Amplification of x-ray free electron laser using core-hole atoms generated with intense optical laser pulse

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Abstracts: *We demonstrated a new scheme for amplifying a power of X-ray Free Electron Laser (XFEL) pulse. Irradiation of an intense femtosecond optical laser to a copper target generated fast electrons, which created core-hole atoms in the target. By utilizing them as a gain medium, we achieved amplification of pulse energies of XFEL light at a photon energy of a copper Kα line (8.05 keV). The highest gain at a spectral peak reached close to a factor of ten.*

Recent advent of X-ray Free Electron Lasers (XFELs) [1,2] has opened the frontiers of various fields of science. However, a current output power of XFELs, which are limited by the FEL parameter, is still insufficient for conducting challenging applications, such as exploring photon-and-vacuum interactions [3], XFEL-pumped x-ray laser [4], and creating extremely high energy density states. On the other hand, state-of–the-art, high power optical lasers are now close to generating extreme outputs above a 10 PW level. Such a drastic enhancement of laser intensities has been realized through the development of an optical amplifier with an external pumping system. If the external amplifier scheme utilized for optical lasers were applicable in the X-ray range, one could directly enhance the power of XFEL pulses.

In this presentation, we will show an amplification of x-ray free electron laser using core-hole atoms generated with intense optical laser pulse. The experiment was performed at BL3 of SACLA [2]. A 20-μm-thick Cu foil was used as a gain medium. Intense Ti:Sapphire laser pulses synchronized with XFEL pulses were used to generate fast electrons. Here the fast electron energy was estimated to be 70 keV, which is high enough to create the core-hole atoms of Cu with an ionization energy of 8.98 keV for the K-shell electrons. A photon energy of XFEL pulses was tuned to be 8.05 keV, corresponding to the Cu-Kα1 line. The XFEL light was focused down to 10 μm irradiated to the Cu foil. To observe the amplification, we measured single-shot spectra of XFEL pulses [5] through the Cu foil. Intense peak at 8.05 keV was observed, and we confirmed that the divergence of the intense signal is same as that of XFEL pulses. From these results, we conclude achievement of x-ray amplification. The highest obtained gain at spectral peak was as high as ten. A scaling law indicates that an extreme output of monochromatic hard X-ray laser is achievable simply by increasing the power of the optical lasers.

Reference

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