Chapter 2

Diffractive Optics

2.1 Introduction

Diffractive optics is an emerging technology with many applications. Some of the important applications include the design and fabrication of optical elements such as corrective lenses, antireflective interfaces, beam splitters, and sensors. A particularly important application is replacing conventional lenses by diffractive gratings which are designed and fabricated by interference fringes on holographic plates.

Over the past 30 years, significant technology developments have been made particularly in two areas. High precision micromachining techniques, such as direct-write electron-beam lithography and reactive-ion-etch processing, X-ray lithography and LIGA processing, and single point diamond machining, have permitted the fabrication of complex surface-relief profiles for use as high efficiency gratings and other diffractive structures. The rapid progress in the development of laser technology and nonlinear optical materials. Nonlinear optics as discussed in the National Research Council report is "so scientifically fertile and technologically promising that it is destined to be one of the most important areas of science for the next quarter century". Nonlinear optics has many important applications in laser technology, spectroscopy optical computing, communication, and optical switching.

The basic electromagnetic theory of gratings has been studied extensively since Rayleigh's time of 1907. Recent advance has been greatly accelerated due to several new approaches and numerical methods including differential methods, integral methods, analytical continuation, variational method, and others.

Diffractive optical elements, as opposed to the traditional optical lenses, have many advantages. They are light, small, and inexpensive. Often diffractive structures exhibit certain periodicity. There are two classes of grating structures: lin-

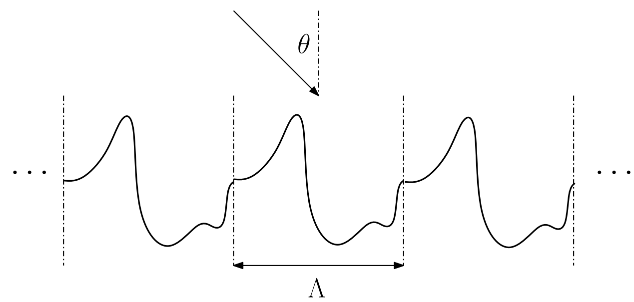

Figure 2.1: Grating geometry.

ear gratings (one-dimensional gratings) and crossed gratings (biperiodic or two-dimensional gratings).

Throughout we are mainly interested in micro diffractive optics, i.e., optical devices with very small structure features often in microns.

Traditional optical devices are constructed with structure features on length scales much larger than the length of a typical light wave, 0.5 micron. The diffraction is modeled by the scalar model, i.e., light is considered to propagate as waves of scalar amplitude. Also at the surface of the obstacle, the phase of the wave is modified in accordance with the obstacle's height profile. The amplitude of the reflected and transmitted waves is taken as the amplitude of the incident wave multiplied by the reflection or transmission coefficients for normal incidence.

The scalar approach is valid only as long as the wavelength of the incident light is small compared with characteristic transverse dimension of the structure. However, in many applications the structure dimensions are of the order of the wavelength of the incident light. In that case, the vectorial electromagnetic character of light becomes of interest. We are then speaking of the vector theory. In the vector model, polarization properties specified by the electric and magnetic fields in accordance with Maxwell's equations must be studied.

The basic problem of electromagnetic grating theory is to study: how the electromagnetic energy of the incident field is distributed over the diffractive waves and transmitted waves? or what are the relative intensities of the diffracted orders?

2.2 Grating geometry and fundamental polarizations

Throughout, a grating is always assumed to be infinitely wide. Figure 2.1 shows the grating geometry. We denote by period and incident angle by Λ and θ, respectively.