Reflective and Diffractive Optics for Coherent Ultrafast Radiation at Extreme Ultraviolet and Soft X-Ray Wavelengths

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Synopsis: We present recent developments of novel reflective and diffractive optics at the Center for X-Ray Optics (CXRO), Lawrence Berkeley National Lab, for use with coherent ultrafast x-ray sources such as high order harmonic generation and free electron lasers. At extreme ultraviolet (EUV) wavelengths, we demonstrated high efficiency multilayer-based reflective optics and the capability to fabricate aperiodic structure with optimized thickness variations for desired bandwidth and phase response, enabling pulse shaping at sub-femtosecond scale. Also described is an attosecond beam splitter, which converts a single attosecond incoming pulse into two replicas with precisely controlled time delay. This can be used in SPIDER experiments for full characterization of attosecond pulses. For coherent soft x-rays, novel diffractive optics designs implementing Fourier optics technique enables phase manipulation and provides phase contrast enhancement and extended depth-of-focus.

At EUV wavelengths, the efficiency of reflective optics can be greatly enhanced by multilayer coatings. CXRO has developed coatings using various material combinations to achieve reflectivity higher than 45% across the whole EUV spectrum from 30 to 120 eV, and as high as 70% at ~ 90 eV.

Aperodic multilayer, consisting of layers with varied thickness, offers greater flexibility on tweaking the bandwidth and phase response. By incorporating practical coating parameters, we have successfully fabricated aperodic multilayers whose characterization matched the prediction of simulation model [1] (fig. 1a).

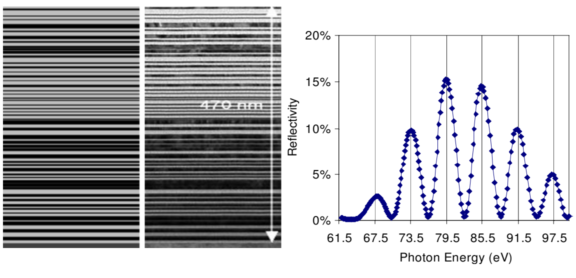

Fig. 1. (a)An aperiodic multilayer coating. (b) Spectral response of an attosecond beam splitter.

Attosecond SPIDER experiment has been proposed [2] to fully characterize an attosecond pulse. A key component for such experiment is a beam splitter that can produce two replicas of the incoming pulse, with their time delay precisely controlled. We developed a Fabre-Perot-like structure with two multilayer stacks separated by a silicon layer. The spectral response of this structure (fig. 1b) confirms the existence of two duplicated pulses separated by 67 as (¼ period of the 800 nm pump field).

At soft x-ray wavelengths, Frsenel zone plates fabricated by electron beam lithography are used in x-ray microscopes, achieving better than 15 nm spatial resolution[3]. Novel diffractive optics being developed at CXRO, for example spiral [4], Zernike [5], and cubic zone plates, utilize coherence properties of radiation to achieve phase contrast enhancement or extended depth-of-focus.

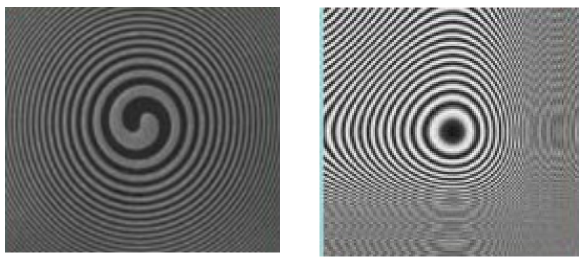

Fig. 2. A spiral (left) and cubic (right) zone plate.

The novel optics mentioned here will find new applications with the newly available coherent ultrafast sources, and together they can open new opportunities in attosecond sciences.

References

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