Planar waveguide laser in Er/Al-doped germanosilicate


A singlemode DBR laser is demonstrated in an Er/Al-doped germanosilicate planar waveguide. 0.4mW of output power has been obtained at 1.55μm using internal Bragg reflectors produced by UV-induced index modulations.

Introduction: To meet the demands for low-noise light sources with narrow linewidth, substantial attention has been directed towards the development of Er-doped fibre lasers [1, 2] and Er-doped planar-waveguide lasers [3, 4]. Using highly wavelength selective Bragg reflectors, these lasers can be tailored to give a narrow-linewidth output in the 1.55μm band, suitable for sensor applications, as well as transmitters in WDM systems [5]. A particularly attractive method for producing these lasers consists of UV-inducing a periodic refractive-index structure directly in a fibre or planar waveguide, utilising the photo-sensitivity of Ge-doped silica glass.

Planar waveguide structures are promising for laser applications because of their inherent mechanical stability and the possibility for integrating lasers with other devices such as power amplifiers, splitters and couplers. Furthermore, when manufactured on a silicon substrate, temperature stabilisation is facilitated by the excellent thermal conductivity of silicon. In the case of planar waveguides, however, the combination of photosensitivity and sufficient gain is not easily achieved, and has only been reported by a few groups [4].

In this Letter we report a singlemode 1.553μm waveguide laser produced in Er/Al-doped germanosilicate, with internal UV-written distributed Bragg reflectors (DBRs). To the best of our knowledge this is the first DBR planar waveguide laser made in Er/Al-doped germanosilicate. Fig. 1 shows a schematic view of the device, which is described below.

Experiment: The Er-doped planar waveguide was produced by plasma-enhanced chemical vapour deposition (PECVD) and reactive ion etching (RIE). A silica buffer layer was deposited on a 4° silicon substrate followed by deposition of an Er/Al-doped germanosilicate core layer. The PECVD process uses SiH₄, N₂O, and GeH₄ precursors for the growth of germanosilicate. Erbium and aluminium were supplied from a liquid source containing Er- and Al-chelate dissolved in an organic solution. The liquid flow was metered, flash-evaporated and subsequently driven into the PECVD reactor with a carrier gas. The resulting dopant concentrations were 0.5 wt.% and 0.26 wt.% for erbium and aluminium, respectively.

Waveguide structures were defined by photolithography and subsequent etching using a fluorine based RIE process [6]. Finally, the waveguide was covered with a boron/phosphorus-doped silica top cladding, index matched to the buffer layer. The waveguide structure was covered with a boron/phosphorus-doped silica top cladding, index matched to the buffer layer. The waveguide dimensions were 4.5 × 10μm² and the core index had been adjusted to obtain singlemode guidance in the 1.55μm Er-emission range.

The waveguide was pumped by 979nm light from a Ti:sapphire laser coupled into a 980nm singlemode fibre. The fibre was butt-coupled to the waveguide, and the backward propagating laser output was collected by the same fibre. A wavelength-selective fibre directional coupler was used to filter out the 979nm pump light and the 1.55μm light was spectrally resolved with a 0.05nm resolution double-monochromator optical spectrum analyser (OSA). A scanning Fabry-Perot interferometer with a free spectral range (FSR) of 2.4GHz was used to investigate the lasing mode. Finally, the linewidth of the laser output was measured using a self-heterodyne delay line method.

Results and discussion: Fig. 2 shows an output spectrum measured with the OSA using 65mW of pump power. When the pump power was increased to 265mW the laser output was more than 60dB higher than the amplified spontaneous emission level, measured with 0.05nm resolution. The output power was 0.4mW when the pump power was increased to 265mW. The laser output power against pump power for planar waveguide laser is shown in Fig. 3, and the lasing threshold was 21mW. The inset shows a scanning Fabry-Perot spectrum of laser output, demonstrating the singlemode operation of planar waveguide laser.

A transmission spectrum of the waveguide containing the two UV-induced Bragg gratings is shown as an inset in Fig. 2. The reflection coefficient of each grating was calculated from the transmission spectrum to be 96.7% at 1.553μm, assuming equal grating strengths. The 3dB transmission bandwidth was 1.1nm. To achieve singlemode operation in the relatively long cavity (34mm) it is necessary to reduce the spectral overlap of the two gratings to a value comparable to the mode spacing of the laser cavity. In the present case the centre of reflection of one Bragg grating was displaced by ~0.2nm with respect to the other. A fit to UV exposure the waveguide was annealed at 200°C to improve the long-term stability of the gratings.

Fig. 1 Schematic view of planar waveguide laser

Fig. 2 OSA spectrum of planar waveguide laser using 65mW of pump power

Inset: transmission spectrum of waveguide with two photo-imprinted Bragg gratings, recorded with spectral resolution of 0.05nm

Fig. 3 Lasing power against pump power for planar waveguide laser

Inset: scanning Fabry-Perot spectrum of laser output, demonstrating singlemode operation of planar waveguide laser
codoped glasses. A Fabry-Perot scan of the waveguide laser is shown as an inset of Fig. 3. The peak separation corresponds to the FSR of the Fabry-Perot etalon, demonstrating longitudinal as well as polarization singlemode operation of the laser. The singlemode operation was very robust and no mode-hopping was observed by uniform heating or application of mechanical shocks to the waveguide.

Although the laser showed robust singlemode operation it was plagued by amplitude noise which was at least partly induced by the pump laser. Because of this amplitude noise it was only possible to obtain an upper limit for the linewidth. This upper limit was measured to be 120kHz.

Conclusion: We have demonstrated the first Er/AI-doped germanosilicate planar waveguide laser. The laser is made on a silicon substrate, and has a wavelength-selective cavity defined using internal UV-written Bragg reflectors. The laser operates in polarization and longitudinal singlemode, and it has an output power of 0.4mW, with a peak wavelength of 1.553μm, and an outstanding signal-to-noise ratio of 60dB.

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