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Single-mode UV-written buried channel waveguide lasers in direct-bonded neodymium-doped SGBN

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We present the first demonstration of single-mode buried channel waveguide lasers in Nd:SGBN by combined direct bonding and direct UV writing. Characterised devices exhibit milliwatt-order lasing thresholds and propagation losses of < 0.3 dB cm^{-1}.

Direct UV writing provides an attractive route towards low-cost integrated optical components in silica-on-silicon wafers. Extending these results towards bulk glass types offers more versatile host compositions, improved spectroscopy, and an extended range of integrated devices and structures. In this paper we present the first demonstration of single-mode buried channel waveguide lasers in neodymium-doped SGBN glass [1] by a combination of direct bonding [2] and direct UV writing [3] techniques. Based on intersubstrate ion-exchange between specifically designed glass substrate materials [4], we have used direct bonding to provide a region of atomic contact between Nd:SGBN and a potassium-rich borosilicate cladding substrate, between which K^+-Na^+ ion-exchange can occur. By taking this approach we have achieved a low-loss buried planar waveguide layer in the Nd:SGBN glass, which retains the photosensitive characteristics of the bulk material and into which single-mode channel waveguide structures can be directly written using a focussed UV beam (Fig.1).

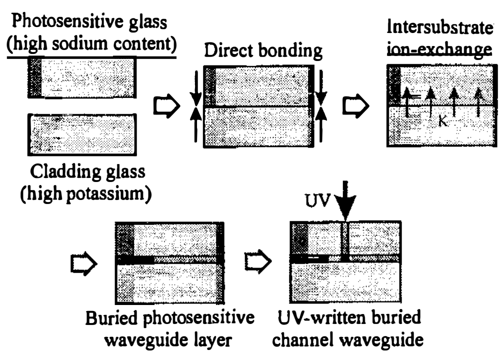

Fig.1. Key processing stages in the design and fabrication of a buried channel laser waveguide by a combination of direct bonding and direct UV writing techniques.

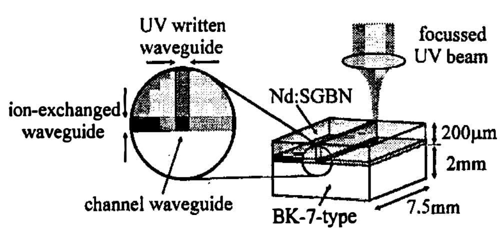

Fig.2. Typical dimensions of the buried channel waveguide lasers used for device characterisation. In each structure a separation of 50 μm was allowed between UV-written waveguides, facilitating multiple devices in every sample.

For this initial demonstration, a Nd:SGBN substrate containing SiO_2 (60 wt.%), GeO_2 (10 wt.%), B_2O_3 (10 wt.%), Na_2O (19 wt.%), and Nd_2O_3 (1 wt.%), was prepared and direct-bonded to a potassium-rich glass of similar composition to BK-7. The potassium-rich BK-7-type substrate was prepared with an additional ~ 4 wt.% of K_2O, for which an equal amount of Na_2O was removed. Such offset in glass composition allowed the realization of a buried waveguide layer in the Nd:SGBN substrate by an internal ion-exchange process during high temperature annealing of the direct-bonded interface [4]. The direct bonded structure was then cut and polished to dimensions appropriate for direct UV writing and subsequent laser action (Fig.2).

Direct UV writing into the buried waveguide layer was performed using a frequency doubled argon laser at 244 nm. Channel confinement was created in the buried waveguide layer by translating the sample under the focussed UV beam, inducing a localised positive refractive index change in the photosensitive material [1,3]. Optimisation of the channel waveguide geometry was performed by adjusting the writing intensity and translation speed of the focussed UV beam, and writing conditions of 200 mW input power at a translation speed of 10 mm min^{-1} were determined to give single-mode channel waveguide confinement in the buried ion-exchanged layer. Under these conditions over 50 single-mode channel waveguides were written into several similar devices, proving that this is a robust technology.

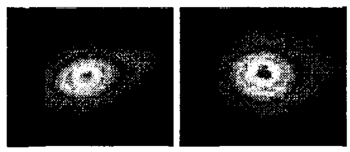

Fig.3. Typical mode profiles for (a) the laser and (b) the pump transmissions of a buried channel waveguide.

Characterization of a 7.5-mm-long buried channel laser waveguide device was performed using a Ti:Sapphire laser operating at 808 nm. The resultant 1059 nm laser output exhibited milliwatt-order laser thresholds, single-mode operation (Fig.3), propagation losses of < 0.3 dB cm^{-1}, and a maximum output power of 2 mW for 32 mW of absorbed pump power. These initial results demonstrate that optimisation of glass composition and direct UV writing parameters could lead to efficient low-loss buried waveguide devices in versatile bulk multicomponent oxide glasses for use with integrated optics.

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