Mode-selective toroidal mirrors for unstable resonator planar waveguide and thin slab solid-state lasers
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Summary
We have developed two new fabrication methods for mode-selective highly-curved toroidal mirror lasers based on laser micromachining of cylindrical substrates that already have the small lateral curvature (R₁ > 1m) provided by conventional polishing. These mirrors are produced by a two-step CO₂ laser machining process with high resolution ablative laser cutting [1] and then laser polishing [2], or by vaporization of silica in the CO₂ laser smoothing process at higher than usual power. We have produced mirrors with R₂ ≈ 32mm and 16mm radius of curvature in the transverse direction and 14mm lateral length for use with the 200µm core height Nd:YAG [3] and a 150µm core Yb:YAG planar waveguide laser respectively. Proof of principle of fabricated mirrors was confirmed in the mode-selective configuration (Case III) for the Yb:YAG planar waveguide laser.

Objectives
- The use of mode-selective silt-shaped toroidal mirrors for the unstable resonator configuration in planar waveguide or thin slab solid-state lasers.
- Fabrication of highly-curved (R₁/R₂ > 10) toroidal mirrors using a CO₂ laser for the mode-selective waveguide resonator configuration (Case III).
- Investigation of effectiveness of the fabricated mirrors with the Yb:YAG/sapphire planar waveguide laser.

CO₂ laser fabrication of highly curved toroidal mirrors

Technique 1: A two-step CO₂ laser machining process with high-resolution ablative laser cutting (made by PowerPhotonic Ltd.) and then laser polishing.

- Silica cylindrical lens with 240mm lateral RoC used as a substrate.
- Desired shape and transverse curvature of a mirror obtained by precise ablative laser cutting.
- Roughness of 300µm wide laser-cut mirror removed by localized laser polishing.
- Lateral RoC is decreased by surface stress produced by polishing.

Features of the ablatively-cut toroidal mirrors:
- Toroidal mirrors have 14mm long and 300µm wide optical aperture.
- Transverse radius of curvature, R₁ = 50, 32 and 36mm.
- Mirror radius in the lateral direction is well-defined, R₂ = 216mm.
- The surrounding rims of reverse curvature and side-grooves designed to dispense higher order laser modes.
- Some low spatial frequency features in the lateral direction that may introduce beam distortion.
- The toroidal mirror with R₂ ≈ 32mm matches Case III coupling for 200µm core height Nd:YAG planar waveguide laser [3].
- Mirror suitable for the unstable resonator configuration.

Technique 2: Vaporization of fused silica in the laser polishing process at higher than usual laser power

- 2mm thick planar fused silica used as a substrate.
- 300µm wide trench made by CW raster scan area laser polishing, but at higher than usual laser power.
- Depth of desired profile is controlled by laser power used.

Features of the cylinder mirrors made by vaporization:
- Small stress RoC in lateral direction, R₂ > 2m.
- RoC in transverse direction R₁ from 10 to 45mm.
- The mode-selective effect is less pronounced than in the laser-cut mirror but still useful.
- Mirror with R₂ = 16mm matches Case III coupling for 150µm core height Yb:YAG planar waveguide laser.

Testing of fabricated mirrors with Yb:YAG/Sapphire planar waveguide laser

Beam images for the ablatively-cut toroidal mirror (R₂ = 20mm, R₁ = 216mm)

- Transverse curvature slightly smaller than required for Case III configuration.
- 40W output power at 35A diode current.
- Mode selectivity in the transverse direction.
- Appropriate for unstable resonators in planar waveguide or thin slab solid-state lasers.

Beam images for the cylinder mirrors made by vaporization with different R₂

- Mirror mis-matched Case III coupling.
- 46W output at 35A.
- Visible high order modes.
- Mirror matches Case III.
- 56W output at 35A.
- Suppressed high order modes in the transverse direction.
- Transverse RoC larger than required.
- 54W output at 35A.
- High order modes appeared.

References