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Title: **Erbium doped Waveguide Amplifier in Glass Fabricated by a Hot-Pressing Technology**

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Abstract: A hot-pressing fabrication technology has been applicated to realise planar optical waveguide amplifiers. Internal gain of more than 14 dB was achieved in a 32 mm waveguide, made by an efficient low cost fabrication technology.

Erbium doped Waveguide Amplifier in Glass Fabricated by a Hot-Pressing Technology

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Optical amplifiers are required for high bandwidth, low crosstalk transmission, especially in wavelength multiplexed configurations. Moreover integrated optical amplifiers are of special interest in access networks, providing services to thousands of customers, resulting in high numbers of low cost lossless splitters, realised by Y-branches and amplifiers.

In this work planar optical waveguides were fabricated by an alternative potential low cost method [1]. This method enables to fabricate waveguides consisting of an undoped glass for substrate and cladding and a doped glass for the waveguide core. By this structure zero absorption in the cladding is achieved thus lowering the amplifier threshold. This feature and the straight forward fabrication technology call for cladding and core glass with several properties to fit in the right way. The glass for core and cladding have to be matched in a sense that the expansion coefficients differ only slightly and the refractive index of the core glass is about 3% higher than the index of the cladding and the substrate. Further the procedure requires that the viscosity of the core glass is considerably lower at the pressing temperature than that of substrate and cladding. In addition the structures for the waveguides should be transferable into the substrate by etching processes.

The waveguides are produced by etching structures in the substrate and pressing the core material into them at temperatures above the softening point of the core material. A plate of the cladding glass is used as the pressing stamp. Surplus core glass is squeezed out sidewards leaving traces in the gap between substrate and cladding. The substrate is bonded to the cladding glass at temperatures slightly below their transformation temperature. For the realisation of the waveguides commercial glasses, BK7, an undoped borosilicate glass from Schott and Q89, a phosphate glass for laser applications from Kigre doped with 3% Erbium showed to be suited. The grooves can be formed in BK7 by a combination of dry and wet etching.

For the experimental setup a titanium sapphire laser (<470 mW @ 976 nm) and a tunable laser diode (1525 - 1565 nm) are used as pump and signal source. Pump and signal were joined in a WDM and coupled to the amplifying waveguide. The out coming light was measured following a second WDM with an optical spectra analyzer. A measure for amplifier performance is the ON/OFF ratio, the ratio of the output signals in the pumped and the unpumped state. This is not the amplification itself because there is the erbium absorption in the unpumped state which is bleached out by the pump light when the ground state is depleted of electrons. A correction is made using absorption data of the channel waveguide measured separately. Furthermore by subtraction of external gain and the internal gain the sum of coupling- and scattering losses were quantified. The figure of merit is the 'internal gain' of the channel. This gain does not include losses in the channel by scattering and absorption and reflection losses at the endface. Measures to reduce endface losses (field matching between fiber and channel, antireflection coatings etc.) were not within the scope of the work. Channels with a length of up to 34 mm and cross sections of 4 µm x 4 µm were evaluated. In a channel of 34 mm length an ON/OFF ratio of 33 dB was measured at 1533 nm and with 470 mW pump- and 100 nW signal power (Fig 1). The external amplification (including coupling and scattering losses) was 7 dB. Erbium absorption of the channel is 19 dB at this wavelength. As a result the internal amplification of this channel was 14 dB. The difference of 7 dB must be attributed to coupling losses and internal losses mainly caused by scattering at the rough sidewalls of the etched structures, which have to be minimised in the future.

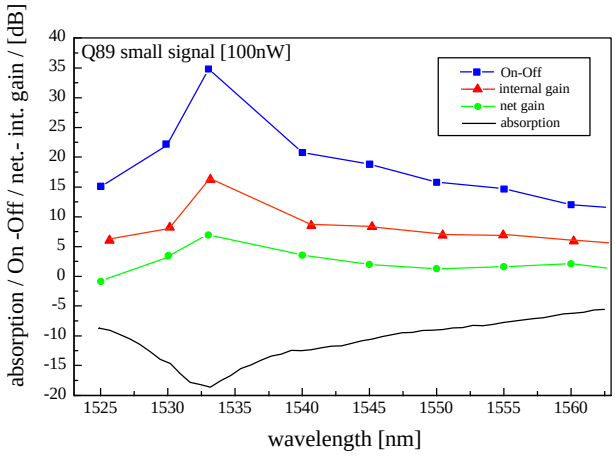

Fig. 1 Gain evaluation of 34 mm erbium doped waveguide

Waveguide amplifiers of serveral centimeters have been realized by the hot-pressing method, achieving an internal gain of 14 dB / 34 mm. Applying the hot-pressing method, waveguide amplifiers can be fabricated by a low cost, time efficient technology.

[1] J.Graf, H. Sautter, R. Müller-Fiedler; European Symposium on Lasers and Optics in Manufacturing, SPIE Vol 3099, 1997