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# Monomode glass waveguide lasers pumped by a single-stripe laser diode

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## Abstract

Single-transverse-mode waveguide lasers, fabricated by two-step thermal ion-exchange in neodymium-doped BK-7 glass, were pumped with a single-stripe laser diode.

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Ion-exchange in neodymium-doped glasses has been used to fabricate waveguides which were optically pumped to realise lasers[1-3]. The application of these lasers as light sources will enhance the functionality of integrated optic systems in glass, allowing integration of active and passive devices. To obtain practical light sources, the neodymium-doped waveguides must be laser diode pumped to provide compact laser systems. We report on monomode waveguide lasers pumped by a single-stripe laser diode fabricated in neodymium-doped BK-7 glass.

Buried channel waveguides were fabricated by a two-step thermal $K^+$-$Na^+$ ion-exchange in BK-7 glass doped with 1.5 wt% neodymium oxide[1]. The mask used in the first step had stripe openings varying in dimensions from 1.5$\mu$m to 7$\mu$m in steps of 0.2$\mu$m and were 100$\mu$m apart. The waveguides were 25mm long and their numerical aperture was approximately 0.13.

The insertion loss spectrum of the waveguides including monomode fibre input and output coupling loss is shown in Fig. 1. The maximum loss was obtained at a wavelength of 812nm and the contribution to this loss by the absorption of neodymium ions was estimated as 5.2dB/cm. The fluorescence lifetime in the waveguides was 380$\mu$s and the peak emission wavelength was 1059nm.

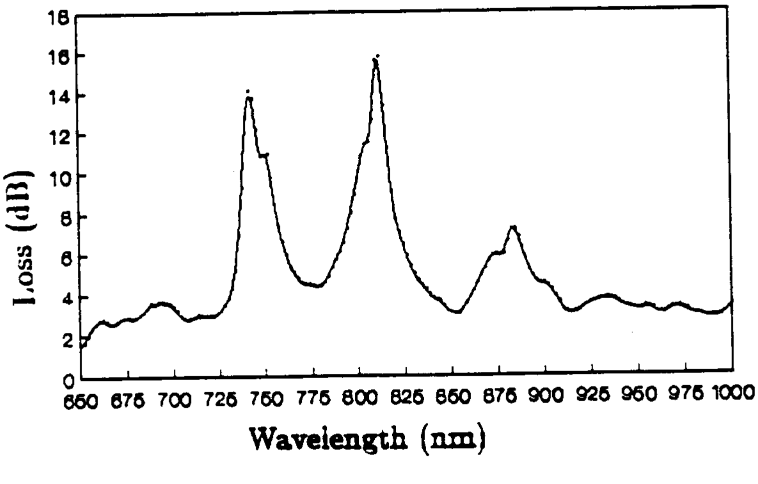



**Fig. 1.** Loss spectrum

Laser cavities were made by epoxying multilayer dielectric mirrors on polished ends of the waveguides. The transmission of the mirrors at 810nm was 90% and their reflectivities at 1060nm were 99.5% for the input and 82% for the output mirror respectively. Light from a laser diode operating at 810nm (polarised parallel to the substrate surface) was end-fire coupled to the waveguides using lenses. Observation of the near-field pattern by a vidicon showed that all the waveguides were single mode at both pump and lasing wavelengths in the depth (into substrate) and width dimensions. However, they were all elliptical with the depth as the smaller dimension. The ellipticity increased with the mask opening through which the individual waveguides were fabricated.

The waveguide laser thresholds were measured using the launch optics described above and are shown in Fig. 2 as a function of the mask opening through which the individual waveguides were made. The threshold powers are specified in terms of the laser diode output power, which is a significant measure of overall performance for practical applications. The laser with the lowest threshold was that made through a 3.7$\mu$m mask opening, because its field pattern best matched that of the laser diode, which increased the power coupled into the waveguide.

Fig. 3 shows the lasing characteristic of the lowest threshold laser. The laser had a threshold of 20mW and an overall slope efficiency of 5% with respect to the laser diode output power. When pumping with orthogonally polarised light the threshold was 2mW higher. The state of polarisation of the laser light was found to be the same as that of the pump light; the power in the orthogonal polarisation was more than 17dB lower than in the main polarisation, being the measurement limit of our experiment.

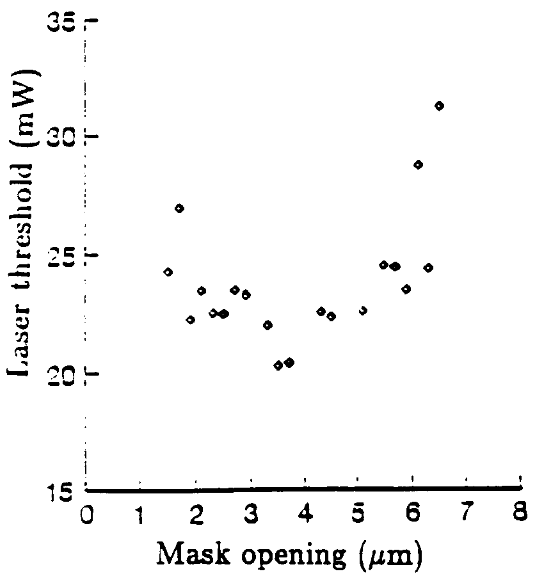



Fig. 2. Lasing thresholds

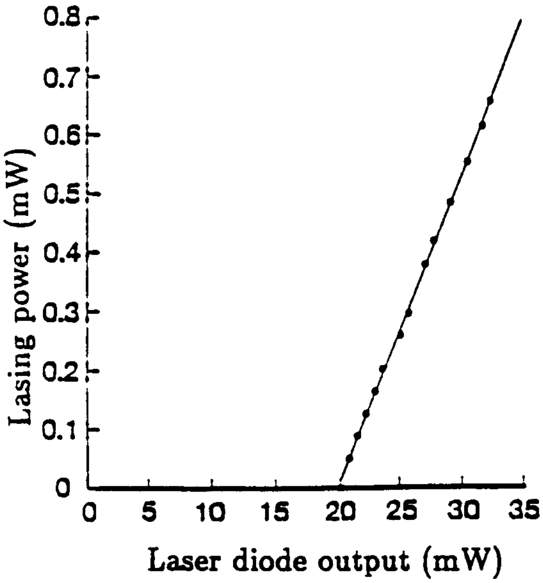
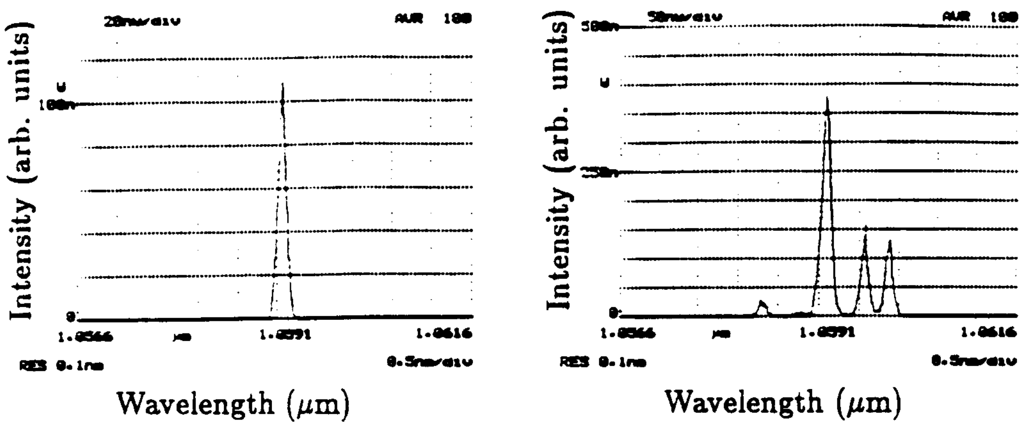



Fig. 3. Lasing characteristics

Fig. 4 shows the lasing spectrum of a waveguide laser. Near threshold, the spectrum has a single peak at a wavelength of 1059nm as shown in Fig. 4(i). As the pumping level is increased other peaks appear in the spectrum as shown in Fig. 4(ii).




(i) (ii)

Fig. 4. Lasing spectrum

In conclusion, the characteristics of laser diode pumped waveguide lasers in neodymium-doped BK-7 glass have been presented. By matching the strongly elliptical mode of the laser diode to that of the waveguide, it is possible to reduce the pump power required from the laser diode for the waveguide laser to reach threshold. These lasers are expected to find wide application as light sources for integrated optical systems.

## References

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