PL-21 AAPPS-DPP2019

3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Progress of inner-shell ionized hard x-ray laser pumped by intense XFEL pulses

Hitoki Yoneda

Institute for Laser Science, University of Electro-Communications, Tokyo, Japan

e-mail: yoneda@ils.uec.ac.jp

The intense hard x-rays from recent x-ray free electron lasers can create high excitation density conditions of a specific ionization state of the atoms in solid materials. About 20% of the atoms in a solid metal can be ionized in a very short time interval (<10fs) at XFEL intensity of 10^{20}W/cm^2. In addition, ultra-short pulse pumping and resonance absorption of 1s-free level of atoms, atomic positions can be frozen at their initial lattice position even in a high energy density state of more than 10^7J/cm^3. This well-ordered nonequilibrium condition is suitable for new hard x-ray lasers. For example, we have succeeded to obtain Kα (1s-2p) inner shell ionized laser of Cu atoms, with 0.15 nm wavelength and 8 keV photon energy. In this laser, we need high inversion density of the corresponding atomic system and sufficiently large gain-length product. In that sense, high density condition with high 1s inner shell ionization is important.

This success of the Kα laser also means that we achieve strong interaction between resonant hard x-ray laser field and high density inner shell ionized atoms. We observed intense resonant light controls the emission process of the atoms. By using this mechanism, the spectral control of laser emission with injection seeding method was also demonstrated. One example for using this strong interaction is double pulse generation due to the gain modulation. We have succeeded to produce beautiful regular frequency fringes within the Kα emission line profile. That is the first observation in the hard x-ray photon energy region. We now propose and demonstrate to use this fringe spectrum for fs-pump-probe experiment to detect ultra-fast transient states in the metal.

By using strong induced emission process, we are also able to generate new x ray line emission of Cu atoms. In Cu atoms, the 4s electron orbit is the outer most electron state so that after creation of 1s vacancy, there are Kα (1s-2p) and Kβ (1s-3p). However, if the 1s electron is excited onto the just above Fermi-surface of the metal, and if intense resonant light (1s-4p) enters the system, higher Rydberg line emission can be generated. In the experiment, 9.1 keV laser is used for the pump and 9 keV laser is used as a seed. Finally, we succeed to generate gain of 1s-4p transition of Cu atoms for the first time. This new type of lasing will give a precise monitor of outer electron states by hard x-ray probe.

Recently, we propose Bragg diffraction controlled hard x-ray lasers, which is similar to the mechanism of the distributed feedback lasers in optical communication devices. In our newly proposed lasers, the crystal Bragg resonance condition is used for achieving a standing wave in the high gain medium pumped by intense XFEL pulse. Up to now, we demonstrate spatial mode controlled laser, cavity controlled emission wavelength laser, and anti-resonance lasers. These advances in hard x-ray laser science will be used for new diagnostics of material condition, new type of laser induced spectroscopy, and new physics of high density plasma strongly coupled with resonant x-ray waves.

References

1. H. Yoneda, Y. Inubushi, K. Nagamine, Y. Michine, H. Ohashi, H. Yumoto, K. Yamauchi, H. Mimura, H. Kitamura, T. Katayama, T. Ishikawa, M. Yabashi, Nature, 524, 446 (2015).

2 H. Yoneda, Y. Inubushi, M. Yabashi, T. Katayama, T. Ishikawa, H.Ohashi, H. Yumoto, K. Yamauchi, H. Mimura, H. Kitamura, Nature Commun., 5, 5080 (2014).