Multilayer mirrors for attosecond pulses

C. Bourassin-Bouchet [1], S. de Rossi [2], F. Delmotte [3], E. Meltchakov, F. Bridou, Y. Menesguen
Laboratoire Charles Fabry, Institut d'Optique, Univ Paris sud, CNRS, RD128 Campus Polytechnique, 91127 Palaiseau, France

Attosecond pulses can nowadays be produced by high harmonics generation (HHG) in the extreme ultraviolet spectral range. But the efficient transport of such a broadband (typically 10 to 40 eV) is very challenging because the usually deposited materials can be strongly absorbents and their optical constants are not always exactly known. Furthermore the intrinsic chirp of the attosecond pulses due to the generation mechanism is a limitation to have a Fourier limited attosecond pulse. Typically a chirp or a Group Delay Dispersion (GDD) of 10000 as² for 40 eV of bandwidth increases the duration of the pulse from 100 as to 300 as. But the compression of such a non-Fourier-limited attosecond pulse is possible thanks to a chirped multilayer mirror. Several works about optimization and realization of such an "atto-mirror" for compression have been investigated near 13 nm for HHG with neon gas [1,2]. We investigate here the optimization, realization and characterization of such multilayer-atto-mirrors for the 35-55 eV spectral range, where the high harmonics are generated in argon gas.

In order to design multilayer mirrors with a large bandwidth, we optimized completely aperiodic structures (for which all layer thicknesses are different). Previous works have been made to experiment the first way for the fabrication of broadband multilayer mirrors [3,4]. We optimized three aperiodic mirrors working between 35 to 55 eV, at 45° incidence angle with a GDD = 0 as² (without compression of the pulse), a GDD = -4300 as² and a GDD = -8500 as². The stacks consist in about 10 layers of Mo-B4C-Si sequence with aperiodic thickness. Reflectivities of 15-25 % on 20 eV spectral range are reached.

All multilayers have been deposited using a magnetron sputtering system equipped with four cathodes. This system has already been described previously [5].

We performed our measurements on the BEAR beamline reflectometer at Trieste Sincrotrone ELETTRA. If the measurement of the module of the reflectivity is now common, the determination of the phase can be difficult. In order to characterize such a phase of the multilayer, we measure the photo-electrons emitted at the top of the multilayer [6] called total electron yield (TEY). In first approximation this yield can be proportional to the standing wave at the top layer level which is the interference between the incident beam and the reflected beam [7,8]. We also need to measure the TEY of a reference sample identical to the top layer of the multilayer. By this way we can extract the phase reflected by the multilayer mirror. Our first experimental results using this technique show a good agreement between theory and experiment.

To complete this study, we plan soon to measure our mirrors on a HHG setup. The phase determination will be obtained by the RABBITT technique [9] allowing a full characterization.

Acknowledgments
The authors appreciate the assistance of Prof. Stefano Nannarone, Dr. Nicola Mahne and Dr. Angelo Giglia during synchrotron radiation measurements at BEAR beamline of Elettra Sincrotrone Trieste. This work was supported by the ANR project 07-BLAN-0150. The multilayer fabrication have been carried out on CEMOX (Centrale d'Elaboration et de Métrologie des Optiques X).

References
[1] A. S. Morlens et al. Proc. SPIE 5963 (2005)
[2] E. Goulielmakis et al. Science **320** (2008)
[3] A.S. Morlens et al. Optics Letters 31(10) (2006)
[4] F. Delmotte et al. Proc. SPIE 5963 (2005)
[5] J. Gautier et al. Applied Optics 44(3) (2005)
[6] S. V. Pepper JOSA 60(6) (1970)
[7] A. Aquila et al. Optics Letters 33(5) (2008)
[8] M. Suman et al. Optics Express 17(10) (2009)
[9] Y. Mairesse et al. Science 302 (2003)

[1] E-mail : charles.bourassin-bouchet@u-psud.fr
[2] E-mail : sebastien.derossi@u-psud.fr
[3] E-mail : franck.delmotte@u-psud.fr