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Anomalous enhancement of water window X-rays emitted from laser produced Au plasma under low-pressure nitrogen atmosphere

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Water window (WW) soft X-ray (wavelength: 2.3-4.4 nm) is a suitable light source for observing nanometer-size structure of living cells and bio-molecules. Although laser produced plasma has been expected as a bright and short pulse X-ray source, the conversion efficiency from driving laser pulse energy to WW radiation is far below 1%, which hinders the realization of a compact and low-cost X-ray microscope. Recently, it was found that the WW radiation increased, when an Au target was irradiated by the GEKKO XII laser (1053 nm, 500 ps, 120 J) under low-pressure nitrogen atmospheres up to 400 Pa [1]. However, the fact that the laser facility is huge and its repetition rate is very low makes it impossible to apply this X-ray source to the microscope. In order to realize the practical microscope capable of reducing size and cost, the bright X rays generated with a joule class pulsed laser with a high repetition rate is essential. Therefore, under N_2 atmospheres we measured the WW spectra emitted from Au plasma generated with a commercial nanosecond laser with a low-output energy and 10Hz-repwtition.

In the experiment, the gold slab target placed in a vacuum chamber was irradiated with a Nd:YAG laser beam (1064 nm,~7 ns,~1 J) normal to the target surface. The target was mounted on motorized XYZ and goniometer stages, by which the precise alignments for the laser focus and spectroscopic observation could be done the fresh surface was supplied without breaking vacuum. The laser intensity was ~1×10^{10} W/cm^2. The nitrogen was fed into the chamber through a mass flow controller. For X-ray spectroscopy, two grazing incident spectrometers were used: the first had a flat field grating (1200 grooves/mm), while the other one had a 2400-grooves/mm grating and a Pt coated toroidal focusing mirror for measurement of spatial emission distribution.

Figure 1 shows the X-ray spectra for various N_2 gas pressures. The spectral dip around 3.1 nm is attributed to nitrogen K edge. As clearly seen, X-ray count measured at 50 Pa significantly decreases compared with that in vacuum. However, the signal increases above 100 Pa, indicating that the trend in the enhancement of X-ray observed in the GEKKO experiments is reproduced.

Figure 2 plots the total CCD counts in the WW region. X ray yield at 350-Pa N_2 atmosphere increased twice as much as the value measured in vacuum. Taking the substantial X-ray absorption in N_2 gas into consideration, the intensity enhancement by a few orders is expected.

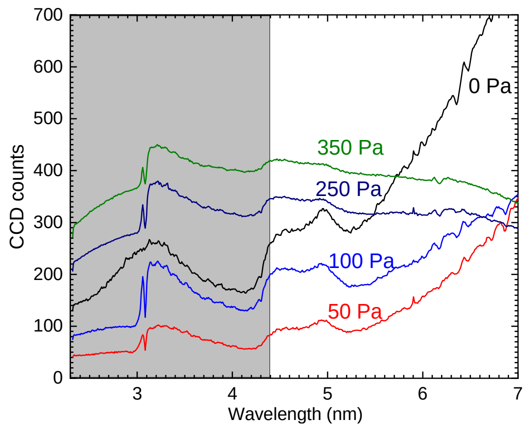

Figure 1. X-ray spectra in the water window wavelengths measured for various N_2 pressures.

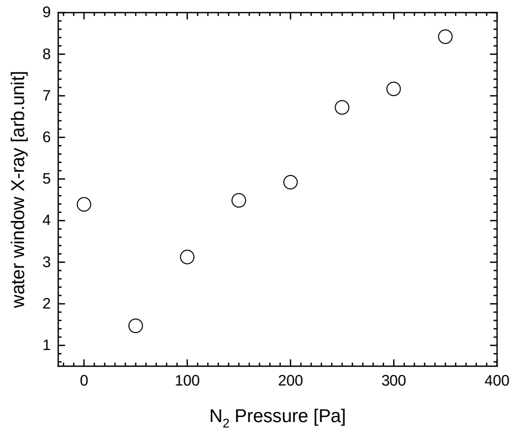

Figure 2. Total CCD counts in the water wavelength.

The mechanism underlying this phenomenon was proposed in terms of atomic process, especially, innershell photoionization of N_2 and subsequent Auger process. In addition, numerical study by using 2D radiation-hydro code Star2D [2] was performed for understanding the experimental results.

References

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