Optimization and application of attosecond multilayers

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Abstract: The emerging field of attosecond physics aims for the temporal investigation and eventually the control of electron dynamics in matter (atoms, molecules or solids) on its genuine time scale, the temporal range of attoseconds (10^{-18} seconds). Recent experimental examples are the characterization of the photoionization time delays of core electrons in neon atoms [1] or the photoemission time delay between valence and core states of magnesium. Such experiments are based on the generation of attosecond pulses in the extreme ultraviolet to soft x-ray range by high harmonic generation in gases [2], which is nowadays a well established method and is constantly pushed toward ever higher photon energies by improved laser systems. It will eventually reach the important water window spectral range, between the 1s states of carbon and oxygen (284 eV–543 eV), with adequate photon numbers in the foreseen future. This will extend attosecond physics to biological specimens and may facilitate groundbreaking results in the field of biophysics. Besides the source development, there is a strong demand for corresponding optics development to steer and control attosecond pulses. Multilayer mirrors are key components in attosecond physics with a high degree of freedom, facilitating e.g. the tailoring of attosecond pulse parameters [3]. The designs, the accurate nano-fabrication, the characterization and application of periodic as well as aperiodic multilayer mirrors will be presented. The extremely precise control of the ion beam deposition process enabled for the first time the experimental control of the so-called attochirp [4] as well as the realization of the first chirped multilayer mirrors for the water window with a theoretically precise phase control, which can be used for a pulse compression down to 69 attoseconds above 300 eV [5]. The reflectivity performance of the multilayer mirrors was additionally improved by assisted ion beam polishing of the interfaces [6], resulting e.g. in a peak normal incidence reflectivity (21% at the scandium L3-edge) which is among the highest measured reflectivities of a pure chromium/scandium multilayer mirror. Besides the application of multilayer systems as reflective element a transmission multilayer quarter wave retarder has been designed, fabricated and characterized to transform linearly polarized attosecond pulses to elliptically polarized pulses [7], which could allow for the investigation of ferromagnetic materials or chiral molecules with a high temporal resolution. Various material systems have been investigated for multilayer systems [8,9] to allow for (attosecond) optics covering the spectral photon range from the lower extreme ultraviolet with few electronvolts up to the soft X-ray range with kiloelectronvolts. This allowed for example the realization of different multilayer mirrors and their application to spectrally select and shape radiation from a laser-plasma driven undulator table-top source, which resulted e.g. in the successful isolation and characterization of femtosecond pulses in the water window close to 300 eV, the highest measured photon energy from such a table-top source so far. Optimized multilayer mirrors have been applied to high harmonic radiation to access the attosecond time scale in the soft x-ray range by the generation and characterization of isolated attosecond pulses at 145 eV [10], up to now the highest central energy for characterized (by attosecond electron streaking) table-top attosecond pulses. The results demonstrate that the control of attosecond pulses by multilayer optics has been extended to higher photon energies (into the water window), to a better pulse dispersion control (for shorter pulses) and polarization control. This will pave the way for entirely new experiments in attosecond physics in the near future.

References:

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