Temporal Coherence Effects on a Low-Cost Interference Lithography System

Hasan Korre[1], Corey P. Fucetola[1], Jeremy A. Johnson[2], Karl K. Berggren[1]
[1]*Department of Electrical Engineering and Computer Science,*
[2]*Department of Chemistry,*
Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Interference lithography is an ideal method for the rapid production of periodic nanostructures. The Lloyd's mirror interference lithography system utilizes a simple and rigid setup in order to produce one- and two-dimensional patterns. Previously we have demonstrated that newly available low-cost 405 nm GaN diode-laser modules could be used in a Lloyd's mirror setup, which included only simple and essential elements to produce periodic diffractive nanostructures.[1]

Our previous experiments resulted in diffraction gratings that displayed beating of the fringe contrast. Although we then postulated temporal coherence as the cause, there were other effects, which were not eliminated from contention such as spatial coherence and fluctuating laser current and power. Here, we explore methods to increase the quality of the diffraction gratings and eliminate these factors. We used commercially available blue laser diodes in combination with a laser driver to control injection current and output power. We also spatially filtered the light to improve its spatial coherence. However, our resulting grating continued to display aberrations, suggesting that temporal coherence of the laser light is the limiting factor for our Lloyd's mirror.

It had previously been shown that optical feedback from an etalon can narrow the spectrum of semiconductor lasers.[2,3] We chose this method to show that it is possible to simply and cheaply modify the laser spectrum in order to eliminate the artifacts on our substrates. Figure 1 shows our original Lloyd's mirror setup and our modified setup including reflectance feedback from an etalon and a spatial filter. Using a 0.5-mm-thick fused silica etalon we were able to narrow the full-width at half-maximum of the laser spectrum from 2.01 nm to 0.03 nm.

Figure 2 presents the measured spectrum of a blue laser diode with and without etalon feedback and the calculated fringe visibility. By obtaining a single-mode spectrum, the multiple peaks in the fringe visibility have been eliminated. These results suggest that using optical feedback from an etalon we can increase the area of diffraction nanostructures using low-cost blue laser diodes.

[1] C.P. Fucetola, H. Korre, K.K. Berggren, J. Vac. Sci. Technol. B **27** (6), 2958 (2009).
[2] H. Hemmati, Appl. Phys. Lett. **51** (4), 224 (1987).
[3] M.V. Romalis, Appl. Phys. Lett. **77** (8), 1080 (2000).

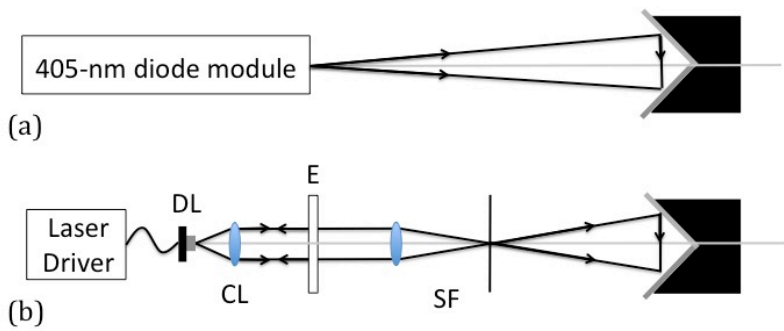

Figure 1. Configurations of Lloyd's Mirror: (a) Previous setup including prepackaged laser diode module and mirror/substrate chuck. (b) New setup used to identify causes of substrate artifacts. Includes laser driver, diode laser (DL), collimating lens (CL), etalon (E), and spatial filter (SF), and mirror/substrate chuck.

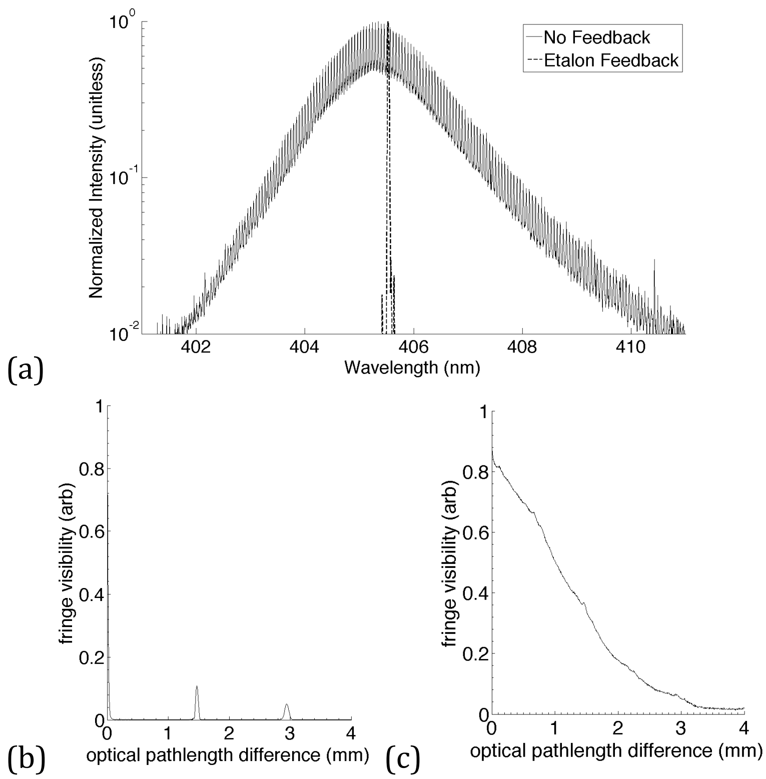

Figure 2. Measured laser spectrum and calculated fringe visibility. (a) Laser spectrum without etalon feedback (solid) and etalon feedback (dotted). (b) Calculated fringe visibility from spectrum without feedback. Fringe visibility drops abruptly and shows a periodic recurrence. (c) Fringe visibility resulting from spectrum with optical feedback. Plot is much wider than in (b) and is monotonically decreasing.