# Preface

The book will review the most recent achievements in optical technologies applied to photon handling and conditioning of extreme-ultraviolet (XUV) and soft X-ray coherent sources.

The developments in laser technology over the past 30 years led to the generation of coherent optical pulses as short as a few femtoseconds, providing a unique tool for high-resolution time-domain spectroscopy that revolutionized many areas of science from solid-state physics to biology. While femtosecond optical lasers offered unique insights into ultrafast dynamics, they are limited by the fact that the structural arrangement and motion of nuclei are not directly accessible from measured optical properties. This scientific gap has been filled by the availability of ultrafast coherent sources in the extreme-ultraviolet and X-ray spectral region, such as high-order laser harmonics and free-electron lasers.

High-order laser harmonics, that are produced by the interaction between a very intense ultrashort pulsed laser and a gas/solid target, exhibit high brightness, high degree of coherence, and high peak intensity. The combination of the use of advanced phase matching mechanisms and interaction geometries as well as intense ultrafast laser has made possible to obtain radiation down to the water window region (2.3–4.4 nm). Moreover, the radiation generated with the scheme of the high-order harmonics using few-optical-cycles laser pulses is presently the most advanced tool for the investigation of matter with attosecond resolution.

Synchrotron radiation has provided over the past 40 years an increase in flux and brilliance of more than ten orders of magnitude in the extreme-ultraviolet and X-ray spectral regions. The free-electron-laser sources generate spatially coherent XUV/X-ray radiation with characteristics similar to the light from conventional optical lasers, ultrashort time duration, and an additional increase of 6–8 orders of magnitude on the peak brilliance with respect to synchrotrons.

In order to investigate the properties of these laser-type sources as well as to exploit their new capabilities in terms of scientific return, the instrumentation that is used to handle, condition, and characterize the photon beam has a fundamental role. The development of optical technologies suitable for photon handling of coherent XUV/X-ray sources is a typical field where a strong collaboration between research and industry is required to reach new exciting results. On one side, the impressive developments of lasers have opened the way to major improvements in terms of performance from the sources. On the other side, new optical techniques have been studied and demonstrated in order to exploit the full potentialities of coherent light in the XUV/X-ray, especially in terms of coherence preservation and temporal resolution. An increasing number of scientific and industrial partners are collaborating on the development of the applications based on next-generation light sources, and in the twenty-first century many secondary sources came out of the laboratory to be proposed as "machine" to perform experiments. The optical technologies described in this book represent the achievement of the scientific development and the beginning of the technological life of the coherent light sources.

The book is organized as follows.

Chapters 1 and 2 are focused on the two free-electron laser facilities that are presently in operation with photon emission in the extreme-ultraviolet region: FLASH in Germany and FERMI in Italy. Photon beam transport and diagnostic techniques on the two facilities are reviewed.

Chapters 3 and 4 review the techniques related to high-order laser harmonics to generate intense pulses in the femtosecond and attosecond timescale. Recent experimental progresses in the field of attosecond sources and on high-flux ultrafast sources are discussed.

Chapter 5 is focused on the use of high-order laser harmonics as seeding sources for free-electron lasers, joining the two techniques previously described, namely free-electron lasers and high-order laser harmonics, to obtain a coherent source with increased performance.

Chapter 6 reviews the diagnostic techniques to measure the pulse duration, that is an essential tool to assess the ultrafast time regime. The most important methods for temporal pulse characterization are discussed, with particular emphasis on attosecond pulses generated by high-order harmonics and on femtosecond soft X-ray pulses emitted by free-electron lasers.

Chapter 7 is focused on the metrology of the optical elements that are requested to handle the coherent photon beam. Particularly demanding are the requirements on optical elements for free-electron lasers, where an improvement of one order of magnitude in terms of figure error has been achieved with respect to the optics for third generation storage rings.

Chapters 8 and 9 review the main technologies used for photon handling, beam conditioning, spectral selection, and temporal shaping of ultrafast pulses, namely multilayer mirrors and reflection gratings.

Finally, as editors, we would like to thank all the authors for their appreciable contributions to the book.

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