論　文　の　要　旨

題目　Water Window X-ray Emission from Gold Foil Targets under Nd:YAG Laser Pulse Irradiation
(Nd:YAGレーザーパルスによる金箔ターゲットからの水の窓X線放射に関する研究)

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Soft x-ray sources developed by laser produced plasma (LPP) hold great promise for applications in diagnostic and manufacturing nano-devices. Particularly, soft x-rays in the water-window (WW) region (2.3-4.4 nm) offer significant advantages for biological diagnostics. The K-absorption edges for C (4.4 nm), N (3 nm) and O (2.3 nm) fall within this wavelength range, providing high transmission contrasts in living biological cells rich in these elements. Consequently, it is employed in soft x-ray microscopy (SXM) for biological diagnostic in various scenarios. This not only allows imaging of relatively thick living organ samples without sample pretreatments (such as dehydration and sectioning), but also enables the observation of organelles in the cytoplasm with high contrast.

The imaging resolution and quality for SXM are significantly limited by the photon fluence reaching the sample surface. Currently, only large facilities using synchrotron radiation sources can achieve a brightness exceeding 10^{14} photons/ (sr · s · μm^2 · 0.1% bandwidth) for high-quality imaging. However, the brightness of LPP hinders the widespread deployment of SXM, not to mention the associated costs and availability of the required devices. Hence, it is crucial to enhance the photon fluence produced by tabletop devices.

One of the methods is to use laser-produced Au plasma. Due to the n=4-4 and 4-5 transitions in the highly ionized Au ions, x-ray emissions emitted from countless energy levels forms unresolved transition arrays (UTA) with a peak wavelength within the WW region. On the other hand, WW x-ray emission enhances when generating laser-produced Au ions in a low pressure N_2 gas, benefiting from the KLL-Auger electrons emitted from the N atom interact with the highly charged Au ions. These make Au a suitable material for LPP scheme to develop a WW x-ray source.

The contact type SXM is favorable for the laser-produced Au plasma scheme. The generated x-rays with short pulse duration effectively reduce blur, while the focused laser spot can confine the emission in a small region with high brightness. However, a high-repetition tape target system is needed to develop a practical contact SXM. An optimal target thickness not only reduces the target cost drastically but also decreases plasma debris, extending the durability of the optical components.

In this work, a comprehensive measurement on the optimal Au target thickness for WW emission was conducted. Foil targets and thermal deposition Au targets ranging from 300μm to 0.1 μm were manufactured and tested. A subsequent optimization of the laser focus condition at a fixed laser energy was also applied to find the most effective condition for WW radiations. The experimental results were compared with the numerical simulations using the Flexible Atomic Code and the Star-2D code. Thermodynamics of the particles in the plasma were studied, providing a comprehensive explanation for the emission behavior observed by the emission spectroscopy.