MS13-P05

Spatial displacement of forward-diffracted X-ray beams by perfect crystals. Cases: Laue and Bragg geometry

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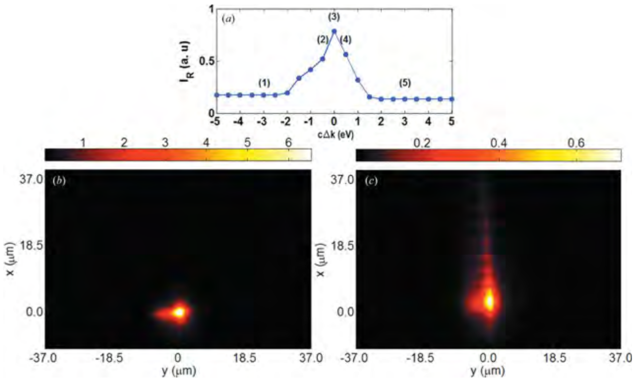
Hard X-ray free-electron lasers (XFELs) are novel photon sources, which rely on the self-amplified spontaneous emission (SASE) process to obtain peak brightnesses in the soft and hard X-ray regime that are orders of magnitude larger than those achieved with insertion devices at third-generation synchrotron light sources. The SASE radiation arises from amplification of stochastic noise in the electron bunch. Therefore, it consists of many longitudinal modes, and exhibits strong shot-to-shot fluctuations of both the mean pulse energy and the pulse spectrum, showing relative bandwidth typically of the order of 10−3. Self-seeding has been proposed as an intensity-efficient mode of operation for XFELs [1]. After SASE amplification in a first undulator section, the electron bunch is separated from the photons and delayed by a magnetic chicane, which also refreshes the electron bunch by suppressing the microbunching that results from the SASE process. The XFEL pulse thus obtained is characterized by the same narrow bandwidth and by a stable wavelength set by the monochromator.

In the hard X-ray regime, monochromators are typically based on perfect crystals. Geloni *et al.* [1] have proposed generating the narrow-band seed with a thin crystal in the Bragg condition. This process of forward Bragg diffraction (FBD) is described by the dynamical diffraction theory presented for spatiotemporal effects by Shvydko [2], which accounts for multiple-scattering effects relevant in perfect crystals. For most of the radiation in the incoming SASE pulse the crystal is transparent. Only the wavelengths that are close to or satisfy the Bragg condition are affected, and a series of time-delayed pulses of low intensity but narrow bandwidth, called echoes, are generated in the temporal tail of the transmitted pulse [1,2].

The work presented here aims to gain a better understanding of space-, time- and frequency-domain effects in the FBD process. The results reported represent the first direct and unambiguous experimental evidence of the spatially displaced echoes in the forward transmitted photon beam, made possible using an X-ray beam focused down to the micrometer scale. Our results are backed up by simulations that confirm the interpretation of the experimental signals in terms of FBD echoes [3]. Fig. 1 shows results obtained from an energy scan at 12 keV with a 400 um thick diamond single crystal with orientation (110) set to diffract at the (220) reflection in Bragg Geometry.



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Keywords: Forward Diffraction, femtosecond, multiple-scattering