DWDM DFB laser matrix realized by ion exchange on glass substrate

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This paper presents the realisation of DFB laser matrices realised on Erbium-Ytterbium codoped glass substrates. Results obtained on a multi-wavelength comb of lasers integrated on a single chip are shown. Indeed, matrices of 8 DFB lasers with a 100 GHz frequency spacing were demonstrated. The fibre output power of each laser is better than 1mW and a stable emission wavelength is achieved without any temperature regulation. Finally, packaging improvements are discussed in terms of output power and stability.

Keywords: DFB laser, glass integted optics, laser matrix, 100GHz ITU grid

Introduction

In the past decade, a huge growth of the worldwide telecommunication network occurred thanks to the development of optical information transport technology. One way to increase the bit-rate of optical telecommunication is the DWDM (Dense Wavelength Division Multiplexing), in which several signals with different wavelengths are launched in a single optical fibre. Because of the use of Erbium Doped Fibre Amplifiers (EDFA), these wavelengths are set in the third telecommunication window around 1.55μm and should be spaced by 100, 50, or even 25 GHz, as defined by ITU standards [1]. This brings important constraints on both multiplexer/demultiplexer systems and laser sources developed for this application. Considering the latter, the main issues are the output power, the laser linewidth, the wavelength stability, and finally the output power noise.

Two main families of laser sources are nowadays commonly employed around 1.55 μm : semiconductor based lasers [2] and optical fibre lasers [3]. In this paper, a third alternative is presented : glass integrated optics lasers which combines the main advantages of both semiconductor and fibres lasers. Indeed, integrated optics provides planar integration and compactness whereas the use of ion-exchanged waveguides realised on Erbium-Ytterbium doped glass entails a wide bandwidth amplifying medium with a low sensitivity to thermal variations.

This paper first deals with the realisation of the ion-exchanged DFB lasers matrices then the measurement of their performances are presented. Finally, packaging improvements are discussed.

Laser Matrix realisation

The lasers are realised on $2.5 \times 10^{26} m^{-3}$ Erbium and $2.5 \times 10^{26} m^{-3}$ Ytterbium codoped phosphate glass substrates. The phosphate glass is chosen for its excellent properties as an host for Erbium and Ytterbium ions [4]. The waveguides are realised by a silver-sodium ion exchange which enables a high index increase of 10^{-1} and the realisation of low losses buried waveguides [5]. In our case, the burying depth d has been set to 4 μm in order to preserve a good interaction of the guided mode with the surface Bragg grating in charge of the feedback. Indeed, as a single frequency emission and a planar integration are required, lasers are designed to work on a Distributed FeedBack (DFB) configuration. The realised device is depicted on

Figure 1, the chip contains 15 waveguides separated by 250 μm, and is 3 cm long. A 1.7 cm long Bragg grating has been etched by RIE on the device surface. It has been realised by a holographic exposure on a standard microelectronic photoresist [6]. Grating's path Λ has been controlled by the measurement of the angle of minimum deviation at $\lambda = 632.8$ nm and it is 501 ± 1 nm. Grating's depth h has been measured by Atomic Force Microscopy (AFM) to be 300 ± 50 nm.

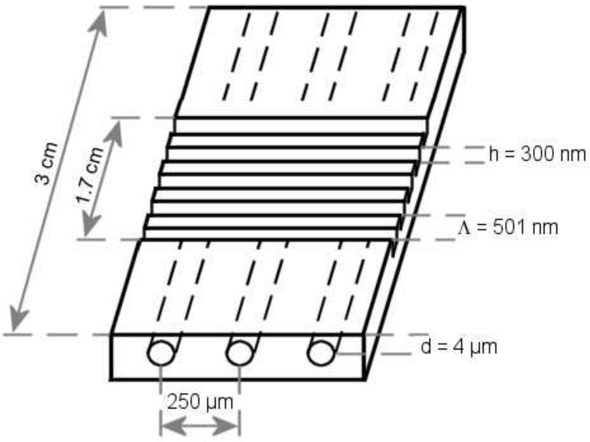

Fig. 1. Schematic representation of the realised chip

The emission wavelength λ_{em} of a DFB laser is given by the relation : $\lambda_{em} = 2\Lambda n_{eff}$, where Λ is the grating period and n_{eff} the effective index of the lasing mode. Therefore, there are two possibilities to select the emission wavelength for lasers realised on the same chip : the first one is to realise gratings with different paths, this is however really hard to achieve for 25 to 100Ghz spaced lasers because it requires a control of the grating period better than the Angström; the second solution consisting in a change of the effective index has been implemented here : it is indeed possible to control the relative effective index change of ion-exchanged waveguides with an accuracy of 10^{-4} by adjusting their opto-geometrical parameters. In our case, the 15 waveguides have been realised with diffusion aperture widths ranging from 0.8 μm to 6 μm.

Characterisation

The matrix chip has been characterised in terms of emission wavelengths, output power, emission linewidth and relative intensity noise. Each laser has been individually tested with a 220 mW fibre output power laser diode emitting at $\lambda_p = 977$ nm as a pump . The light coming from the fibre output of the pump diode is first injected into a 980 $nm/1550$ nm fibre duplexer and then coupled into the laser using micro-positioning stages. The emitted light is collected on the 1.55 μm output of the duplexer and directed on either a power-meter or an Optical Spectrum Analyser (OSA). Figures 2 and 3 display respectively the comb of wavelengths obtained with that device and the fibre output power response of one of the matrix's laser (laser number 9). From Figure 2, it can be seen that two comb of respectively seven 25 GHz spaced lasers and eight 100 GHz spaced lasers have been obtained. In order to assess the stability of the emitted spectra, they have been recorded for 16 hours at maximum pump power and no drift has been measured within the accuracy of the OSA (0.07 nm). These results demonstrates the potential of the ion-exchanged integrated optics technology to realise matrix for the DWDM. The linewidth of lasers has also been measured with a Fabry-Perot analyser leading to a value of 130 MHz which is in fact the nominal resolution of the analyser. Therefore it can be said that the linewidth of the lasers are smaller than 130 MHz and measurements based on heterodyne techniques are currently carried out to obtain their actual values. It can be noticed from Figure 3 that the fibre output power of the laser reaches 1.5 mW with a pump power of 100 mW. Laser threshold is at 35 mW of pump power for a laser efficiency of 2.5%.

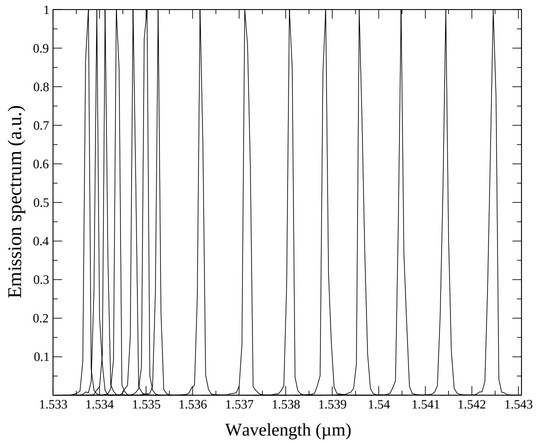

Fig. 2. Superposition of the normalized emission spectra of the 15 waveguide lasers

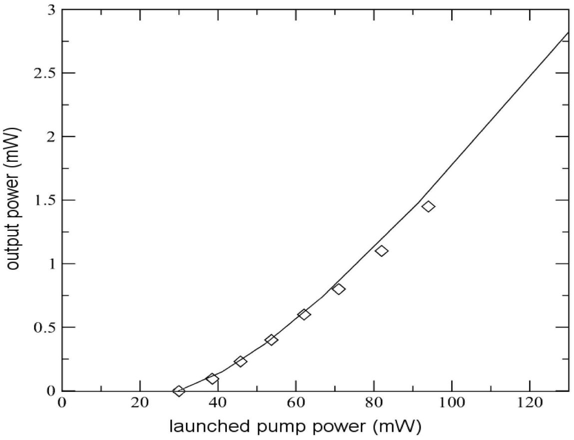

Fig. 3. Output power characteristic of laser number 9

Although the fibre output power is high enough for telecom applications, it must be noticed that the laser efficiency is actually low. This fact can be explained by the parasitical diffractive effect of the grating on the pump. Indeed, the excess losses induced the grating at λ_p have been measured to be 5.5 dB/cm. However, this problem can be overcome by adding an appropriate passivation layer on the top device. Indeed, as can be seen on figure 4, the excess losses caused to the pump decreases dramatically with an increase of the superstrate layer's refractive index whereas the coupling efficiency variation at 1.55 μm is smoother. Therefore the use of a polymer based superstrate layer with a refractive index of 1.46 has been tested and is reported on Figure 5.

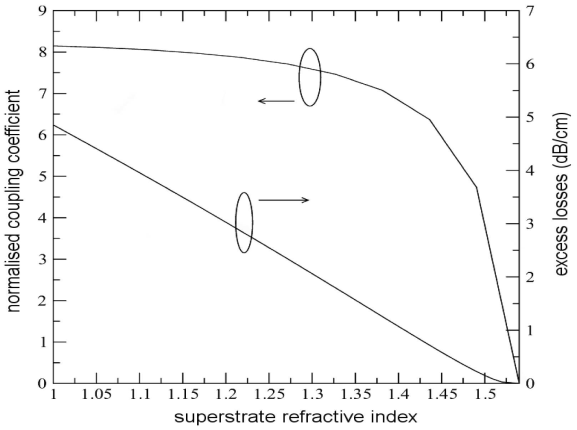

Fig. 4. Evolution of coupling coefficient and excess losses with the superstrate index

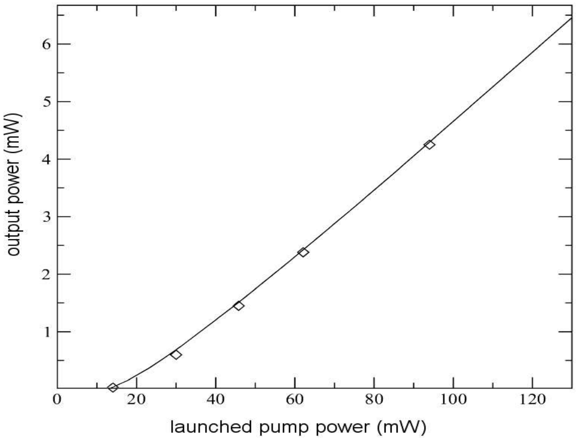

Fig. 5. Output power characteristic of laser number 9 with a superstrate layer

The threshold of the laser is now 20 mW which is the minimum amount of power required to invert the Erbium ions population, and the output power reaches 4 mW with an efficiency of 5.7%. It must also be noticed that this layer provides a mechanical and chemical protection to grating and therefore increases the device reliability.

In order to measure the RIN of the lasers, another device with a 2.4 cm long grating has been used. Its facet has been polished with an angle of 8 degrees and the extremities of the waveguides were post-diffused, creating input and output tapers and improving the coupling efficiency. Finally fibres were glued to the device, and measurement were performed. The improvements of the coupling efficiency has led to an increase of the laser efficiency from 0.07% to 2.7% without the adjunction of a passivation layer. Measurements of the RIN were performed on that device and the RIN falls below -155 dB/Hz after 200 MHz with a peak value of -84 dB/Hz at the 282 kHz relaxation frequency of the laser. These results are as good as the ones typically obtained with fibre lasers [7]. Devices combining both a passivation layer and coupling tapers are currently being realised and simulations show that the lasers efficiency would reach at least 30%.

Conclusion

In this paper, we have presented the realisation of an ion-exchanged DFB laser matrix for DWDM applications. Two comb wavelengths with spacing of respectively 25 GHz and 100 GHz were demonstrated. It was also shown that the use of an appropriate passivation layer reduces the lasers' thresholds and increases their efficiencies by a factor 2. Finally, the improvement of the waveguide coupling efficiency was demonstrated to dramatically improve the behaviour of the device, leading to a low RIN. Future improvements will be focused on the integration of both the passivation layer and coupling tapers on a same device leading to a calculated efficiency of at least 30%.

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