Multilayer Mirror Objective for Focusing Isolated Attosecond Pulse in 40 nm Wavelength Region

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Abstracts: *Recently, isolated attosecond pulse (IAP) generation with pulse energy of a few μJ has been reported in a 40 nm wavelength region. For diffraction-limited focusing of the IAP, we are developing the Schwarzschild objective made of two-curved multilayer mirrors. To generate intense light fields with the maximum intensity of over 10^{16} W/cm^2 on focus of the objective, in this paper, we describe design, fabrication, and test of multilayer mirrors with three different material pairs, i.e., SiC/Mg, Cr/Mg, and Sc/Si, for practical high reflectivity in the 40 nm wavelength region.*

Recently, isolated attosecond pulse (IAP) generation in a 40 nm wavelength region has been reported, where an isolated intense pulse with pulse energy of a few μJ was demonstrated by applying the novel two-color gating method.[1)] When such the attosecond high-power extreme ultraviolet (EUV) pulse is focused with diffraction limited objective to produce a small focal spot with size of a few handled nanometers, we can generate extremely intense fields with the maximum intensity of over 10^{16} W/cm^2, which enables us to access the new frontier of nonlinear optics in EUV region. For the diffraction-limited focusing of the IAP, we are developing the Schwarzschild objective made of two-curved multilayer mirrors.[2)] The objective has two practical advantages, i.e., high spatial resolution resulting from large-numerical aperture optical design, and spectral selectivity based on the Bragg reflection on multilayer mirrors. To realize the objective, firstly, we need multilayer mirrors with practical high reflectivity. In this paper, we describe design, fabrication, and test of multilayer mirrors that is suitable for the focusing application in the 40 nm wavelength region.

After applying the selection rule for high reflectivity, which has been given by Yamamoto,[3)] three material pairs, i.e., SiC/Mg, Cr/Mg, and Sc/Si, were chosen. The period and thickness ratio of the mirror were numerically optimized to give the maximum reflectivity at a wavelength of 40 nm. The three multilayer coatings were deposited by using the magnetron sputtering apparatus (SPL-500, Canon Anelva Corp.). At-wavelength reflectivity was examined with the EUV reflectometer equipped on beamline BL5B of UVSOR. We observed relativity high reflectivity of over 30% on the Mg-based multilayer mirrors. Especially in SiC/Mg multilayer mirror, practical high reflectivity of 40% and wide band width were confirmed simultaneously, where we can expect the maximum intensity of over 10^{16} W/cm^2 with pulse duration below 800 attosecond on the focus of the two-mirror objective. In the presentation, we also report experimentally measured phase change on reflection, which corresponds to group delay dispersion modulating pulse duration on ultra fast optics.

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