Development and applications of betatron x-ray radiation for high energy density science

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Betatron x-ray radiation, driven by electrons from laser-wakefield acceleration, has unique properties to probe high energy density (HED) plasmas and warm dense matter. This source is produced when relativistic electrons oscillate in the plasma wake of a laser pulse. Its properties are similar to that of a synchrotron, with a 1000-fold shorter pulse. This presentation will focus on the experimental challenges and results related to the development of betatron radiation for applications at large scale HED science laser facilities. We will present recent experiments performed at the Linac Coherent Light Source (LCLS) at SLAC and the Jupiter Laser Facility (JLF) at the Lawrence Livermore National Laboratory.

At LCLS, we have recently commissioned the betatron x-ray source, driven by the Matter under Extreme Conditions (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, 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 sub-picosecond resolution, the electron-ion equilibration mechanisms in warm dense matter.

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). We will show a detailed source characterization, as well as electron spectra above 200 MeV and forward laser spectra indicating a strongly self-modulated laser-wakefield acceleration regime. The results, benchmarked against Particle-In-Cell (PIC) simulations, are promising for future applications of the source at larger scale laser facilities such as OMEGA and NIF.

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