SEEDING OF EXTREME ULTRAVIOLET FREE ELECTRON LASER WITH HIGH-ORDER HARMONIC

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Frontiers in optical science in the short-wavelength region have greatly been expanded by the advent of intense, single-pass free-electron lasers (FELs) based on a self-amplified spontaneous emission (SASE) scheme [1, 2]. However, their temporal profile and frequency-domain spectra are composed of random and uncontrollable spikes, exhibiting shot-to-shot fluctuation originating from the stochastic start-up process intrinsic to spontaneous radiation. The most straightforward method for improving the temporal coherence of FEL is to inject the high-order harmonic (HH) generated by a laser into an FEL amplifier. In this paper, we fist demonstrate [3] the 13th harmonic (61 nm) [4] of a Ti:sapphire laser in the plateau region was injected as the SPring-8 Compact SASE Source test accelerator [2].

Figure 1 shows the recorded spectra of the FEL radiation in fifty successive shots both without (a) and with (b) the HH injection. They exhibit sharp increases in the spectral intensity for several shots shown as red lines in Fig. 1 (b). The small event-number ratio of the enhancement, which is typically $\sim$ 10 shots per 1000 shots, is caused by the timing jitter between the seeding laser pulse and the electron bunch. In addition, we investigated the resonance effect by changing the deflection parameter, K, of the undulator (i.e., the central wavelength of undulator radiation) by varying the undulator gap. The high-intensity pulses are observable only in the vicinity of the conditions with the central wavelength of 61.2 nm, as shown in the inset of Fig. 1 (a). This resonance behavior can be regarded as an evidence of the successful operation of the seeded FEL in this EUV region.

When the amplification conditions were fulfilled, strong enhancement of the radiation intensity by a factor of 650 was observed. The random and uncontrollable spikes, which appeared in the spectra of the SASE based FEL radiation without the seeding source, were found to be suppressed drastically to form to a narrow-band, single peak profile at 61.2 nm. The properties of the seeded FEL radiation were well reproduced by numerical simulations. We will discuss the future precept of the seeded FEL scheme to the shorter wavelength region.

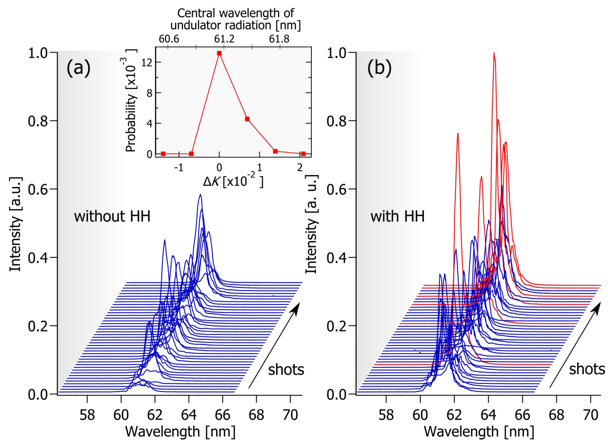

Figure 1: Spectra of FEL radiation in fifty successive shots without (a) and with (b) HH injection. The red lines in (b) show profiles that have higher intensities above the threshold level. The inset shows an appearance probability of the high-intensity condition as a function of the deviation of K-value, $\Delta K = K - 1.37944$ (lower axis), and the central wavelength of the undulator radiation (upper axis).

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