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High-Efficiency 800 nm Multi-Layer Dielectric Gratings for High Average Power Laser Systems

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Abstract: We report on the design, fabrication, and performance of a 1740 l/mm multilayer dielectric diffraction grating for use with 800 nm light. At an input angle of 8° from Littrow and a wavelength from 770 to 830 nm, >90% diffraction efficiency is achieved, with peak diffraction efficiency of >97% at 800nm. We will also comment on laser damage threshold and power-handling properties.

In recent years, the demand for compact lasers that provide ultrashort pulse durations and high average power has increased significantly. Laser systems with output average powers ranging from several tens to greater than 100 W at megahertz repetition rates have been demonstrated.[1,2] Chirped-pulse amplification (CPA) has enabled lasers to produce powerful pulses in the femtosecond and picosecond time regime. The development of rep-rated high average power short-pulse lasers is hampered by absorption of energy by traditional gold-overcoated diffraction gratings utilized in the compression stage, leading to thermally-induced wavefront errors at relatively low average powers. These limitations led to the development and successful demonstration of small aperture multilayer dielectric (MLD) gratings at Lawrence Livermore National Laboratory (LLNL) in the mid 90's.[3,4] The next generation of high average power Ti:Sapphire based lasers will benefit from multilayer dielectric (MLD) diffraction gratings for pulse compression owing to their high efficiency and low-loss characteristics. The challenge has been to demonstrate large bandwidth properties of MLD gratings for ultrashort pulses.

We will present our work on the characterization of MLD gratings for 800nm light, and study the diffraction efficiency as a function of wavelength and incident angle. We first discuss the design of the MLD coating stack and show results of diffraction efficiency calculations.

The optical design of a high-efficiency MLD grating is subject to a number of constraints related to its manufacturability[5]. We choose to design a dichroic multilayer coating that is highly reflective at the use angle and wavelength, and minimally reflective at the holographic exposure angle and wavelength. This is to minimize 'standing waves in the photoresist film, common to pattern generation in photoresist on reflective structures, that impacts linewidth control. The UV transmission criterion in particular places demands on the accuracy of the coating deposition. We could choose to deposit a simpler quarter-wave design and use a sacrificial reflective coating between the multilayer stack and the photoresist film, but this increases complexity and risk for other aspects of the grating manufacturing process, particularly at large apertures. The design must also be insensitive to grating linewidth variations that can be expected to occur over the apertures considered here.

The starting point for the design is the center emission wavelength of Ti:Sapphire of 800 nm. The grating period of 1740 l/mm was chosen to achieve high diffraction efficiency and high dispersion for minimal grating separation. The final design is the result of numerous iterations based on performance and deposition error-tolerance considerations. In general, our designs require deposition of two materials during the coating run. In the case of these demonstration gratings, the high-and low index layers were comprised of a 20-layer $(NbTa)_2O_5/SiO_2$ ion-beam sputter-deposited stack on a fused silica substrate. Figure 1 shows a plot of the calculated diffraction efficiency of an optimized design as a function of wavelength and input angle.

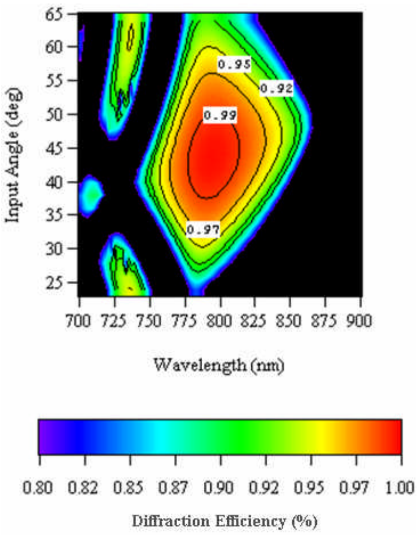

Fig. 1. Calculated diffraction efficiency as a function of grating depth and duty cycle.

Figures 2 shows line out plots of calculated diffraction efficiency as function of input wavelength and angle for these demonstration gratings with a grating profile height of 230 nm , and duty cycle of 0.30.

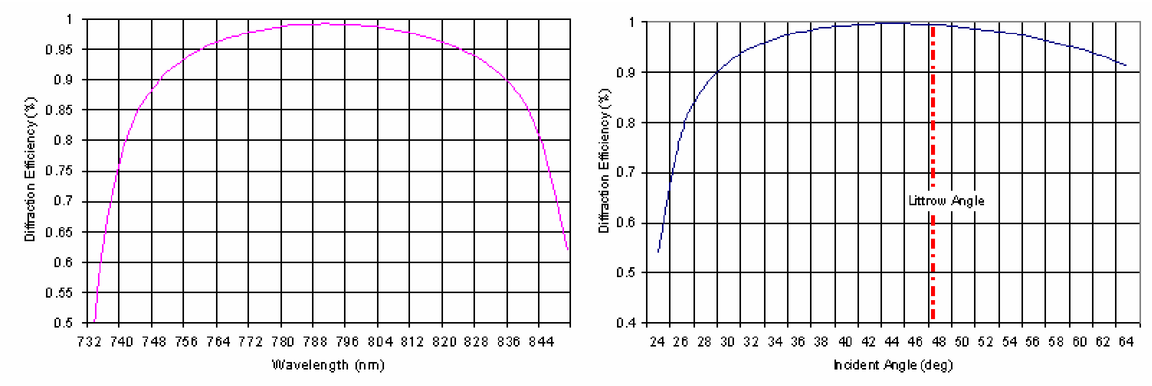

Fig. 2. Calculated diffraction efficiency as a function of wavelength and input angle for a grating depth of 230nm, duty cycle of 0.30, and 800 nm light.

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