We report on the first experiments, showing dose dependent biological damage of tumour cells by laser-accelerated protons [1]. In order to apply the dose in a controlled way an energy filter system as well as a dedicated dosimetry system and an in-air cell irradiation site has been set up. The cells could be irradiated with protons of an energy range between 5 and 15 MeV applying doses of a few Gray within a few minutes.

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WeS2-1.

Compact laser-produced plasma EUV sources for processing polymers and nanoimaging

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Extreme ultraviolet (EUV) can be produced from a high-temperature plasma generated by interaction of high power laser pulses with matter. Laser plasma EUV sources are considered to be used in various applications in physics, material science, biomedicine, and technology. In the paper new compact laser plasma EUV sources developed for processing polymers and imaging are presented. The sources are based on a gas puff target formed by pulsed injection of a small amount of gas under high-pressure into a laser focus region. The use of the gas puff target instead of a solid target allows for efficient generation of EUV radiation without debris production [1]. The compact laser plasma EUV source based on a gas puff target was developed for metrology applications [2, 3].

The EUV source developed for processing polymers is equipped with a grazing incidence axisymmetrical ellipsoidal mirror to focus EUV radiation in the relatively broad spectral range with the strong maximum near 10 nm. The size of the focal spot is about 1.3 mm in diameter with the maximum fluence up to 70 mJ/cm^2. EUV radiation in the wavelength range of about 5 to 50 nm is produced by irradiation of xenon or krypton gas puff target with a Nd:YAG laser operating at 10 Hz and delivering 4 ns pulses of energy up to 0.8 J per pulse. The experiments on EUV irradiation of various polymers have been performed. Modification of polymer surfaces was achieved, primarily due to direct photo-etching with EUV photons and formation of micro- and nanostructures onto the surface [4]. The mechanism of the interaction is similar to the UV laser ablation where energetic photons cause chemical bonds of the polymer chain to be broken. However, because of very low penetration depth of EUV radiation, the interaction region is limited to a very thin surface layer (<100nm). This makes it possible to avoid degradation of bulk material caused by deeply penetrating UV radiation. The results of the studies should be applicable in biomedical engineering.

The compact laser plasma EUV source has been also used in a microscope based on a Fresnel optics for nanoimaging. Quasi-monochromatic EUV radiation at 13.8 nm was obtained by selection of a single line from the argon plasma spectrum produced using the argon gas puff target. The Mo/Si ellipsoidal mirror of 80 mm in diameter and the 45° incidence angle was applied as the selector. Using the Fresnel lens with the outer zone width of 50 nm the spatial resolution (half-pitch) of 70 nm was obtained [5].

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WeS2-2.

Attosecond shot noise

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The spatio-temporal characteristics of electromagnetic radiation can be monitored on the basis of first order interference or higher-order correlation techniques, by measuring the moments of the field strength at different space-time points. In most cases the informaton is mediated by photoelectrons whose current – owing to the granular nature of electricity – is subject to particle noise. An attosecond pulse train (or an isolated pulse) is usually viewed as an extreme signal stemming from a nonlinear dipole moment associated to bound-continuum-bound electron transitions, containing very high-order harmonics of the exciting radiation [1]. As long as this source is approximated by an expectation value of the otherwise quantal dipole moment, the resulting attosecond radiation is automatically set to be a many-mode coherent radiation in the strict sense of quantum electrodynamics. Then, according to Glauber's quantum coherence theory [2], all the moments characterizing the correlations in such signals would factorize, giving no possibility to overcome the usual shot-noise limit. The question naturally arises, whether to what extent can attosecond pulses be considered as simply broad-band classical signals [3]? If they are not classical, then by what means could one sample them to study their spatio-temporal structure? Instead of first-order interference, we propose to carry out intensity-intensity correlation measurements on split nano-pixels [4], which are not sensitive against phase distortions. By changing the tilt angle of the impinging attosecond pulses with respect to the detector array, the modal structure of the pulses could be monitored by measuring the current-current correlations, and this would yield a delayed coincidence curve. We have modelled the attosecond pulses by many-mode quantum-mechanical phase eigenstates [5], and a contrast ratio 4/3 relative to the Poissonian shot noise level of the coincidence curve has been derived.

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