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Ion-Exchanged Nd:Glass Tapered Waveguide Laser

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Abstract

We report an efficient (>40% slope) and low threshold (~10mW) ion-exchanged Nd:Glass tapered waveguide laser with near-diffraction-limited output. This structure is compatible with high-power, broad-stripe, diode pumping.

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Summary

The concept of using tapered waveguides to couple from planar to channel waveguides is well established and various designs for adiabatic expansion of the lowest-order spatial mode from a channel to a planar waveguide region have been described. Tapered waveguides have also been employed in diode-laser systems in an attempt to produce high-power, low-divergence, diffraction-limited outputs [1], although these are often used as power amplifiers to avoid facet damage caused by having high average powers in the small channel section. Indeed, these amplifiers are often simply a flared gain region rather than an actual tapered waveguide. Here we describe the laser operation of tapered waveguides based on ion-exchanged Nd:BK7 glass. A tapered waveguide is of interest as it could allow end-pumping with broad-stripe diodes and, for materials with a strong pump absorption, side-pumping with high power diode bars. If the taper is combined with a single-mode channel and adiabatic expansion of the lowest-order spatial mode can be achieved, then there is good potential for simple and compact, high-power sources with good output beam quality.

Our initial investigations have used K^+-Na^+ exchange in Nd:BK7 glass as both the laser host and the fabrication technique are well established [2]. The commercially available BK7 glass was doped with 1.5wt.% Nd_2O_3 and several 30 by 20 by 2mm substrates were cut and one large face polished in preparation for the exchange process. A 250nm-thick aluminium film was deposited on the polished surface and standard photolithographic techniques were used to create openings in the film corresponding to both simple 2.5μm-wide channels and 2.5μm-wide channels with a 12.5mm-long linear taper section opening out to a 175μm-wide region. Ion-exchanged waveguides were then formed through these openings by immersing the substrates in molten potassium nitrate at 395°C for 12 hours. The substrates were then end-polished perpendicular to the channels leaving, 24mm-long waveguides. The laser resonator was formed by directly butting thin light-weight mirrors to the polished end-faces and the channels were pumped by a Ti:sapphire laser tuned to the ~810nm absorption band. Lasing at 1.06μm was achieved with threshold powers (incident on the launch objective) as low as 5mW for the channels and 8mW for the tapers. Using an ~80% reflectivity output coupler, powers of 148mW and 147mW were obtained from the tapered and the channel waveguides respectively, for 600mW of incident pump power. This corresponded to a slope efficiency with respect to absorbed power of 42% in both cases. The very similar laser performance indicates similar propagation losses in the channel and the taper. This in turn confirms the near-adiabatic nature of the taper, as significant conversion to higher-order modes would lead to high internal losses as the beam is re-launched into the channel section. The output beam from the broad planar end of the taper was measured to be ~1.5 times diffraction limited in both planes, while the output from the normal channel guide was ~1.0 and ~1.2 times diffraction limited in the horizontal and vertical planes respectively. The prospects for compact, diode-pumped lasers of high beam quality based on adiabatic tapered waveguides will be discussed.

[1] T.Tamanuki, T.Sasaki, and M.Kitamura, "*High power and narrow lateral far-field divergence 1.5 μm eye-safe pulsed laser diodes with flared waveguide*," Opt. and Quantum Electron., **28**, 513 (1996).

[2] E.K.Mwarania, J.Wang, J.Lane, and J.S.Wilkinson, "*Neodymium-doped ion-exchanged waveguide lasers in BK-7 glass*," J. Lightwave Technol., **11**, 1550 (1993).