Critical Optical Components for High-Power Lasers

Priscilla Vazquez¹,
Mentors: Aaron Davenport¹, Alex Meadows¹, Emmett Randle², C.S. Menoni¹
¹Electrical and Computer Engineering, CSU, Fort Collins, Colorado
²Department of Physics, CSU, Fort Collins, Colorado

Abstract

Diffraction gratings were designed for a Yb:YAG Chirped Pulse Amplification laser system. These optical components are critical to improving the output intensity of short-pulse, high-power lasers. The mirror stack and groove profile of the diffraction grating was optimized to increase the reflected efficiency of the -1st order and the laser damage threshold. Thin film multilayers were deposited via Ion Beam Sputtering. Extensive optical characterization of the multi-layer dielectric films was performed using spectrophotometry, ellipsometry, and photothermal common-path interferometry.

Diffraction Gratings

- Optical components used to stretch the laser pulse temporally before amplification and subsequently, compress it.
- Consist of a high reflectance mirror with a periodic structure engraved on top.
- Light impinging on periodic surface will diffract at specific angles, known as orders.
- Diffraction efficiencies depend on the dielectric permittivity, groove shape, and incident field polarization.
- Underlying high reflectance mirror (HfO₂/SiO₂)₁⁵ quarter wave stacks designed using OptiLayer® software.
- The refractive indexes were obtained from experimental ellipsometry measurements from materials grown using Ion Beam Sputtering at CSU.
- Diffraction gratings designed using Virtualab® software, importing layer thicknesses, optimizing for etch depth and duty cycle.

Spector® Ion Beam Sputter Deposition (IBS)

- Environmentally stable, optically dense thin-films with low absorption and scattering losses
- Process parameters tailored to produce desired film properties:
  - voltage and current of the sources
  - O₂ partial pressure
  - deposition time for materials from individual targets.

Characterization of the High Reflectance Mirrors

Transmission

OptiLayer® Simulation

(HfO₂/SiO₂)₁⁶ quarter wave stacks with 2/1 top SiO₂ layer for increased Laser Damage Threshold

Photothermal Common-Path Interferometry

Onset Laser Damage Threshold (J/cm²) @1030 nm

Summary

- Diffraction gratings for a Yb:YAG CPA laser system operating at 1030 nm were designed to maximize diffraction efficiency of the -1st order to 99.929% and minimize process variations in fabrication.
- High reflectance mirrors were deposited using Ion Beam Sputtering. The conditions were selected to minimize absorption in the structure.

Acknowledgments

Thank you to Professor Menoni, my team members, H. Wang, and M. Fazio for their help and guidance throughout my research.