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A 1317NM NEODYMIUM DOPED FLUORIDE GLASS WAVEGUIDE LASER

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Abstract: Laser emission at 1317nm has been observed for the first time in a neodymium doped fluoroaluminate glass waveguide fabricated by a combination of hot dip spin coating and direct UV writing.

Introduction

The advent of Allwave™[1] optical fibre and DWDM has stimulated interest in sources and amplifiers operating at wavelengths outside the telecommunications window centred at 1.55μm. Neodymium doped glasses have the potential to provide gain around 1.3 μm in integrated devices thereby producing multiple channel sources and amplifiers on a single chip. As a key step to such devices, we have successfully demonstrated the first integrated neodymium doped waveguide laser operating at a peak wavelength of 1317nm in a glass host and report the lowest loss channel waveguide fabricated from a fluoride glass.

Although both neodymium doped fibre lasers /1/ and waveguide lasers /2/ have been reported in the literature, they have been unable to provide peak gain in the 1.3μm window due to excited state absorption. Praseodymium doped glasses can lase at shorter wavelengths /3/ but the small absorption cross-section at the pump wavelength around 1.02μm makes them unsuitable for integrated devices. Some examples of laser wavelengths reported for neodymium doped devices are given in Table 1. Of the devices shown, only two are integrated devices and operate further away from the centre of the 1.3 μm window.

Table 1: Comparison of peak laser emission from neodymium doped fibre and planar waveguides

Glass Host	Peak laser emission wavelength (nm)
Fluoroaluminate (this paper)	1317 (planar)
LHG-5 phosphate /4/	1325 (planar)
Fluoride /1/	1340 (fibre)
ZBLANP /5/	1354 (fibre)
Phosphate /2/	1358 (planar)

In order to achieve laser action at 1317nm, low loss channel waveguides were fabricated from a neodymium doped fluoroaluminate glass composition which had been developed to minimise excited state absorption /6/ and provide maximum gain at the peak of the emission spectrum. Hot dip spin coating was used to produce thin film waveguides and photothermal expansion to provide lateral confinement.

Fabrication

The hot dip spin coating process /7/ was developed for the fabrication of fluoride glass thin film waveguides for which traditional production methods, such as ion exchange /8/ and physical vapour deposition /9/, could not reduce the propagation losses to below 1dB/cm. The technique has the added advantage of reproducing the bulk composition and hence spectroscopy of the original glass.

A layer of core glass was deposited on a 32mm diameter, 2mm thick polished substrate using a substrate temperature of 430°C, a melt temperature of 1000°C and a spin speed of 2500 rpm. This core film was overclad with a cladding glass layer at the same substrate temperature but with an elevated melt temperature of 1050°C. For optimum uniformity, the overclad layer was spin coated at 2000rpm. The resulting waveguide structure consisted of a 10 μm thick core glass waveguide with a 25 μm thick overcladding layer. The core glass composition used had a refractive index (n_D) of 1.432 whilst the cladding glass used for the substrate and overclad layer had a refractive index of 1.417.

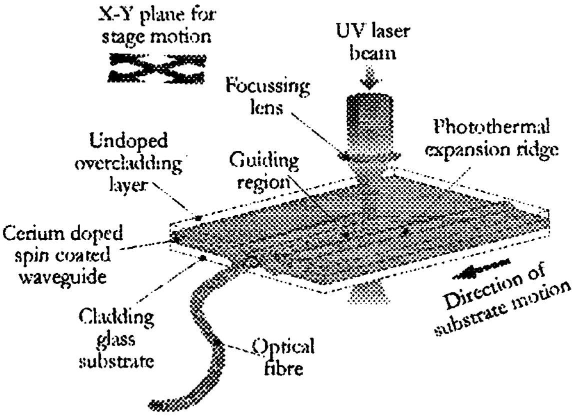

Figure 1: Fabrication of channel waveguides by direct UV writing using photothermal expansion

Lateral confinement in the planar waveguides was achieved by photothermal expansion /10/ induced by direct UV writing with a frequency doubled argon-ion laser operating at 244nm. Cerium was preferentially added to the core glass material to provide a strong absorption in the ultraviolet. When the cerium doped core glass was exposed to the UV laser beam, the waveguide core region was locally heated to a temperature above its melting point such that it photothermally expanded as shown in figure 1. As the laser beam was passed across the sample, the photothermally expanded region rapidly cooled to a lower density and lower refractive index state. Refractive index changes as high as 10^{-2} were achieved for a laser power of 200mW, a scan speed of 10mm/min and a spot diameter of 10 μm.

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[1] Lucent Technologies-Murray Hill, NJ

Laser measurements

Minimum threshold and laser emission at both 1048 and 1317nm were observed in a 10 µm thick, 100 µm wide and 16mm long channel written with a UV power of 175mW and a scan speed of 50mm/min. A laser cavity was formed by the attachment of plane mirrors to the parallel polished end faces of the waveguide. The output from a Ti:sapphire laser at 802nm was end-launched into the waveguide using a ×6 microscope objective. The laser performance was remarkable since, due to the thickness of the spin coated waveguide and the width of the guiding region, the pump spot was highly multi-mode leading to a poor overlap between the laser mode and the population inversion.

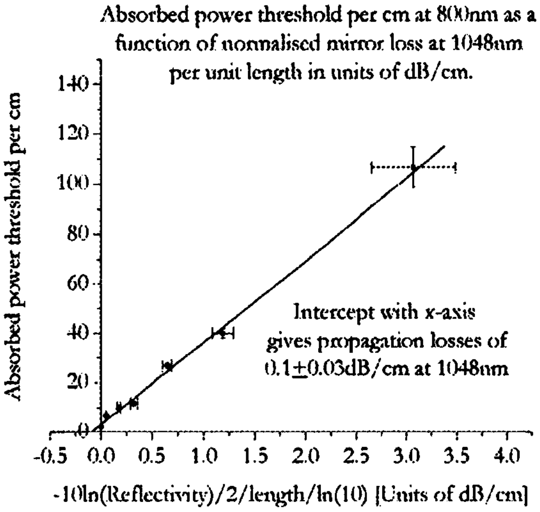

Figure 2: Propagation loss measurement at 1048nm

Several output couplers were available for the more dominant 1048nm transition which allowed the waveguide loss at this wavelength to be determined using the Findlay-Clay technique /11/. From figure 2, the waveguide losses were determined to be 0.1±0.03dB/cm at 1048nm. This was consistent with the threshold expected for the pump and signal mode sizes and was close to the bulk loss of the glass of 0.05dB/cm.

A slope efficiency of 26% with respect to absorbed power was obtained at 1048nm for a 56% output coupler and an absorbed power threshold of 60±1mW at 802nm (Figure 3). A slope efficiency of 2% at 1317nm was obtained using two non-optimised output couplers of 0.3% on each face of the waveguide with a measured threshold of 32±1mW (Figure 4).

Conclusions

The demonstration of lasing at 1317nm is a major step in the development of DWDM sources and amplifiers for the second telecommunications window. Extrapolating the measured losses of around 0.1dB/cm to single mode guides, which are currently being investigated, would suggest that laser thresholds of a few milliwatts and gains of 0.3dB/mW at 1317nm could be achieved using inexpensive 800nm diode sources.

Acknowledgements

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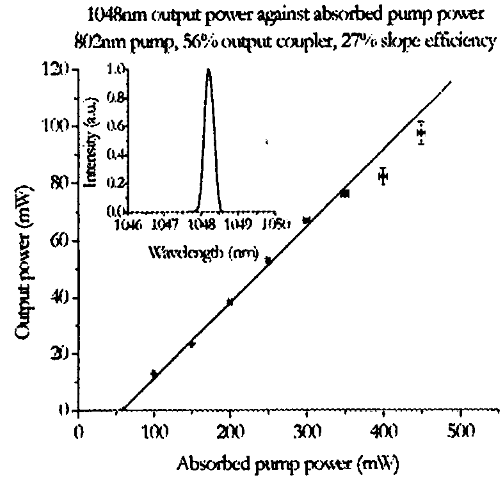

Figure 3: Lasing at 1048nm

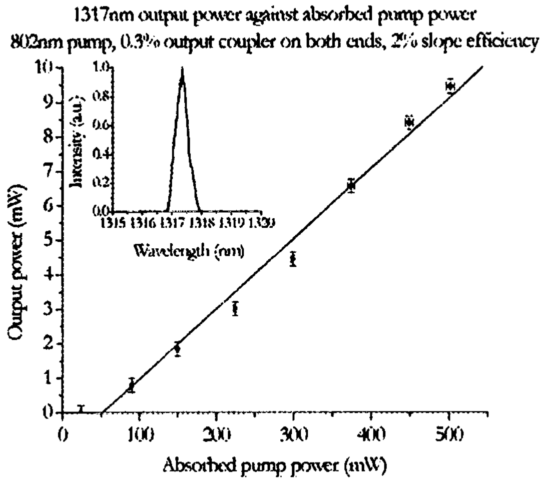

Figure 4: Lasing at 1317nm

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