Relativistic nanophotonics: creating extreme plasma conditions from nanostructures with ultrafast lasers

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The trapping of femtosecond laser pulses of relativistic intensity deep within ordered nanowire arrays can volumetrically heat dense matter into a new ultra-hot plasma regime [1]. Electron densities more than 100 times greater than the critical density with multi-keV temperatures are achieved using ultrashort laser pulses of only one Joule energy. Extraordinarily high degrees of ionization (e.g. 52 times ionized Au) are observed with gigabar pressures only exceeded in the laboratory in the central hot-spot of highly compressed thermonuclear fusion plasmas. The fundamental physics of relativistic laser pulse interactions with nanostructures and their promising applications will be reviewed. The large electron density, which shortens the radiative lifetime\combined with the large plasma volume that increases the hydrodynamic cooling time allow for greatly increased conversion into x-rays. Recent experiments in which gold nanowire arrays were heated by ultra-high contrast pulses at intensities of ~ 4 x 10^{19} W cm^{-2} produced record 20 percent conversion efficiency into picosecond x-ray pulses [2]. In a different set of experiments the acceleration of deuterons from a dense deuterated nanowire array to MeV energies resulted in a record number of monochromatic fusion neutrons per Joule for a compact laser. The neutron production was 500 times larger than that obtained irradiating flat solid targets of the same material (CD_2) with the same laser pulses [3]. Results of the first experiments conducted at an increased intensity of ~ 5 x 10^{21} W cm^{-2} with ultra-high contrast pulses from a frequency-doubled petawatt-class laser will be presented and compared with 3-D relativistic particle-in-cell simulations.

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