Laser Plasma X-ray Source Based on Cryogenic Targets

S. Amano

Laboratory of Advanced Science and Technology for Industry, University of Hyogo, Ako, Hyogo, Japan

**E-mail: sho@lasti.u-hyogo.ac.jp*

Abstracts: *A laser plasma source based on cryogenic targets generating continuously repetitive X-ray pulses has been developed. It has a translating substrate system with a closed He gas cryostat that can continuously supply solid Ar, Kr and Xe targets for 1~ 10 Hz laser pulse, and stable output powers from the plasma emissions were achieved continuously. The average X-ray powers obtained were 19 mW at 3.2 nm, 33 mW at 10.0 nm and 66 mW at 10.8 nm, with 10% bandwidths, from the Ar, Kr and Xe solid targets, respectively, with a laser power of 1 W.*

Laser plasma radiation from high density, high temperature plasma which is achieved by illuminating a target with high-peak-power laser irradiation, constitutes an attractive, high brightness point source for producing X-ray radiation. There have been many studies on application of laser plasma X-ray sources such as X-ray microscopes, EUV lithography, micro processing, etc. To apply these studies in industry, plasma sources, which can generate high average X-ray power with continuous repetitive pulses, not a single shot, is required. Therefore, we have been studying such a continuously emitting plasma source based on a cryogenic target of solid rare gas. The rare gas is considered to be an ideal deposition-free target because of an inert gas, and its chemically inactive debris will vaporize instantly, rather than be deposited on mirrors near the plasma. This is an advantage in a continuous operation. We had also decided to use a cryogenic solid target to provide higher conversion efficiency and higher brightness because of its higher solid density. Additionally, a smaller gas load for evacuation by the exhaust pump system was also expected in the solid state when compared with gas and liquid jets.

To continuously supply cryogenic targets, we originally developed a target supplying system. The one-dimensionally translating substrate system with a closed He gas cryostat that can continuously supply various cryogenic targets for 1 ~ 10 Hz laser pulses has been developed. The system was successfully operated at a lowest temperature of 15 K and at a maximum up-down speed of 12 mm/sec. To supply a fresh target surface for every laser shot and generate stable repetitive X-ray pulses continuously, we studied optimum parameters of a translation speed and a gas flow rate for a laser frequency. Under the optimum conditions, we succeeded in supplying Ar, Kr and Xe solid targets continuously and demonstrated continuous generation of laser plasma emission up to a repetition rate of 10Hz, produced by a commercial Nd:YAG Q-switched rod laser.

The observed spectral peaks for the Ar, Kr and Xe targets are at 3.2, 10.0 and 10.8 nm. When the targets were irradiated with 1 J energy pulses at 1 Hz, the spatially integrated average powers with the 10% bandwidth were roughly estimated to be 19 mW at 3.2 nm, 33 mW at 10.0 nm and 66 mW at 10.8 nm, for the Ar, Kr and Xe solid targets, respectively. The solid Ar target emits strongly the soft X-ray in “water window” between 2.3 nm and 4.4 nm used for microscopy applications, and its power was estimated to be more than 100 mW. In this paper, we will show the details of characteristics of our developed X-ray source.