spherical surface relief lenses. The calculation was restricted to two dimensions and was performed for the TE-polarization.

To summarize, the first-order Born approximation was proposed for the treatment of refraction, reflection, and diffraction of any field distribution at various interfaces, such as single, refracting surfaces and blazed gratings. This application of the Born approximation to refraction and reflection is based on the fundamental equivalence of Snell's Law of Refraction and the Laue-Equation. In the case of single surfaces, the evaluation of the refracted field requires no approximations and only a straightforward fast Fourier algorithm. It has also been shown that this new theoretical approach includes a visual description of the involved optical processes, *e.g.*, the diffractive and refractive effects at blazed prism arrays.[1]

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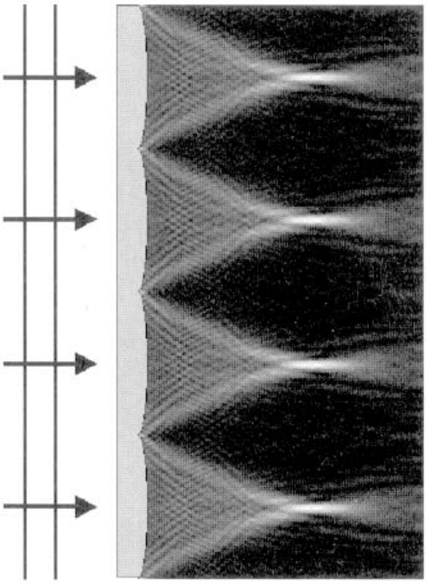

Figure 1: Intensity distribution of a plane wave, refracted at four lenses of a lens array with spherical surface relief lenses.

DIFFRACTIVE SYSTEMS

High-Efficiency Multilayer Dielectric Diffraction Gratings

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Diffraction gratings have been produced by mechanical ruling since 1883 and by interferometric or "holographic" techniques since the early 1970s.[1] Whether produced by mechanical ruling or interferometric exposure, high diffraction efficiency is achieved in conventional reflection gratings by overcoating the grooves with a metal that exhibits high reflectance over the wavelength of interest. Most metallic gratings exhibit a diffraction efficiency determined by the shape and depth of the groove profile and the reflectivity of the metal. Due to the inherent broadband reflectivity of metals, frequency selectivity is accomplished only by dispersion. Finally, the low threshold for optical damage of metallic gratings limits their use with high power lasers.[2]

In 1991, we postulated fabricating grating structures within the high damage threshold multilayer dielectric films commonly used as reflectors for high power laser systems. Such gratings should demonstrate a high optical damage threshold resulting from minimal absorption of laser light and enhanced material strength. Also, as a result of the inherent frequency selectivity of the

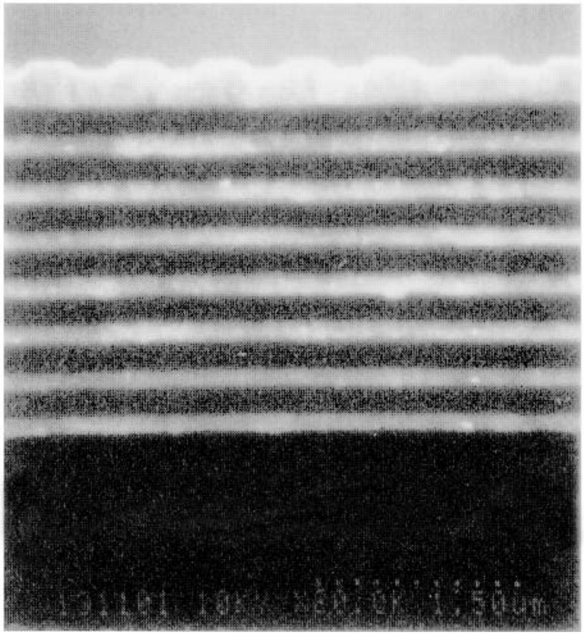

Figure 1. Scanning electron micrograph of a 1480 l/mm multilayer dielectric grating.

multilayer coating, these gratings could be fabricated with an adjustable bandwidth. High diffraction efficiency (>98%) into the first order was theoretically achievable by controlling the depth of the grooves and the design of the multilayer itself.

Due to fabrication issues, we concentrated on designs with the grating in the top layer of the multilayer. The grooves are formed in the top layer via an interferometric exposure in photoresist followed by transfer etching (see Fig. 1). In general, the transfer etching may be performed by a host of standard techniques, *e.g.*, conventional wet etching, or reactive or sputter ion etching. The choice of dielectric material, groove spacing, and groove depth will determine the appropriate technique for pattern transfer. Examination of various fabrication techniques led to a collaboration with Hughes Electrooptic Systems to develop these multilayer gratings by ion etching.

An alternate fabrication approach is to produce the grating structure on top of the multilayer by deposition or directly in the photopolymer. For low power applications, the photoresist profile can serve as the final grating or it can serve as the mask for deposition of a more damage resistant material.

To date, we have achieved a diffraction efficiency in reflection exceeding 98% at 1053 nm with gratings manufactured by both techniques.[3] The frequency selectivity of these gratings is demonstrated in the image on the cover where the grating serves as a broadband diffractor in reflection, a high efficiency yellow reflector (zero order), a high efficiency transmitter in the blue-green, and a notch filter in the transmitted diffracted order.

The damage threshold of our multilayer oxide gratings is over 5 J/cm^2 for 1 nsec pulses, nearly an order of magnitude greater than metallic gratings. For 100 fsec pulses, the damage threshold drops to 0.6 J/cm^2, compared to between 0.2 and 0.4 J/cm^2 for gold gratings used in the 800 to 1100 nm range. Further development is expected to increase the femtosecond damage threshold to over 1 J/cm^2.

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Low-Threshold Optical Switching in Non-uniform Nonlinear Distributed Feedback Structures

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Photonic band structure of a nonlinear distributed feedback (DFB) device can be altered by increasing the intensity of the input light. Local changes in refractive index of the DFB structure lead to a variety of all-optical effects[1, 2] including switching, multistability, low-velocity energy transfer, pulse generation, and pulse shaping. However, a strictly periodic nonlinear DFB (NLDFB) must be operated at prohibitively high intensity levels, requiring both high-power sources and low-absorption nonlinear materials. As an illustration, a millimeter long GaAs device would require switching intensities ~1 GW/cm^2. We have recently shown that by introducing non-uniformities in the DFB structure, either in a continuous or in a discrete fashion, the required switching intensities can be reduced by several orders of magnitude.[3, 4] A generalized non-uniform DFB design shown in Figure 1a includes tapering, chirping, and multiple phase-shifted regions. In addition, the material nonlinearity is allowed to vary along the device length, accounting for non-uniform doping levels.

In our search for an optimal non-uniform nonlinear structure, we have developed a new design method. The method, referred to as the generalized transfer matrix (GTM) method, provides an extremely fast, semi-analytic characterization of an arbitrary nonlinear DFB device. Figure 1b illustrates the use of the method in characterizing the transmission of a nonlinear $\lambda/4$-shifted structure. This structure, extensively used in linear photonic design,

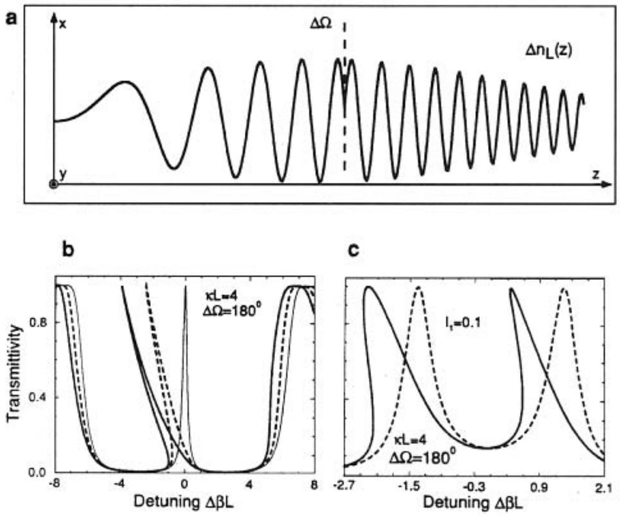

Figure 1 (right). a) Linear index profile of non-uniform DFB includes taper, chirp, and multiple phase shifts. b) Transmission characteristic of $\lambda/4$-shifted nonlinear DFB device for different input intensities: $I_{in}=0.2I_C$ (heavy solid curve), $I_{in}=0.1I_C$ (dashed curve), and $I_{in}=10^{-5}I_C$ (thin solid curve). c) Transmission characteristic of multiple phase-shifted NLDFB. Phase shifts of $\Delta\Omega=\pi$ are positioned at $z=0.35L$ and $z=0.65L$. Solid curve corresponds to $I_{in}=0.1I_C$, while dashed curve corresponds to $I_{in}=10^{-5}I_C$. Critical intensity parameter I_C is defined in Ref. 4.