Hard X-ray Laser Photonics

Hitoki Yoneda

Institute for Laser Science, University of Electro-Communications
**E-mail:yoneda@ils.uec.ac.jp*

Abstracts: *Recent x-ray free electron lasers open new chance to create x-ray active control science. Up to now, we already demonstrate saturable absorber, optical guiding, gain, and spectral control in hard x-ray region. By using these new phenomena, we are now creating x-ray coherent photonics with hard x-ray lasers.*

Recently, several nonlinear optical phenomena have been successfully observed in hard and soft x-ray wavelength lasers. Those include lasing[1,2], two-photon absorption[3], second harmonic generation[4], saturable absorption[5], control of the branching ratio in an atomic system[2] and self-guiding lasers[5]. These phenomena are actually key component for photonics. By combining them, we can make lasers with well-controlled waveform, spectrally controlled lasers, ultra-short pulse lasers in the x-ray range. Specially, to consider difficulties of preparation of wave-front-control or wave separation & combining optics in hard x-ray, it is suitable to develop functional medium, which generate controlled spectral and waveform x-ray laser pulses required from applications. .

To realize this goal, we demonstrated several x-ray lasers pumped by intense x-ray free electron lasers. Those include double-pulse generation, spectral shifted laser by materials, and spectral broadening by MOPA (master oscillator and amplifier) method. For example, in order to produce a double pulse in a single medium, we use gain dynamics after pump by the XFEL and using a nano-surface geometrical structure, we successfully achieved temporally coherent double pulse x-ray laser pulse. The separation of the pulses is several fs and each pulse has sub-fs pulse duration. With a crystal spectrometer, we observe high visibility interferometric fringes of frequency domain in hard x-ray. We are now trying to use such a pair of pulses for ultra-fast pump-probe experiments.

In this talk, the details of development of these functional devices will be reported together with their implications for future x-ray coherent photonics.

[1] Rohringer, N. et al., *Nature* **481**, 488-491 (2012).
[2] Yoneda H., et al, Nature 14894 (2015)
[3] Tamasaku et al, *Nature Photon* **8** 313 (2014)
[4] Shwartz et al., *PRL* **112** 163901 (2014)
[5] Yoneda et al., *Nature Commun., 5, 5080* (2014)