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Betatron x-rays from laser plasma accelerators: a new probe for warm dense matter at LCLS

FELICIE ALBERT, Lawrence Livermore National Laboratory

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. Betatron radiation is produced when relativistic electrons oscillate in the plasma wake of a laser pulse. Its properties are similar to those of synchrotron radiation, with a 1000 fold shorter pulse. This presentation will focus on the experimental challenges and results related to the development of betatron radiation for x-ray absorption spectroscopy of HED matter at large-scale laser facilities. A detailed presentation of the source mechanisms and characteristics in the blowout regime of laser-wakefield acceleration will be followed by a description of recent experiments performed at the Linac Coherent Light Source (LCLS). 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 for investigating the X-ray absorption near edge structure (XANES) spectrum at the K- or L-edge of iron and silicon oxide driven to a warm dense matter state (temperature of a few eV and solid densities). The driver is either LCLS itself or an optical laser. These experiments demonstrate the capability to study the electron-ion equilibration mechanisms in warm dense matter with sub-picosecond resolution. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and supported by the Laboratory Directed research and development program under tracking codes 13-LW-076, 16-ERD-041 and by the Office of Fusion Energy Sciences under SCW1476 and SCW1569.