N94-17356

Applications of Advanced Diffractive Optical Elements

W. Hudson Welch, James E. Morris and Michael R. Feldman

Digital Optics Corporation
8701 Mallard Creek Rd., Suite 220
Charlotte, NC 28262
(704)549-5556, FAX:(704)548-9050

University of North Carolina at Charlotte
Optical Engineering, Applied Research Center
Charlotte, NC 28223
(704)547-3224, FAX: (704)547-3331

1. Introduction

Digital Optics Corporation is a UNC-Charlotte spin-off company, established to transfer technology developed at UNC-Charlotte for the design and manufacture Computer Generated Holograms (CGH's) and to market products based on CGH technology. DOC acquired core technologies from UNC-Charlotte including: (1) a CGH encoding process that can provide holograms with extremely high diffraction efficiency, (2) a low cost, high precision CGH manufacturing process, and (3) extensive holographic and refractive element design capabilities for design and evaluation of complex optical systems.

These technologies have been used to design and/or manufacture optical components for a variety of applications including:
(1) Generation of Spot arrays
(2) Fiber optic coupling elements
(3) Optical interconnects between VLSI chips within and between Multichip Modules
(4) Imaging systems for Head-Mounted Displays (HMDs).

2. Spot Array Generation

Several holograms for generation of spot arrays have been fabricated. These holograms were designed with the Iterative Discrete On-axis encoding method [1,2]. In Ref. 1 a hologram was designed to generate a 3x3 array of spots. While the theoretical diffraction efficiency for this hologram was 74%, due to fabrication limitations a hologram with only 64% could be fabricated.

Recently improvements have been made in the fabrication process on CGH's as well as in the design methods[2]. This has resulted in higher efficiency holograms for spot array generation. For example, the RSIDO method was used to design a hologram to produce a 32x32 spot array. The experimental diffraction efficiency was 73% with a uniformity of ±5.

3. Fiber-optic Coupling Elements

An F/1 collimating element for a laser diode was designed with the recently developed Radially Symmetric Iterative Discrete On-axis (RSIDO) encoding method. The RSIDO method is similar to the previously reported[1] IDO method. However, the RSIDO method can be used to achieve higher diffraction efficiencies for design of Holographic Optical Elements (HOE's)[3]. During the design process fabrication constraints such as minimum feature size limitations are employed.

The principal advantage of the RSIDO method is that the resulting hologram has extremely high performance for a given set of fabrication constraints. For example, for a 0.5 μm minimum feature size, the RSIDO method can be used to design an F/1 hologram with a diffraction efficiency of 85%. For the same minimum feature size, a comparable hologram designed with previous methods can only achieve a diffraction efficiency of 60%.

Several prototype designs for binary optic lenses for laser diode collimating and focussing were developed and subsequently employed for fabrication. One design had a diffraction efficiency of 87-94% over a 30 nm optical bandwidth. The spot size of this hologram varied between 1 and 1.5 mm over this bandwidth and a distance of 0.7 m from the hologram (hologram diameter was 1.5 mm). For comparison an analytically designed diffraction limited CGH would have a spot size that varied from 0.75 mm to 3.9 mm over the optical bandwidth range.

Over 1,000 fiber optic coupling elements have been fabricated to date by Digital Optics Corporation. These holograms are being tested for insertion into actual systems. Specific manufacturing, packaging and alignment issues have been addressed for each application.

4. Optical interconnects between VLSI chips within and between Multichip Modules

Several holograms have been fabricated for optical interconnection of VLSI chips within and between multichip modules. We have shown that conventional encoding methods for this application yield very low results. For example, for a CGH with a 27 degree deflection angle, the high spatial frequencies at the edges of the CGH, limit the number of phase levels that can be employed to 2. With conventional encoding methods this will limit the diffraction efficiency to 40%. Since, in order to form a link the beam must pass through 2 such holograms, the net link efficiency is limited to 16%.

The efficiency can be improved by using a lensless version of the IDO method[4], termed Fresnel IDO. Both simulation and experimental results indicate that with Fresnel IDO the link efficiency can be increase to approximately 30% for a 27 degree deflection angle.

To further increase the diffraction efficiency the RSIDO method was modified to allow for non-radially symmetric transmittance patterns. The hologram is divided into several regions. Each region is encoded separately with RSIDO and is therefore radially symmetric. This method has been termed the Segmented Radial Partitions (SRP) method. Experimental results indicate that for a 27 degree deflection angle, the link efficiency is approximately 65%.

The holograms for optical interconnects have been incorporated onto a quartz substrate. Silicon IC and GaAs laser array chips have been attached to the substrate by flip-chip technology. Micro-mirrors, also attached by flip-chip technology, are used to redirect the output of edge-emitting lasers[5, 6].

References

1. M. R. Feldman and C. C. Guest, "Iterative Encoding of High Efficiency Holograms for Generation of Spot Arrays", Optics Letters, **14**, pp. 479-481,1989.

2. J. D. Stack and M. R. Feldman, "Recursive Mean-Squared-Error Algorithm for Iterative Discrete On-axis Encoded Holograms," Appl. Opt., **31**, pp. 4839-4846 , 1992.

3. W. H. Welch, J. E. Morris and M. R. Feldman, "Iterative Discrete On-axis Encoding of radially symmetric computer generated holograms," to be published in JOSA-A , 1993.

4. M. R. Feldman and C. C. Guest, "Design of Computer Generated Holograms for a Shared Memory Network," Proc. of SPIE, **1052**, Jan. 1989.

5. M. R. Feldman, I. Turlik, G. Adema, J. E. Morris, N. Hangzo and W. H. Welch, "Holographic Optical Interconnects for VLSI Multichip Modules," in 42nd Electronic Components & Technology Conference 1992, **1**,pp. 513 - 518 (1992).

6. M. R. Feldman, "Holographic Optical Interconnects for VLSI Multichip Modules," invited paper for IEEE/SPIE International Symposium on Advances in Interconnects and Packaging, Proc. SPIE, **1390-27**, pp. 427-433, 1990.