Betatron x-rays from laser-wakefield accelerators: a novel probe for time-resolved HED science experiments.

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Abstract: We present recent experiments on the development and use of betatron x-ray radiation for high energy density science experiments. This source, driven by laser-wakefield accelerated electrons, is broadband (1-100 keV), collimated (mrad), and ultrafast (sub-picosecond). The experiments were performed at the Linac Coherent Light Source (LCLS) and the Jupiter Laser Facility (JLF).

High Energy Density science laser and free electron laser facilities such as LCLS, SACLA, LFEX, OMEGA, or the National Ignition Facility are now uniquely able to recreate in the laboratory conditions of temperature and pressure that were thought to be only attainable in the interiors of stars and planets. To diagnose such transient and extreme states of matter, the development of efficient, versatile and fast (sub-picosecond scale) x-ray probes with energies larger than 50 kilo-electronvolts has become essential for HED science experiments. Betatron x-ray radiation, a source driven by laser-wakefield accelerated electrons, holds great promise in this field of research. We present recent experiments performed at the LCLS at SLAC and JLF at LLNL. At JLF, we used the Titan laser (150 J, 1 ps), showing evidence of betatron x-ray production in the self-modulated regime of laser wakefield acceleration (SMLWFA). Although Betatron radiation has been observed with picosecond-scale lasers in the direct laser acceleration regime, for normalized vector potentials a_0 greater than 10, this experiment constitutes the observation of Betatron radiation in the SMLWFA regime, for $a_0 \sim 1$-3. This was made possible by the addition of a long focal length optics (F/10), favorable for guiding laser pulses in gas targets. We will show a detailed Betatron x-ray source characterization, as well as electron spectra above 200 MeV and forward laser spectra indicating a strongly self-modulated laser wakefield acceleration regime. At LCLS, we have recently commissioned the betatron x-ray source driven by the MEC short pulse laser (1 J, 40 fs). The source is used as a probe by investigating the X-ray absorption near edge structure (XANES) spectrum at the K- or L-edge of several materials (iron, aluminum, silicon oxide) driven to a warm dense matter state (temperature of a few eV, solid densities). The driver is either LCLS itself or optical lasers. With these experiments we are able to study, with subpicosecond resolution, the electron-ion equilibration mechanisms in warm dense matter.

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