A photonic fiber laser

Elżbieta Bereś-Pawlik[1], Grzegorz Semczuk[1], Jan Wójcik[2]

[1]*Institute of Telecommunications, Teleinformatics and Acoustics, Wroclaw University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wroclaw, Poland;*
[2]*Fiber Optics Technology Department, Maria Curie Skłodowska University, Pl. Marii Curie Skłodowskiej 3, 20-031 Lublin.*

Received June 24, 2010; accepted September 30, 2010; published September 30, 2010

Abstract — Fiber optic lasers based on erbium doped fibers have been the subject of research for many years [1-2], and are still gaining in interest due to their possible applications. Fiber optic lasers present many more advantages than semiconductor lasers [3].
This work demonstrates the construction of fiber optic lasers based on PM (*polarization maintaining*) erbium ion doped photonic fiber as well as the spectra generated by the lasers. Several laser configurations especially line and ring resonators have been presented.
The main purpose of this work was to build a laser with optimal spectral properties for use in the WDM (*wavelength division multiplexing*) transmission. In order to obtain proper single wave signal spectra in the built lasers, FBG (*Fiber Bragg Grating*) fiber optic filters have been used. Lasers with multi-wavelength spectra generated have been built as well. In addition, there have been constructed lasers where a polarizer has been used in the resonator circuit as an element generating laser's single wave spectrum. Tuning within a few nanometers was obtained in this laser by means of propagated signal polarization change. The proposed solutions of a single- and multiwavelength laser allow us to create the WDM-based system which requires the application of laser source of strictly defined spectral parameters.

Investigating fiber luminescence:

Below we present a PM erbium doped photonic fiber, both its construction (Fig. 1) and base parameters (Table 1). This fiber's coat is hexagonal.

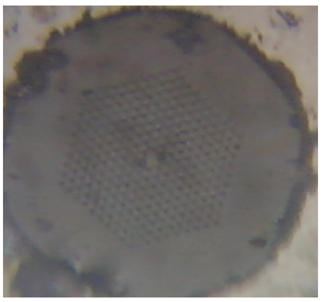

Fig. 1. The construction of a photonic fiber.

The investigated fiber was manufactured by the Fiber Optics Technology Department in Lublin, Poland.
In this paper photonic fiber lasers based on original PM doped photonic fiber were presented for the first time.

Fiber parameters	
Λ (pitch) lattice constant	4.4 μm
d/ Λ filling factor, d – small a hole diameter	0.41
D/ Λ where D – large a hole diameter	0.93
P – diameter of a circle described around hexagon	130μm
Q – diameter of circle inscribed in hexagon	125μm

Table 1. The parameters of the photonic fiber.

To measure fiber luminescence, the light from a pump was introduced into an active fiber optic with great precision. The length of the fiber used was about 30m. The luminescence spectrum with visible starting laser generation of the tested fiber is presented in Fig.2.

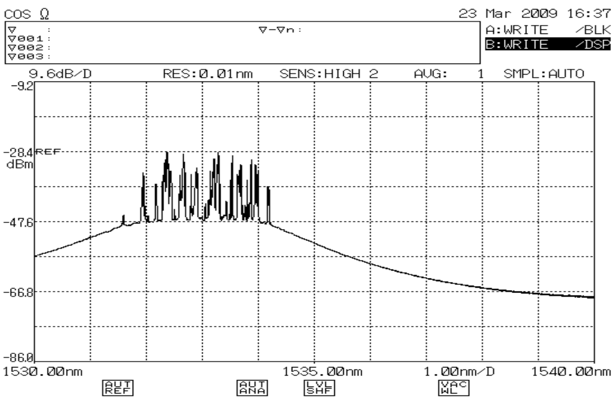

Fig. 2. Luminescence spectra of the fiber.

Construction of lasers using Bragg gratings

Presented below is the design of line lasers using a Bragg grating built to work with a photonic fiber. In the line laser set (Fig. 3) the fiber Bragg grating functions as a selective input mirror. The laser transmits light in a broad spectral range; however, it only reflects a single, selected wavelength.

* E-mail: elzbieta.pawlik@pwr.wroc.pl

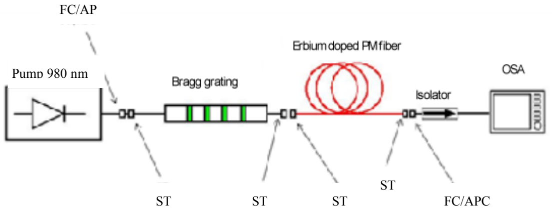

Fig. 3. Scheme of a laser line resonator using the Bragg grating.

The surface of the fiber serves as the second mirror. Fresnel's reflections are used to obtain a laser resonator. The spectral characteristics of the tested laser signal are highly dependent on the spectral width of the Bragg grating. Figure 4 shows luminescence spectra, and following that the laser action obtained with the pumping diode's alternating current. It may be noted that the laser action peak begins to appear at the pump current around I=0.040A. The laser signal output power was analysed in order to define the moment of the laser action threshold.

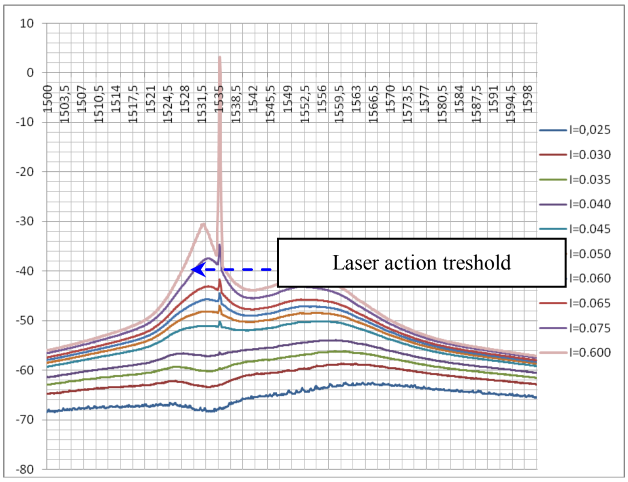

Fig .4. Luminescence spectral characteristics in pump power function.

To build the resonator an isolator was used, where all elements were joined by connectors. The action achieved was stable and the maximum output signal power was about 0.9mW.

Next a ring resonator using a photonic fiber was built (Fig. 5). A 10/90 coupler, circulator, Bragg grating, and WDM couplers were used in this system. To analyse the spectrum with an optical spectrum analyser, 10% of the power was withheld and 90% of the power remained in the laser resonator. The obtained result of the laser signal action is presented in Fig. 6. The 3dB width of the resulting signal peak is approximately 1nm.

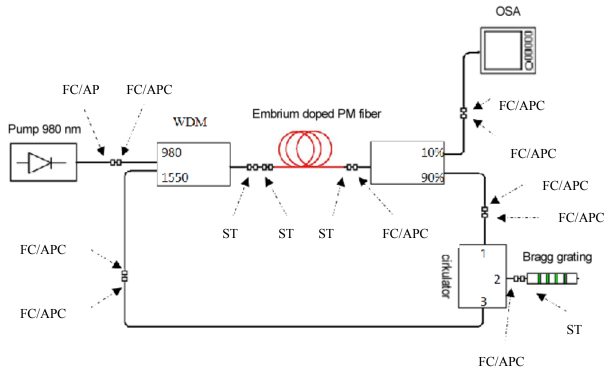

Fig. 5. Diagram of a ring configuration laser using a circulator and the Bragg grating.

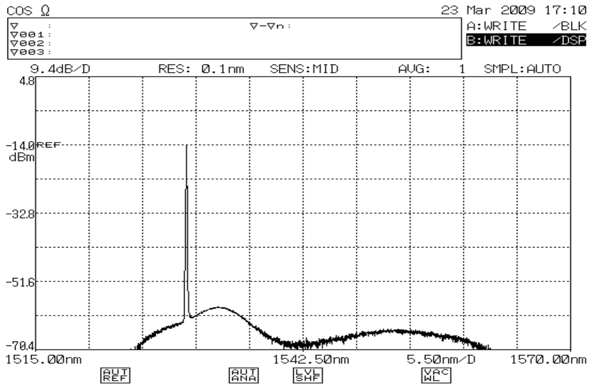

Fig. 6. Laser action achieved in a ring resonator using the Bragg grating.

Multiwavelength action laser design

The examined photonic fiber was also used for designing lasers capable of multiwavelength action. The lasers based on erbium ion doped fibers have a broad amplification band of around 40nm. Multiwavelength action of the laser is presented in Fig.7. Amplification occurred in the range from 1531.9 to 1534.1nm.

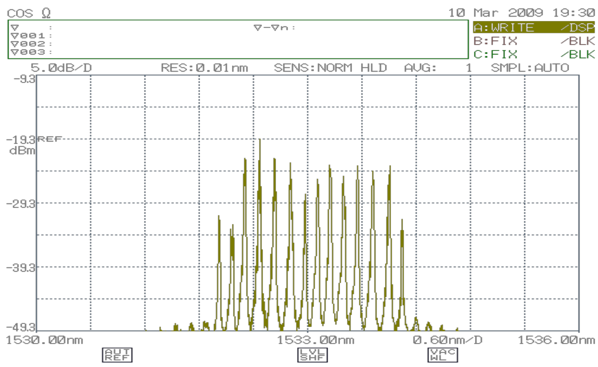

Fig .7. Multiwavelength action achieved in a laser ring resonator

The resulting action is not stable. Because of strong competition among the modes that happen between oscillations on various wavelengths, it is very difficult to obtain stable multiwavelength action. In the tested design of the laser, multiwavelength generation results from the use of a polarization maintaining fiber. In this case it is possible to obtain interwave spacing according to the suggestion ITU. The birefringence and length of the used fiber are the parameters that determine interwave spacing.

Laser spectrum tuning

Figure 8 shows the laser system where a single wave tunable laser spectrum was achieved by means of controlling the state of signal polarization. By shaping laser spectrum we can obtain by a rotary, volumetric polarizer placed between collimators (1550nm) in a ring resonator, including a PM erbium doped fiber.

The achieved laser action depicted in Fig. 9 is stable. We can tune the obtained signal to a limited extent - from 1550nm to 1555nm. In the experiment presented we can see stable, single-wave action with no filters, but only a polarizer used. The proposed source could be the tunable source in a WDM system.

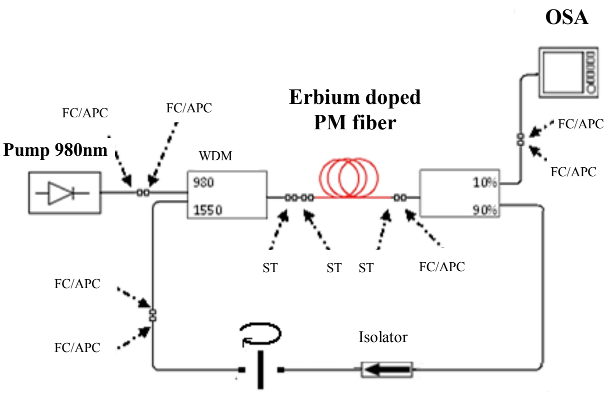

Fig. 8. Ring laser resonator.

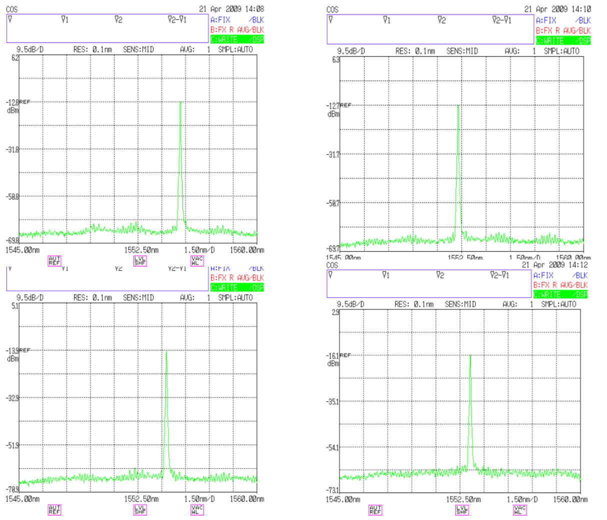

Fig. 9. Spectral characteristics laser action obtained for a few polarizer placement.

In this work several laser configurations, using a photonic, PM erbium ion doped fiber were featured. A capacity was demonstrated to create laser systems for generating single wavelength and multi-wavelength signals. In addition, a photonic fiber laser was presented, where the signal was tuned within a few nanometers by means of changing the propagated signal's polarization state. It is possible to take advantage of the constructed laser in WDM systems where single- or multi-wavelength laser of strictly defined spectral parameters are required.

References

[1] H. Zhang, L. Xiong, Q. Dou, Y. Li, Y. Liu, L. Liu, S. Yuan, G. Kai, X. Dong, Microwav. Opt. Techn. Lett. **45**(1), 12-14 (2005).

[2] E. Beres-Pawlik, P. Gozdz, Proc. of the Symposium on Photonics Technologies for 7th Framework Program, OPERA, 438-441 (2006).

[3] G.Steinmeyer, Journal of Optics A: Pure and Applied Optics, Volume 5, Number 1, 2003, pp.R1-R15 (1)