Diffractive Optics

Design, Fabrication, and Test

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Preface

This work is based on a series of short courses in diffractive optics that have been presented at Georgia Institute of Technology since 1994. The course was started as a hands-on workshop that provided basic theory on diffractive optics and then allowed participants to progress through a series of exercises on the design, fabrication, and testing of diffractive optical elements (DOEs). This type of course was difficult to present because of the intensive support required for the labs. When one of the authors (TJS) and two of his fellow graduate students got their doctorates, we lost all our good, cheap help and we had to radically change the course. The new offering relied on additional lectures and demonstrations to replace the exercises. When we finished with this revision, we knew that the material in the restructured course could serve as the basis for a text on diffractive optics.

This book is intended to provide the reader with the broad range of materials that were discussed in the course. We assume the reader is familiar with basic computational techniques and can stand the sight of an integral or two. It is not our intention to overwhelm the reader with long derivations or provide detailed methods for specific engineering calculations. Instead we introduce the concepts needed to understand the field. Then a number of simple examples, which someone can use as a check on their initial baseline calculations, are presented. While this text is not a "cookbook" for producing DOEs, it should provide readers with sufficient information to be able to assess whether the application of this technology would be beneficial to their work and give them an understanding of what would be needed to make a DOE.

In the work presented in the course we describe two methods of generating the binary masks needed to produce the diffractive optics elements. One is a costly technique that yields state-of-the-art results and is the basis for most commercial production. The second, exploited by the diffractive optics group at Georgia Tech, uses standard desktop publishing techniques and PostScript output to produce masks with modest feature sizes. The latter technique is useful for simple prototyping and for educational demonstrations. In this text we have separated the two approaches by discussing the high-resolution technique as the primary mask fabrication path. For those who want to get their feet wet, we have provided a few boxes set off from the main narrative that describe how the PostScript methods can replace the standard techniques at a savings of time and money, but with a loss of performance.

After a brief introductory chapter on the field, we provide a description of the theoretical basis for the operation of diffractive optical devices. In most cases a scalar theory description will suffice, particularly as an introduction. However, as the wavelength of the radiation approaches the size of the various features in the element, a more precise theory that includes a vector description of the electric fields in the vicinity of the surface is required. Next, a series of chapters describe the procedures used to design elements that can be incorporated into conventional

lens designs, in addition to procedures for designing periodic structures and unconventional devices. This is followed with a description of the various steps in the fabrication and test of diffractive optical elements. Finally, we provide a short survey of a number of applications in which these devices are making an impact on today's technology.

We would like to acknowledge the contributions to the course made by some of the earlier lecturers and assistants. Tom Gaylord at Georgia Tech and Joe Mait of the Army Research Laboratory provided lectures in scalar and vector theory. Willie Rockward and Menelous Poutous (along with TJS) helped put together the exercises for the workshop and conducted the labs. The authors also wish to thank their wives, who put up with a lot. They never have figured out how we could argue so fervently over those little ripples in a piece of quartz.

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