

Water window soft X-ray emission from Au plasmas generated with a picosecond laser pulse

N. Kakunaka¹, C. John¹, M. Kishimoto², Y. Matsumoto¹, N. Hasegawa², M. Nishikino², T. Higashiguchi³, T. Ejima⁴, A. Sunahara⁵, F. Nakajima¹, T. Johzaki¹ and T. Endo¹, S. Namba¹

¹ Graduate School of Engineering, Hiroshima University, ²Kansai Photon Science Institute, National Institutes for Quantum and Radiological Science and Technology, ³Department of Electrical and Electronic Engineering, Utsunomiya University, ⁴ Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, ⁵Center for Material under Extreme Environment, Purdue University
e-mail: m170877@hiroshima-u.ac.jp

Water window (WW) soft X-rays (wavelength 2.3 to 4.4 nm) are easily absorbed by carbon and are hardly absorbed by water around the living cells. Therefore, X-ray microscopy using WW soft X-ray is expected as a technology for observing nanometer scale structure of living cells. In order to obtain a high spatial resolution image with a soft X-ray microscope, a high intensity soft X-ray source is necessary, and usually high-power lasers of 10 J or more is indispensable. This is a major obstacle to spread and development of soft X-ray microscopes in medical and biological research fields.

Recently, it has been found that when a gold target is irradiated with a commercial Nd:YAG laser (1064 nm, ~7 ns, ~1 J) under low-pressure nitrogen atmospheres up to 400 Pa, soft X rays intensity emitted from plasmas increase significantly. Accordingly, a compact and low-cost X-ray microscope can be expected. In this study, in order to generate hot dense plasmas emitting much bright X-ray radiation, picosecond lasers with 10-ps and 500-ps pulse durations were employed.

In the experiment, the gold slab target placed in a vacuum chamber is irradiated with Nd:YAG laser normal to the target surface. In order to examine the dependence of X-ray spectra on the pulse duration, we used a picosecond YAG laser system. The first one is 1064

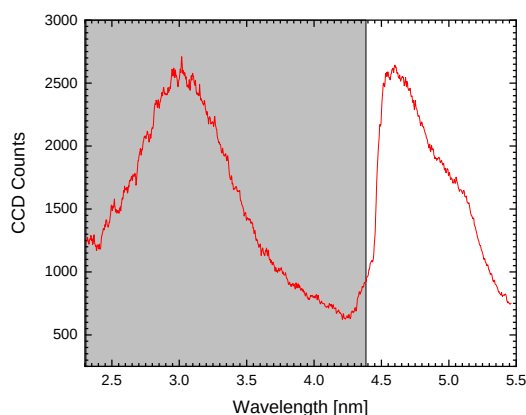


Figure 1. Au spectrum without nitrogen obtained using picosecond laser system

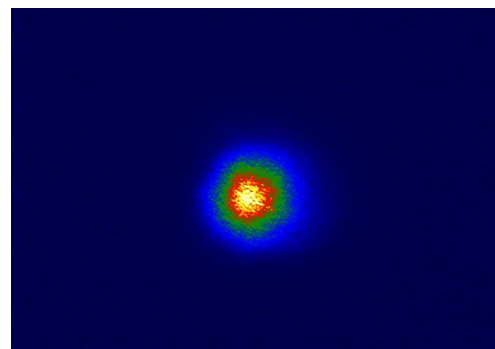


Figure 2. 2D X-ray image without nitrogen gas.

nm, ~500 ps and ~0.9 J, while the other one is 1064 nm, 10 ps and 200 mJ. Motorized xyz stages and a goniometer stage for adjusting target position and a lens position are installed in the vacuum chamber. The laser is focused using a plano-convex lens of $f = 100$ mm. Gas fill circumstance is achieved by introducing nitrogen gas using a mass flow controller. For the soft X-ray measurement, a grazing incidence spectrometer (flat field grating of 2400 grooves / mm) with a toroidal focusing mirror is used. A pinhole camera with an aperture of 10- μ m in diameter is also installed to measure two-dimensional X-ray imaging (magnification of 14 $\times$). To block the out-of-band radiation, appropriate thin filters are inserted in the pinhole tube.

Figure 1 shows the Au plasma spectrum without gas injection. The spectral dip around 4.3 nm is ascribed to carbon contamination on the optics. Compared with the ns laser irradiation, the intensity increased by three times. Therefore, the higher the laser intensity is, the brighter X-ray intensity we obtain. Figure 2 shows an X-ray image of the plasma measured by the pinhole camera through a SiN(0.2 μ m) and Ti(0.5 μ m) filters. The emission image was as large as 72 μ m in full width at half maximum (22 μ m for 7 ns laser pulse through a Ti(0.5 μ m) filter).

In this presentation, we will also report the influence on nitrogen gas fill circumstances by using picosecond laser pulses.