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Observation of water-window soft X-ray emitted from laser plasmas generated in N_2 gas atmospheres

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Soft X-rays of the so-called water-window (WW) region (2.3-4.4 nm) are suitable as light sources in microscopes, which allow for observation of living specimen, providing spatial resolutions below 50 nm.

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]. This increase could aid the resolution quality of X-ray microscopes significantly. For practical use in soft X-ray microscopes, a deep and comprehend understanding of the mechanism underlying the X-ray enhancement is essential. In this study, therefore, a set of experimental parameters, such as gas pressure, gas species, laser energy and pulse length, as well as target materials, are varied widely, to verify their influence on the X-ray enhancement.

The experimental setup is depicted in the schematic below (Fig. 1). Nd:YAG-lasers (1064 nm) are used to shoot at a slab target through a lens of *f*=300mm/100mm. The Laser spot size amounts to 34 microns full width at half maximum (FWHM), granting an spatially averaged intensity of around 6 GW/cm^2. The observation apparatus involves a grazing incidence (GI) spectrometer, featuring

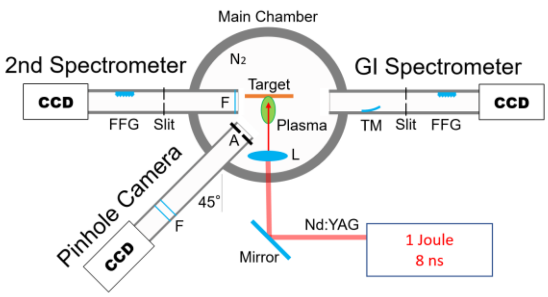

Figure 1: Experimental setup for soft X-ray observation.

a toroidal mirror (TM) and a flat field grating (FFG). A second spectrometer that is installed on the other side, is equipped with a FFG and a thin filter (F). Additionally, a pinhole-camera observes a magnified image of the plasma X-ray image (64×) from the direction of 45° with respect to the target. The emission passes through several metal foil filters (e.g. Be and Ni), which allows for blocking of irrelevant spectral band.

The experiments have proven the enhancement of the WW X-ray under presence of nitrogen atmosphere. Figure 2 shows the accumulated X-ray intensity corrected for the N_2 absorption through the optical path (1417 mm) to the detector, where an Au target was irradiated by

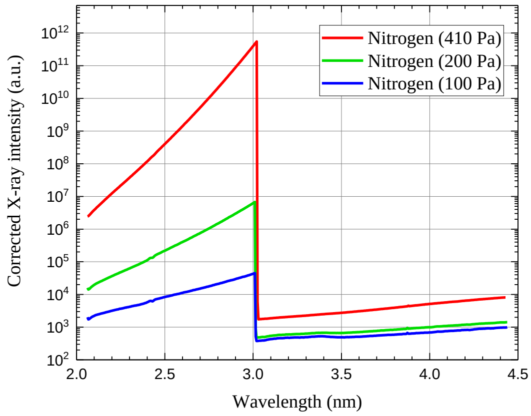

Figure 2: Absorption corrected X-ray intensity (λ) for different N_2 pressures. levels.

Nd:YAG laser pulses (1 J, 8 ns). The plots clearly indicate an emission peak at ~3 nm and highest X-ray intensity at 410 Pa. The pressure level of Nitrogen is assumed to be constant between X-ray source and detector. The N_2-transmission amounts to 40% at 3.2 nm and 10^{-7} % just below the K-edge (both at 410 Pa).

In order to determine the plasma emission profile, the pinhole camera system was employed. Figure 3 shows the typical 2D emission image in the WW X-ray, yielding a full width at half maximum (FWHM) of 13 μm, which is slightly less than half of the laser spot size.

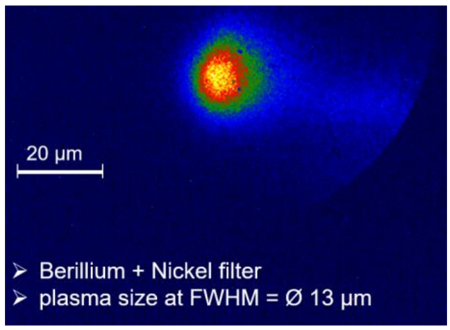

Figure 3: Plasma image under vacuum condition.

In this presentation, we will describe some plausible reasons for the WW X-rays enhancement under N_2 atmospheres in terms of atomic physics.

References

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