Diode Pumped, Garnet Channel Waveguide Lasers

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Abstract

Ion implantation, which can create waveguides in a wide range of materials, has been used to produce very low threshold channel waveguide lasers.

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Summary

Ion implantation is a technique which can be used to form waveguides in a wide range of materials - including crystals of the garnet family for which no alternative techniques exist -by bombarding the material surface with high energy ions and altering the refractive index [1]. We report the use of this method to form channel waveguides in two Nd^{3+} doped materials; Nd:YAG and Nd:GGG both of which have operated as ion implanted planar waveguide lasers [2,3]. The additional confinement in the plane is achieved without any significant increase in propagation losses, which are comparable in the planar and channel guides. In the Nd:YAG system submilliwatt thresholds were observed.

The technique used here for guide formation was bombardment with He ions of energies about 3MeV. In some substances this creates a region of increased refractive index at the surface of the material which can be used as a waveguide. The size of this index increase is 0.2% for Nd:YAG and 0.06% for Nd:GGG. To form channel waveguides the surface of the material has to be masked to prevent the He ions penetrating in regions other than those where guides are to be formed. The first step in doing this was to evaporate a 120nm layer of Ni/Cr on to the crystal surface on top of which a 3μm layer of photoresist was spun and patterned to leave stripes. A 3μm layer of gold was then electroplated onto the exposed Ni/Cr and the remaining photoresist washed off to leave gaps ranging from 4-20μm in width. These were then made into channels by He ion bombardment the details of which are given below.

Material	Ion Energies (MeV)	Dose (ions/cm^2)
Nd:YAG	Multiple energies up to 2.8	$6x10^{16}$
Nd:GGG	2.9	$2x10^{16}$

The channels created had typical losses of 1.5dB/cm for YAG and 1dB/cm for GGG. In each case a 2.5mm crystal length was pumped using a 810nm, 100mW single stripe laser diode. This was made into a cavity by attaching thin dielectric mirrors to the crystal ends using a small drop of fluorinated liquid, chosen because of its high thermal conductivity. Although this produces a more lossy cavity than if the mirrors were directly coated to the crystal end faces it has the advantage that the mirrors can be easily changed. Microscope objectives were used to launch light into the channels and to focus the output from them. Best laser performance was given by the 20μm wide channels in Nd:YAG and the 16μm channels in Nd:GGG. The actual values for absorbed power threshold and slope efficiencies are given in the following table.

	HR mirrors	16% output coupler	
	threshold	threshold	slope efficiency
Nd:YAG	500μW	1.6mW	29%
Nd:GGG	1.9mW	6.6mW	27%

Another feature of the Nd:GGG channels was that they lased in an extended cavity configuration where the output from one end of the channels was collimated onto an external mirror using a microscope objective. This allows for optical elements (such as a tuning device) to be placed in the cavity. Using this arrangement the absorbed power threshold was 8mW for one butted and one external HR mirror.

Ion implantation which has proved to be a versatile method for producing planar waveguide lasers has now been shown successfully to produce channel guides. Both host materials are important Cr hosts and the efficiency of the channel geometry should enable low threshold vibronic lasers to be constructed.

References

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