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Laser Science & Technology
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Fabrication Processes of Beam Sampling Gratings for NIF Validated

We have successfully demonstrated fabrication processes for producing beam sampling gratings (BSGs), meeting all the National Ignition Facility (NIF) specifications. Initial laser damage and conditioning experiments indicate that the BSG fabrication processes and structure of the gratings do not affect the optical damage threshold. To date, a total of 16 BSGs have been successfully fabricated and delivered to the NIF precision diagnostic and optical sciences laser systems.

The BSG, which is a shallow focusing grating etched into a fused silica substrate, has been developed to divert a small amount of the laser light into a diagnostic package containing the 351-nm energy calorimeter and power sensor. The sampled fraction will be used to precisely determine the laser beam energy on target and to achieve power balance on all 192 NIF beams when NIF is fully commissioned. The BSG is located downstream of all the NIF optical components with the exception of the debris shield. This location is selected to minimize laser damage threats to downstream optics due to the beam modulations caused by the interference among various diffracted orders. Both main and sampled beams go through the same optics, thus ensuring a true measurement of energy to target. The BSG is specified to have 0.1–0.3% diffraction efficiency (defined as a fraction of incident light diffracted into the first order) with less than 5% rms diffraction uniformity (standard deviation/mean, across the effective aperture) in order to achieve laser power and energy balance requirements.

To fabricate the BSG, the NIF diffractive optics plate (DOP) is coated with photoresist. The DOP plates are 1-cm-thick, 43-cm × 43-cm fused silica substrates. A two-beam laser interference lithography exposure system is used to write the BSG pattern into the photoresist. In this exposure setup, a diverging F/11 beam is made to interfere with a diverging F/1.7 beam. The exposure geometry is an exact analog of the playback geometry in the NIF final optics assembly, and the exposure wavelength, 351-nm AR-ion line, is sufficiently close to the NIF 3ω wavelength to provide a diffraction-limited focal spot for the sample beam. Figure 1 is a schematic of the BSG pattern. The grating period ranges from 1 to 3 μm. After exposure, the BSG pattern in photoresist is transferred into the fused silica substrate by exposing the substrate to buffered oxide etch solution. Following the etch step, the photoresist is finally removed from the substrate, leaving a very shallow grating (~20 nm) in the fused silica substrate with ~0.2% diffraction efficiency. A novel wet processing machine has been designed and built to provide uniform photoresist coat and precision etch across the part. The ability to achieve better than 10% peak-to-valley intensity variation across the 60-cm-diameter exposure beams is also crucial to obtaining diffraction uniformity across the substrate.

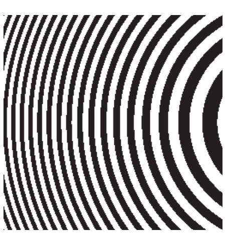

Figure 1. Schematic of the beam sampling grating groove profile.

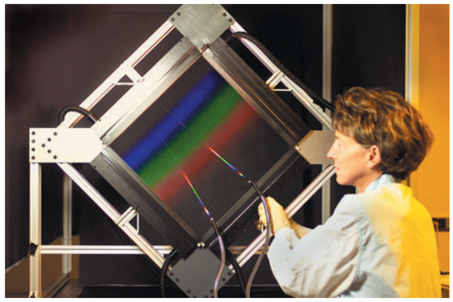

Figure 2. A completed beam sampling grating.

Figure 2 shows a fabricated BSG. After the grating has been imprinted, a scanning photometer is used to simultaneously measure the transmitted and diffracted energy. These measurements are used to verify the spatial uniformity of the diffraction grating and to accurately determine the sampling efficiency. Figure 3 illustrates the measurement result for a BSG with 0.27% diffraction efficiency and 3.3% diffraction uniformity.

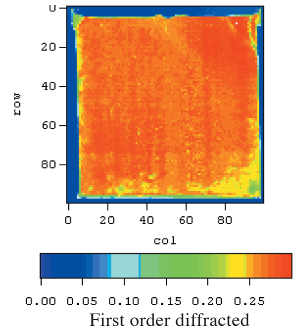

Figure 3. Photometer scan of a fabricated beam sampling grating shows the part to have 0.27% diffraction efficiency with 3.3% rms diffraction uniformity.

The BSG sees the full power of the NIF laser beam, given its location on the system. Thus, laser damage is a critical issue for this optic. Laser damage and conditioning tests were performed on bare fused silica substrates and patterned BSG substrates to validate the BSG fabrication process and to ensure that the final optic satisfies the NIF damage fluence requirements. In addition, laser conditioning and mitigation processes are being developed for BSGs to ensure that the optics will meet the NIF lifetime goals without compromising BSG performance. The most recent 3ω laser conditioning and mitigations experiment showed that the BSG imprinting processes do not induce laser damage on the BSG surface. Photometer data also showed that the laser conditioning and mitigations process do not alter the grating performance. Figure 4 shows the diffraction efficiency map of a part prior to and after the laser conditioning and mitigating process. The diffraction efficiencies across the part remain unchanged.

—J. Yu, L. Summers, and J. Britten

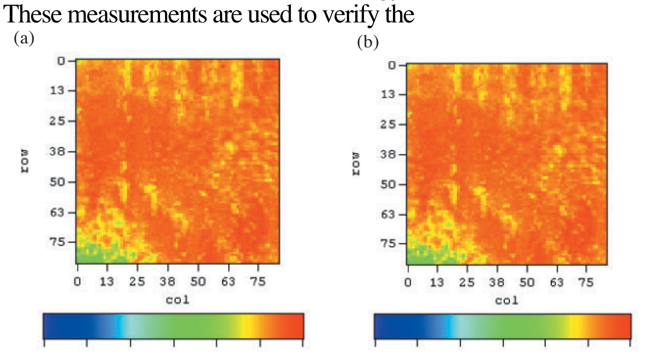

Figure 4. Photometer scans of a beam sampling grating prior to and after the conditioning and mitigation step show that the first order diffraction efficiency is not affected by the laser conditioning and mitigation process.

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