Photo-Thermo-Refractive Glass Doped with Rare Earth Ions as a Substrate for Monolithic Integration of Optical Elements

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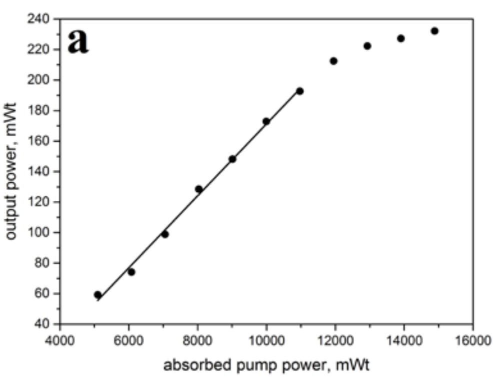
Today with progress of miniaturization, optical microsystems integrate a large number of functionalities in a small volume. There are two approaches for developing integrated optical devices: hybrid and monolithic integration. The latter one suggest performing all components of a device on one substrate. Materials for monolithic integration should allow emission, propagation, amplifying, multiplexing/demultiplexing, and detection of light. In this work, we present new material for monolithic integration that can be used in integrated optics.

The standard PTR glass is a photosensitive multi-component sodium–zinc–aluminosilicate one containing fluorine (6 mol.%), bromine (0.5 mol.%), and doped with small amounts of additives (cerium, antimony and silver) that are responsible for the photo-thermo-induced precipitation of silver nanoparticles and sodium fluoride nanocrystals [2]. Currently, Bragg gratings recorded in PTR glasses used as laser line narrowing and stabilizing filters, spectral and spatial filters, compressors for fs- and ps-lasers, spectral beam combiners, high power beam splitters, etc. [3]. For a long time PTR glass is considered only as a holographic material. However, application area of PTR glasses can be extended dramatically by developing polyfunctional PTR glass that combine properties of monofunctional materials.

For this purpose, Yb-Er co-doped PTR glass based on the Na_2O-ZnO-Al_2O_3-SiO_2-F system was synthesized. The glass synthesis was conducted in an electric furnace at T = 1500 °C in the air atmosphere using platinum crucibles; the melts being homogenized with the platinum stirrer.

Laser action on Yb-Er doped PTR glass is demonstrated for the first time. Dependence of output power on pumping is shown in Fig. 1a.The following parameters were obtained: laser wavelength 1575 nm, laser threshold ~ 3.3W, maximum output power 240mW, and slope efficiency 2.36%. It should be noted that doping PTR glass with rare earth ions had not effect on the recording Bragg gratings with high diffractive efficiency (more 95%). Thus, combination of laser and holographic properties of the PTR glasses can be used for developing solid state distributed feedback and distributed Bragg reflector lasers [4].



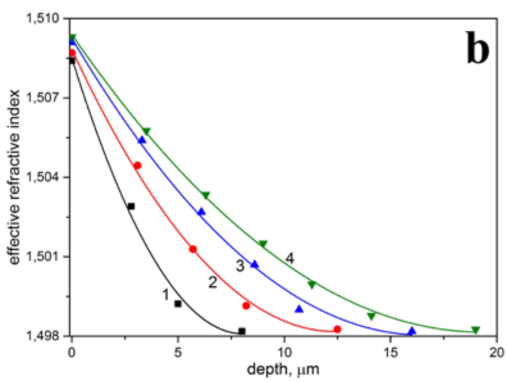


Fig.1. a - dependence of output power on pumping with output coupler 1%; b – refractive index profiles (λ=632.8 nm) of optical waveguides formed by $Na^{+}\leftrightarrow K^{+}$ ion exchange for 1 h (1), 3h (2), 6h (3), and 9h (4).

The presence of sodium in the PTR glass composition allows one to focus on the ion exchange technology for fabricating the waveguide structures [5]. In order to investigate ion exchangeable properties, the PTR glass samples were immersed in a salt melt of KNO_3 at 350 °C for 1-9 hours. Multimode optical waveguides were formed in the PTR glass, refractive index profiles for TE polarization are presented in Fig. 1b. Increment of refractive index reaches 0.011 and waveguide depth varies from 8 to 18 microns with increasing duration of the ion exchange. Moreover, the waveguides reveal birefringence caused by stresses formed in ion exchange layer. Such stresses was shown to improve microhardness of PTR glasses [6].

In this work photo-refractive, laser, and ion exchangeable properties of the PTR glasses doped with Yb^{3+} and Er^{3+} ions were demonstrated for the first time. Thus, PTR glasses doped with rare earth ions allows to integrate waveguides, lasers and amplifiers, and Bragg gratings on one substrate with monolithic integration (Fig. 2). The developed PTR glass can be used for developing various devices of integrated optics and photonics.

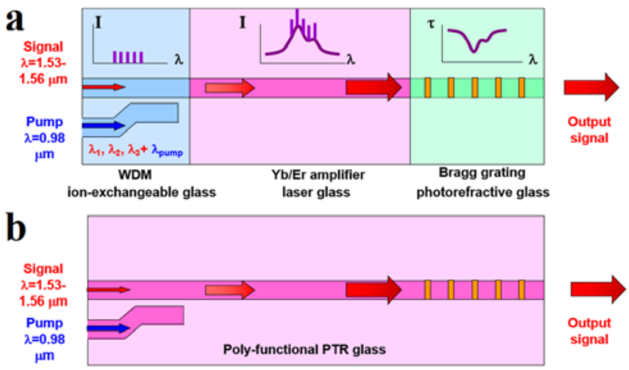


Fig. 2. Schematic image of a hybrid integration (a) of three elements: (i) WDM, (ii) amplifier channel and (iii) Bragg grating playing a role of spectral flattening filter that made with the use of three materials and monolithic integration (b) of these elements made with the use of polyfunctional PTR glass.

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References

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