Time-dependent Behaviors of X-ray Photons in Crystal Cavities

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We report the details of the recent x-ray back diffraction experiments, in which interference fringes due to x-ray cavity resonance are unambiguously observed. Emphasis is placed on the time-dependent behavior of X-ray photons in the Fabry-Perot type cavities, which consist of monolithic two-plate and eight-plate silicon crystals of a few tens to hundreds μm thickness with a gap of similar size. The (12 4 0) back reflection and synchrotron radiation of energy resolution ΔE=0.36 meV at 14.4388 keV are employed. Interference fringes in angle- and photon-energy scans for two-plate and eight-plate cavities are shown. It is showed that the temporal coherence of X-rays relative to the crystal gap at the normal incidence diffraction geometry plays an essential role in revealing resonance fringes for a crystal cavity. That means the coherent time of the incident x rays should be larger than the round-trip time for photons traveling between the two adjacent crystal plates. In addition, the Fourier transforms of the energy scans demonstrate that the transmitted X-ray photons are steadily stored in a period of picoseconds and the formation of standing waves inside the cavities ensures better coherence for the X-rays. We anticipate that the transmitted X-rays can be used as a new source for high-resolution time-resolved X-ray scattering, imaging, microscopy, and spectroscopy.

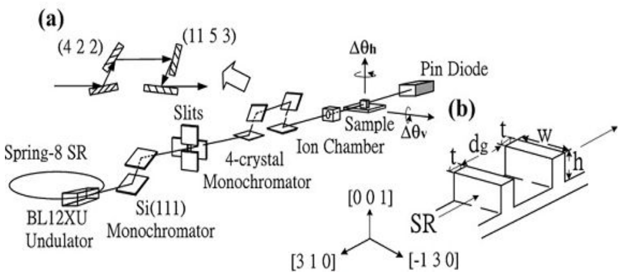


Figure 1. (a) the side view of the fourcrystal high-resolution monochromator; (b) the crystallographic orientation of the two-plate cavity.

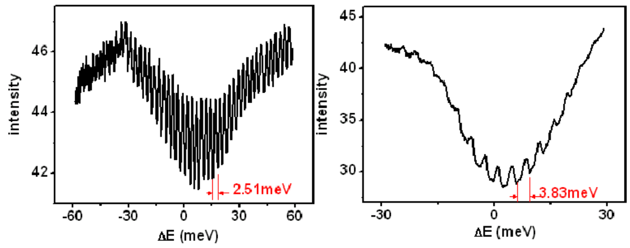
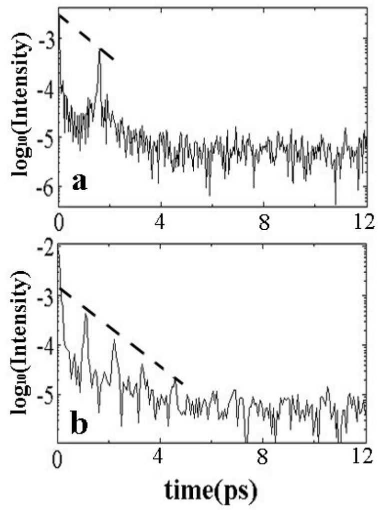


Figure 2. (a) the thick two-plate cavity (100/150), and (b) an 8-plate (25/150) cavity.



Figures 3(a), (b) show the Fourier transformed I(t) against time t of Fig. 2a and 2b, respectively. In Fig. 3(a), the maximum transmitted intensity occurs at t = 1.67 ps for the 2-plate cavity, which is equal to 2d/c with d=250 μm. This indicates that X-ray photons are periodically trapped in between the two crystal plates. In Fig.3b, there are four maximum peaks for the 8-plate cavity at t = 1.11, 1.18, 1.15, and 1.32 ps, which are also approximately equal to 2d/c with d=175 μm. The longitudinal coherent time of the incident beam is 1.8 ps, which is longer than $t_f/2$. (t_f=1.67 ps for two-plate cavity; t_f=1.17 ps for 8-plate cavity). This implies that the transmitted photons through the first plate, as well as the reflected photons from the second plate, have many chances to interact coherently with the doubly reflected beams inside the cavity, consequently leading to periodic constructive interferences, thus generating intensity maxima as time goes by.