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High-energy-density States in Nanowire Targets Irradiated by Relativistic Femtosecond Lasers

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We demonstrate the high-efficiency generation of water-window soft x-ray emissions from polyethylene nanowire array targets irradiated by femtosecond laser pulses at the intensity of 4×10^19 W/cm^2. The experimental results indicate more than one order of magnitude enhancement of the water-window x-ray emissions from the nanowire array targets compared to the planar targets. The highest energy conversion efficiency from laser to water-window x-rays is measured as 0.5%/sr, which comes from the targets with the longest nanowires.

Moreover, by using deuterated polyethylene nanowire targets, high neutron yield of 10^6/J was achieved due to the high-energy-density states formed in the nanowire targets. The energy density of the plasma under irradiation was studied with PIC simulations. It's revealed that more laser energy flows to the confined protons for the nanowire array targets with the larger length of about 5-10 μm and moderate diameter of approximately 20% solid density, resulting in the higher energy dense plasma formation. The energy density of ions reaches 10^8 J/cm^3 when the targets were irradiated by joule-class lasers, exceeding that of the planar target by an order of magnitude.

We explored the properties of the high energy density states by varying the parameters of the Nanowire targets including the diameters, length, and interspace of the nanowires. It is found that the diameter of about 50 nm, length of 5 μm is optimal for the x-ray emission for femtosecond laser pulses, the underlying physics is discussed.

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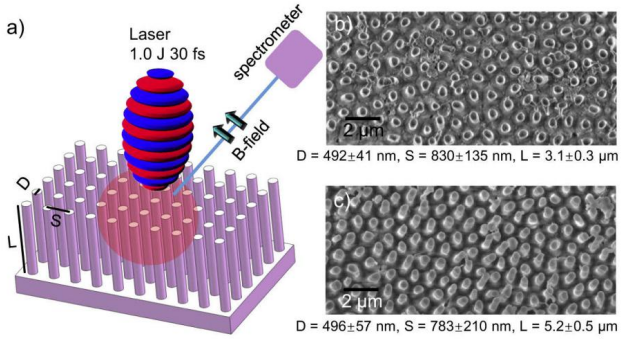

Figure 1. The experimental set-up. a) A schematic diagram of the laser and the NWA targets. The laser incidence angle is 90°. A flat-field grazing-incidence spectrometer is placed at 45° to the laser axis in the reflection direction to measure the x-ray emissions. b) and c) SEM images of the PE NWA targets with different lengths of nanowires.