4:00pm - 4:15pm
TuP2

Hard X-ray emission from high-intensity femtosecond laser plasma and its application to X-ray diffraction

S. Grantham, C. Kim, C. DePriest, M. Richardson

Center for Research and Education in Optics and Lasers
University of Central Florida
4000 Central Florida Blvd.
Orlando, FL 32816-2700
(Tel) (407) 823-3296
(Fax) (407) 823-3570
(Email) chkim@lorien.creol.ucf.edu

Ultrashort pulse X-rays generated by high intensity femtosecond laser plasmas have been studied for their application to time-resolved X-ray diffraction, scattering, and absorption.[1] The hard X-rays from laser plasmas are generated by hot electrons produced near the focal spot in a laser-matter interaction.[2] Upon penetrating into the cold target beyond the heat front, these electrons emit bremsstrahlung radiation via collisions with ions, or produce line radiation by removing bound electrons. As X-ray sources in time-resolved studies of the dynamics of materials, laser-plasmas have a number of valuable characteristics. They are capable of producing very bright x-ray pulses with a wide range of durations down to few picoseconds with source sizes as small as a few micrometers. One of the most useful characteristics of laser-plasma x-ray sources for time-resolved studies is that they can be accurately synchronized with other laser sources and apparatus.

In this paper we discuss characterization and optimization of high-intensity femtosecond laser-produced plasmas as ultrashort x-ray sources for time-resolved x-ray diffraction and their applications to x-ray diffraction with the Laue method..

Plasma generating apparatus in our experiments is Cr:LiSAF based Terawatt laser System[3] in the Laser Plasma Laboratory(LPL). Laser pulses centered at 845 nm wavelength from a mode-locked Ti:Sapphire oscillator, 60 fs (FWHM), 5 nJ per pulse, are stretched to 250 ps with a 16 nm bandwidth. These pulses are amplified to ~500 mJ/pulse through regenerative and four Cr:LiSAF amplifiers and compressed to 120 fs (FWHM), and then are focused to a 10 μm spot onto a 120 μm diameter wire target with a F/1 off-axis paraboloid. The resultant laser plasmas and X-rays generated by them are characterized using a suite of X-ray diagnostics, such as an X-ray pinhole camera, hard X-ray spectrometer, X-ray CCD cameras and Si PIN X-ray diode detectors with Ross filter. The characterization includes laser absorption measurement, X-ray source size measurement, and X-ray spectral flux measurement for line and continuum emission. Then the X-ray sources are optimized for specific X-ray diffraction experiments. In this paper, we present Laue diffraction experiments using this source as preliminary experiments for time-resolved X-ray Laue diffraction.

The Laue method in X-ray diffraction experiments employs an X-ray beam consisting of a range of wavelengths to illuminate a stationary crystal. Numerous lattice planes diffract simultaneously under these circumstances as the Bragg condition is satisfied for each of these planes by at least one wavelength of the spectrum. This method has an advantage over other diffraction methods which use monochromatic radiation, inasmuch as it allows collection of diffraction from many diffracting planes simultaneously, and thus considerably shortens the data

0-7803-4947-4/98/$10.00 ©1998 IEEE

collection time. It is thus ideally suited for time-resolve diffraction if a suitably bright white source is available. Although involving serious complication in data processing (spatial and harmonic overlaps, wavelength normalization, low resolution hole, high sensitivity to crystal disorder), the Laue method has been used successfully using synchrotron radiation.[1] The apparatus for Laue diffraction experiments consists of short pulse laser plasma X-ray source generated by a terawatt laser system described above and an X-ray Laue diffraction camera system. The X-ray Laue diffraction camera includes pinholes which collimate incoming X-rays, a sample holder, and an in-vacuum backside-thinned X-ray CCD camera (1024 × 1024 pixels, pixel size 22.5 μm × 22.5 μm).

X-rays generated in the laser plasma source are collimated and introduced through a pinhole to the sample, which is a single crystal sample located 1 cm away from the source. The x-rays diffracted by the sample in a Laue diffraction configuration are detected by the in-vacuum x-ray CCD camera placed 2 cm from the sample.

This work has been supported by the Department of Energy and the Office of Naval Research.

References

1. J. R. Helliwell and P. M. Rentzepis (eds.), *Time-resolved diffraction*. Oxford, Clarendon Press (1997).
2. P. Gibbon and E. Förster, "Short-pulse laser-plasma interactions", Plasma Phys. Control. Fusion **38**, 769-793 (1995).
3. S. Grantham, J. Eichenholz, C. Depriest, and M. Richardson, "Multi-terawatt Cr:LiSAF Laser Facility", Presented at Ultrafast Optics 1997