Abstract. Systematic experimental and theoretical investigations of different types of Bragg-Fresnel gratings, both static and dynamic, are discussed. Static gratings are produced by etching in a multilayer or by evaporating gold or nickel masks on the surfaces of symmetric or asymmetric Si [111] crystals. These have been used to obtain X-ray diffraction at different energies. The properties of both sagittal and meridional diffraction gratings are discussed. Dynamic diffraction gratings are produced by propagating a surface acoustic wave along a piezoelectric crystal. Experimental data are compared with the theoretical calculations.

28.1 Introduction

Experimental and theoretical data point to a new application of nanometer radiation in diagnostics, transmission and processing of information: X-ray electronics as a branch of the general science of electromagnetic radiation control. This application is based on the development of powerful radiation sources in the nanometer range, synchrotrons, storage rings and X-ray lasers in the future, and on the methods of microelectronics technology that enable fabrication of structures of X-Ray electronic devices with submicron or nanometer element sizes, i.e. micro-photonic devices. As in other fields of engineering associated with receiving, transmission, processing and storage of information, the evolution of micro-photonics is primarily due to the development of elements and methods to control X-Ray beams, their focusing, modulation, etc.

Conventionally the elements of X-ray optics can be divided into the following groups:

- Passive elements designed for deviation or focusing of beams, analogous to optical lenses, mirrors, static beam splitters
- Dispersive elements for spectral devices, monochromators
- Active elements for beam scanning, controlled adaptive optics
- Elements for transforming information of electric, acoustic, optical signals into X-Ray beam modulation
Since the wavelength of nanometer X-Ray radiation is several orders of magnitude less than that of optical radiation, it is possible to investigate radiation that is close to fundamental absorption edges of substances (K, L, M, etc. atom electron shells). The spatial resolution of X-ray nano-photonics systems reaches 0.1 nm [1], which makes possible active elements with a capacity up to \(10^{10}\) Tbit cm\(^{-2}\), exceeding by four orders of magnitude potential of optical recording. A signal modulation frequency may amount to \(10^{10}\) Hz. X-Ray channel energy losses by diffractive beam divergence are six orders less than those of optical systems, which is promising for long-range space communication.

For the fabrication of planar submicron structures with sizes on the order of X-Ray wavelengths, the deposition and growth of thin films of different materials have enabled fabrication of diffraction optical elements in the nanometer range. Optics for X-ray beams means creating effective focusing elements with the structure of three-dimensional Fresnel zones: combined microstructure X-Ray optics [2] or Bragg-Fresnel optics [3]. Multilayer mirrors and crystals provide the basis for such elements and are the primary elements of microphotonics, since they enable transformation of electrical, optical or acoustic signals into X-ray beam modulation [4].

In this chapter we report on systematic theoretical and experimental investigations of volume (Bragg-Fresnel) gratings: (a) static, made with etching technology including a metallic structure on the surface of multilayers and crystals, and (b) dynamic, produced by surface and volume acoustic waves. A Bragg-Fresnel grating is a basic optical element for the construction of a variety of X-ray optical devices including fast X-ray modulators. Understanding its properties is essential for effectively designing high resolution, focusing dispersive X-ray optics.

### 28.2 Static Volume Grating Properties

One can consider two types of volume gratings: gratings etched into a multilayer/crystal mirror, called *etched gratings*, and those made by evaporation (sputtering) metals on the surface of a crystal or multilayer mirror, called *surface gratings*. Such gratings are the basic type of Bragg-Fresnel optics [5]. Once the properties of these elements are known, it will be possible to predict the major properties of more complicated structures, such as Bragg-Fresnel lenses and X-Ray holograms [6, 7].

This chapter describes the important points in the computer simulation and the testing of the particular case of lamellar gratings with a rectangular groove profile.

The gratings are investigated in two different experimental geometries: sagittal diffraction and meridional diffraction. The definitions of a sagittal and of a meridional grating are given in Figs. 28.1 and 28.3.