25Ca04

フェムト秒X線吸収分光計測による
高強度レーザー生成プラズマの過渡的状態の解明

Study of transient states of plasma produced by high-intensity laser using femtosecond X-ray absorption spectroscopy

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A solid matter irradiated by high-intensity laser changes to a plasma maintaining its density. In the initial stage of the plasma formation, high-energy electrons (fast electrons) generated by laser-plasma interactions create transient non-equilibrium inner-shell-ionized plasma via impact ionization processes. In time scale of femtoseconds to picoseconds, the inner-shell vacancies are filled by recombination and deexcitation processes. Then, the plasma reaches thermal equilibrium via collisions of the bulk electrons.

Previously, experimental studies to observe the transient state from inner-shell ionized states to thermal equilibrium were quite difficult, since time resolution was not sufficient. Recently, however, invention of X-ray free electron lasers (XFEL) with pulse durations of <10 fs has enabled us to perform time-resolved measurements in femtosecond region. In this study, as shown in Fig.1, we performed femtosecond time-resolved X-ray absorption spectroscopy based on high-intensity laser pump – XFEL probe technique.

In the experiment, as a probe beam, an XFEL pulse irradiated to a copper (Cu) plasma which was created by irradiation of laser pulses with the intensity of ~10^{19} W/cm^2 to a Cu foil. Figure 2 shows time-dependent transmissions near the K-absorption edge (8980 eV). We can see the drastic increase of the transmission at the high energy side of the K-absorption edge. In addition to the K-absorption edge, X-ray absorption spectroscopy was performed near the Kβ and Kα lines, and we found the differences in lifetime of the outer, M- and L-shell vacancies. Moreover, these results are consistent with a simulation result calculated with a plasma particle simulation code PICLS, which incorporates atomic processes. The present study will contribute to an elucidation of ultrafast phenomena in plasmas and their applications.

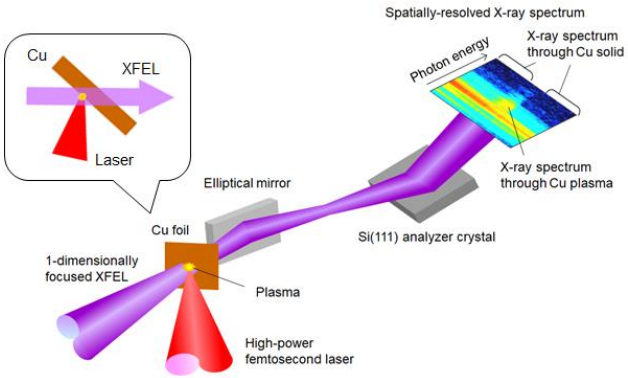

Figure 1. Experimental setup for femtosecond X-ray absorption spectroscopy using high-intensity laser and XFEL.

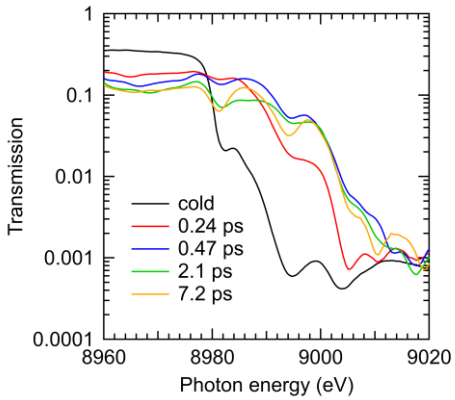

Figure 2. Time-dependence of transmissions near the Cu K-absorption edge (8980 eV).