from solid targets when irradiated by a high power laser. Since its discovery extensive studies have been carried out to enhance the acceleration process either by optimizing the laser pulse delivered onto the target or by utilizing targets with particular features. Targets with different morphologies such as the geometrical shape (thin foil, cone, spherical, foam-like, etc.), with different structures (multi-layer, nano- or micro-structured with periodic striations, rods, pillars, holes, etc.) and made of different materials (metals, plastics, etc.) have been proposed and utilized. Here we review some recent experiments and characterize from the target point of view the generation of protons with the highest energy.

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GENERATION OF MICRO-JOULE LEVEL COHERENT QUASI-CONTINUUM EXTREME ULTRAVIOLET RADIATION USING MULTI-CYCLE INTENSE LASER-ATOM INTERACTIONS

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In the present work we report on the current progress of the recently constructed GW attosecond extreme ultraviolet (XUV) source developed at the Institute of Electronic Structure and Laser of the Foundation for Research and Technology-Hellas (I.E.S.L-FO.R.T.H.). By the implementation of a compact-collinear polarization gating arrangement, the generation of a broadband, coherent XUV quasi-continuum produced by the interaction of a many-cycle infrared field with a gas phase medium is achieved. The spectral width of the

XUV emission generated in Xenon, is spanning in the range of 17–32 eV and can support isolated pulses of duration in the range from 0.4 fs to 1.3 fs and pulse energy in the 1 μJ level. Theoretical calculations, taking into account the experimental conditions of this work, are supporting the observations, offering also an insight regarding the temporal profile of the emitted radiation. Finally, the high intensity of the produced XUV pulses has been confirmed by investigating the two-XUV-photon double ionization process of Argon atoms. The demonstrated results inaugurate the capability of the beamline of producing intense coherent quasi-continuum XUV radiation, supporting isolated as pulses, that can be exploited in studies of non-linear XUV processes, attosecond pulse metrology and XUV-pump-XUV-probe experiments.

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TANGO CONTROLS AND DATA PIPELINE FOR PETAWATT LASER EXPERIMENTS

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The Centre for Advanced Laser Applications in Garching, Germany, is home to the ATLAS-3000 multi-petawatt laser, dedicated to research on laser particle acceleration and its applications. A control system based on Tango Controls is implemented for both the laser and four experimental areas. The device server approach features high modularity, which, in addition to the hardware control, enables a quick extension of the system and allows for automated data acquisition of the laser parameters and experimental data for each laser shot. In this paper we present an overview of our implementation of the control system, as well as our advances in terms of experimental operation, online supervision and data processing. We also give an outlook on advanced experimental supervision and online data evaluation – where the data can be processed in a pipeline – which is being developed on the basis of this infrastructure.

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ABLATION HOLES IN TAPE TARGETS INDUCED BY ULTRA-INTENSE LASER PULSES

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The paper presents a theoretical modelling able to predict the dimensions of mm-sized through-holes produced in interactions of the 1 PW high-power 30 fs Ti:Sa laser VEGA-3 with tape targets. We find that sizes of through-holes can be calculated by assuming that the full heat transferred from the laser-heated electron population to the target by electron–electron collisions drives the evaporation of target material. We demonstrate the good reproduction of experimental results.

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GENERATION OF ENERGETIC HIGHLY ELLIPTICAL EXTREME ULTRAVIOLET RADIATION

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In this study, the generation of energetic coherent extreme ultraviolet (XUV) radiation with the potential for controlled polarization is reported. The XUV radiation results from the process of high harmonic generation (HHG) in a gas phase atomic medium, driven by an intense two-color circularly polarized counter-rotating laser field, under loose focusing geometry conditions. The energy of the XUV radiation emitted per laser pulse is found to be of the order of ~100 nJ with the spectrum spanning from 17 to 26 eV. The demonstrated energy values (along with tight XUV focusing geometries) are sufficient to induce nonlinear processes. Our results challenge current perspectives regarding ultrafast investigations of chiral phenomena in the XUV spectral region.

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FUNDAMENTAL STUDIES ON ELECTRON DYNAMICS IN EXACT PARAXIAL BEAMS WITH ANGULAR MOMENTUM

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Classical electromagnetic radiation with orbital angular momentum (OAM), described by nonvanishing vector and scalar potentials (namely, Lorentz gauge) and under Lorentz condition, is considered. They are employed to describe paraxial laser beams, thereby including non-vanishing longitudinal components of electric and magnetic fields. The relevance of the latter on electron dynamics is investigated in the reported numerical experiments. The lowest corrections to the paraxial approximation appear to have a negligeable influence in the regimes treated here. Incoherent Thomson scattering (TS) from a sample of free electrons moving subject to the paraxial fields is studied and investigated as a beam diagnosis tool. Numerical computations elucidate the nature and conditions for the so called trapped solutions (electron motions bounded in the transverse plane of the laser and drifting along the propagation direction) in long quasi-steady laser beams. The influence of laser parameters, in particular, the laser beam size and the non-vanishing longitudinal field components, essential for the paraxial approximation to hold, are studied. When the initial conditions of the electrons are sufficiently close to the origin, a simplified model Hamiltonian to the full relativistic one is introduced. It yields results comparing quite well quantitatively with the observed amplitudes, phase relationships and frequencies of oscillation of trapped solutions (at least for wide laser beam sizes). Genuine pulsed paraxial fields with OAM and their features, modeling true ultra-short pulses are also studied for two cases, one of wide laser beam spot (100 μm) and other with narrow beam size of 6.4 μm. To this regard, the asymptotic distribution of the kinetic energy of the electrons as a function of their initial position over the transverse section is analyzed. The relative importance of the transverse structure effects and the role of longitudinal fields is addressed. By including the full paraxial fields, the asymptotic distribution of kinetic energy of an electron population distributed across the laser beam section, has a nontrivial and unexpected rotational symmetry along the optical propagation axis.

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