Single Pulse Formation of Fiber Bragg Gratings

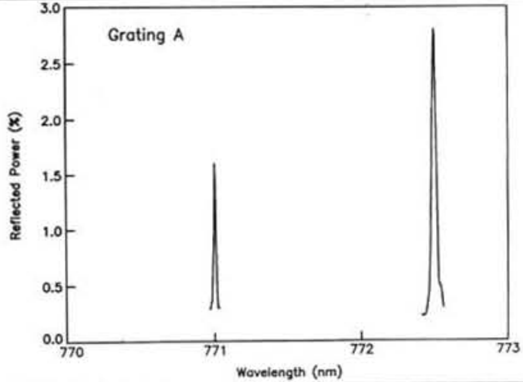
BY CHARLES G. ASKINS, TSUNG-EIN TSAI, GLEN M. WILLIAMS, MARTIN A. PUTNAM, AND E. JOSEPH FRIEBELE, OPTICAL SCIENCES DIVISION, NAVAL RESEARCH LABORATORY, WASHINGTON, D.C.

An exciting recent advance in the field of optics has been the fabrication of narrow bandwidth, reflective gratings in fibers by transverse exposure to interfering beams of ultraviolet light. Meltz and Morey[1] first reported fiber Bragg gratings (FBGs) written using multiple pulses of interfering laser beams. When broadband light is guided in the fiber, the grating reflects a narrow band (< 1Å) whose center wavelength, the Bragg wavelength λ_B, is determined by the period of the index modulation.

FBGs have the potential for numerous applications in optical systems. For example, they have been used as rocking filters and as mirrors for both semiconducting and erbium-doped fiber lasers. The fact that λ_B varies linearly with strain or temperature has been exploited for strain or temperature sensing. Because of number of gratings written with slightly different λ_B on a single fiber can be addressed by a single broadband source, they can be multiplexed into arrays of short gage length distributed strain sensors for smart structure applications. Already, Kersey *et al.*[2] reported individually addressing four FBGs strain sensors in a single fiber.

Our basic research into the origin of the photoinduced index modulation in germanium-doped silica core fibers[3,4] led us to believe that it might be possible to write FGBs with a single laser pulse, rather than the multi-pulse exposures that required holographic stability for periods of minutes. Using a single 20-nsec pulse generated from two interfering beams of a KrF laser (248 nm), we were able to obtain the first single pulse FBG, which had a reflectivity of ~2% and bandwidths as small as ~10 GHz (see figure, above right).[5] Subsequent improvements have led to gratings with reflectivities approaching 100%.

For widespread use of FBGs, especially for smart structure sensing, lower cost and increased reliability are necessary. The single pulse technique can be implemented on a fiber draw tower before the fiber is coated with its protective polymer jacket. The pristine fiber strength is maintained, and fabrication with a single 20 nsec pulse obviates the need for holographic stability. Sensor arrays with a large number of FBGs at different wavelengths can be fabricated at draw speeds of several meters per second by varying the writing angle between the two interfering laser beams. Interestingly, single pulse gratings have the added and unexpected benefit of being thermally stable, surviving temperatures of ~800 °C with only minimal loss of reflectivity, compared to multi-pulse gratings which begin annealing at ~400 °C. Thus, single pulse formation is a revolutionary technique for cost-effectively fabricating a large number of high strength, high stability FBGs.



Reflectance spectrum of a fiber Bragg grating with a linewidth of 12 GHz formed by interfering beams of a single 20 ns pulse from a KrF excimer laser. The weaker line is the second order mode reflection because the fiber is not single mode at this wavelength.

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Resonance-domain Diffractive Optics

BY JARI TURUNEN, EERO NOPONEN, AND EERO TERVONEN, HELSINKI UNIVERSITY OF TECHNOLOGY, FINLAND

In diffractive optics, we try to synthesize a scatterer (rough object) capable of transforming the incident electromagnetic wave into a diffracted wave that possesses certain properties, such as a specified distribution of electric energy density, inside a bounded region *W*. This synthesis problem is traditionally treated on the basis of the paraxial approximation that, in effect, reduces the vectorial boundary value problem into an initial value problem of scalar nature. The response of the scatterer (diffractive element) may then be predicted by geometrical optics, whereas the propagation into *W* is governed by Fresnel/Fraunhofer diffraction integrals. Efficient methods exist for the solution of the synthesis problem in this so-called paraxial domain.[1]

The paraxial approximation is valid only if the scatterer is weak, *i.e.*, the angular width Ω of *W* is small. Consequently, the characteristic transverse features in the permittivity modulation profile of the scatterer must be much larger than the wavelength λ. Using modern microlithography,