Injection seeding of Kα x-ray laser with two color x-ray free electron laser

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The recent success of the X-ray Free Electron Laser (XFEL) [1,2] opens the door to a broad range of new scientific results. Specifically, in the Japanese XFEL SACLA, there are two sophisticated new technologies. One is a 50 nm focusing system [3] and the other is two-color operation [4]. By using these technologies, an 8 keV hard X-ray laser was achieved in SACLA [5]. In this scheme, two-color FEL pulses are used for pumping and seeding of the inner-shell atomic X-ray laser. We measured narrower line width of Kα emission than the width of natural spontaneous emission, and selective lasing in Kα1 and Kα2 emissions, both of which are normally components of Ka emission. For spontaneous emission, it is well-known that these Kα lines have a fixed ratio 2:1. However, we could observe only Kα1 or only Kα2 laser emission in the injection-seeding experiments. These results mean strong induced emission controls deep atomic process and we can control even lifetime of x-ray emission in middle Z atoms. In other words, we can achieve strong coupling of the two levels $K^1L^0M^0$ and $K^0L^1M^0$.

In addition, the two-color FEL pumping and seeding method makes it possible to achieve two-color lasing of Kα1 and Kα2 and extraction of coherent laser light from weak emission transitions such as emission from double excitation ions. If we use these different types of ionized atoms for lasers, about 40eV bandwidth can be obtained. That means a sub 100attosecond laser will be possible. This one is another attractive idea to realize in future.

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[3] Mimura, H. *et al. Nature Commun.* **5**, 3539 (2014)
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[5] Yoneda H., et al, Nature 14894 (2015)

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