Study of Erbium doped fiber laser

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***Abstract*—First its was studied the behavior of a commercial amplifier module for different pumping powers and input powers where it was observed that the gain is higher for lower light intensities, as expected, and a corresponding higher output power with a higher pumping power. The second part consisted in working with Erbium doped fibers using the amplification due to a Fabry-Pérot cavity in two Fiber Bragg Gratings (FBG). Here it was seen a response diode-like and for a position on the rails of 38.87*mm* it was obtained a slope of 0.0261*V* and a current threshold of 50.82*mA*.**

I. INTRODUCTION

Although the current manufactured optical fibers have low losses when considering long distances or high bit rates its intensity drops accordingly, and that's where erbium doped fiber amplifiers (EDFA) play an important role in the optical communication.

Erbium-doped fiber amplifiers make use of the three-level pumping system. Here the incident light beams are amplified by stimulated emission of the excited erbium ions, when the amplifier is pumped to achieve population inversion. In this case the Er^{+} ions are excited to a higher energy state (E_3) through absorption of pump photons and then relax quickly to a lower excited state (E_2). Because there's a stored energy, this one will be then used to amplify a signal beam (see Figure 1).

It's expected that the gain diminishes with the increase of the incident beam, having a saturation threshold. The reason why this occurs it's because of the great number of incident photons that despopulate faster the second level (E_2) than the pumping is able to compensate with the population inversion.

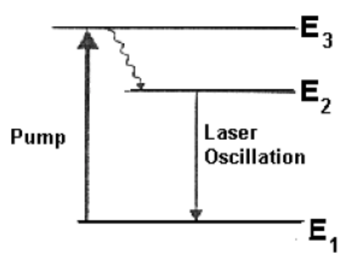

Figure 1. Schematic illustration of a three-level pumping scheme. Wavy arrows indicate fast relaxation of the level population through nonradiative processes. Taken from [2]

The fiber laser used was based on a Fabry-Pérot cavity built with two Fiber Bragg Gratings (FBG) with a small mismatch in the Bragg wavelength. When this mismatch is reduced by longitudinal stress applied to one of the gratings sets off the laser emission.

A Bragg grating is a periodic perturbation of the refractive index along the wave guide, and is formed by exposing it to an intense ultraviolet periodic light pattern created by the interference of two light beams at the same wavelength [1]. In order for this to happen it's necessary that the wave guide materials within the core media are photosensitive, such as the fibers doped with germanium..

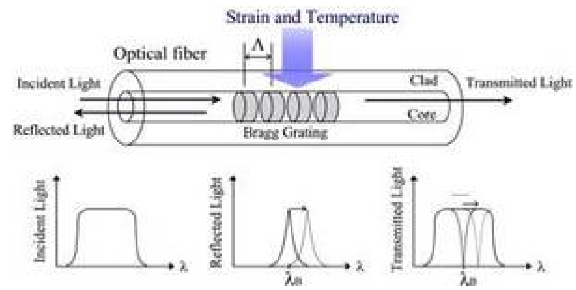

Figure 2. A scheme of a fiber Bragg grating. A change on strain and/or temperature results in a shift in the wavelength reflected by the FBG.

The Bragg wavelength, originated from the successive reflections at each interface of the grating and respective interference, is defined by Λ, which is the spatial period of the index modulation in the following equation:

$$\lambda_B = 2n_{eff}\Lambda$$

where n_{eff} is the effective index of the propagating mode. So the Bragg wavelength can be also changed by affecting the modal effective index such as by temperature change.

The fact that noise is inherent in all amplification systems based on atomic population inversion can be understood by the physical picture of amplified spontaneous emission (ASE). The noise photons emitted randomly by spontaneous decay of excited atoms are initially negligible compared to the stimulated emission due to the presence of a large amount of signal photons (stimulating photons). However, as the signal and noise propagate along the gain medium (the doped fiber in this case), the spontaneous emission, as well as the stimulated emission, is amplified. The higher the gain, the greater the ASE noise.[2]

II. EXPERIMENTAL PROCESS

A. *Response of a commercial module*

In order to characterize an erbium-doped fiber amplifier (EFA) it was used an Optical Spectrum Analyzer (OSA) connected to the output of this EFA that received as an input the light from a diode-pumped solid-state laser. It was used two different optical powers (-14.18 dBm, 0.05dBm) in a range of input power from 100 to 300 mW and for a fixed input power different pumping powers (0.3W, 0.15W).

It's recommended not to use a pumping power over 0.3W because it can damage the optical connectors.

B. Erbium doped fiber laser

For the second part of the experiment it was characterized an erbium-doped fiber laser made with a cavity built with two adjustable Bragg gratings using the set ups displayed in Figure 3. If the two Bragg wavelengths are correctly aligned it will amplify the signal greatly due to multiple reflections on the cavity.

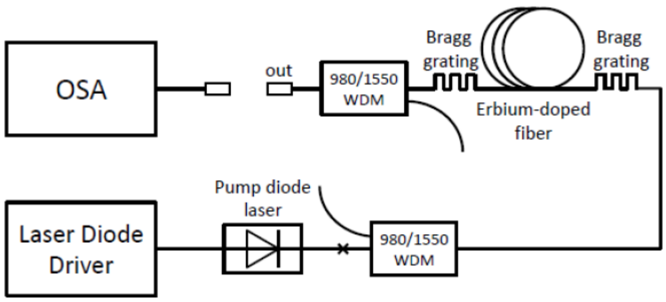

Figure 3. Experimental scheme used for the EFA.

It was used a 980nm diode laser controlled by current connected to the pump diode laser. The optical cavity is set between the wavelength division multiplexer (980/1550) with the Bragg grating of the right serving as mirror and the one of the left transmitting to the output which can be an OSA or an optical multimeter. This last Bragg grating is set on a carriage in order to tune or not the cavity. The diode drive current was set to 150 mA and decreased by steps of 10 mA for a mismatch configuration of the Fabry-Pérot cavity.

III. Results and discussion

As it can be seen in Figure 4 it was confirmed that the gain is higher for lower light intensities going through the fiber.

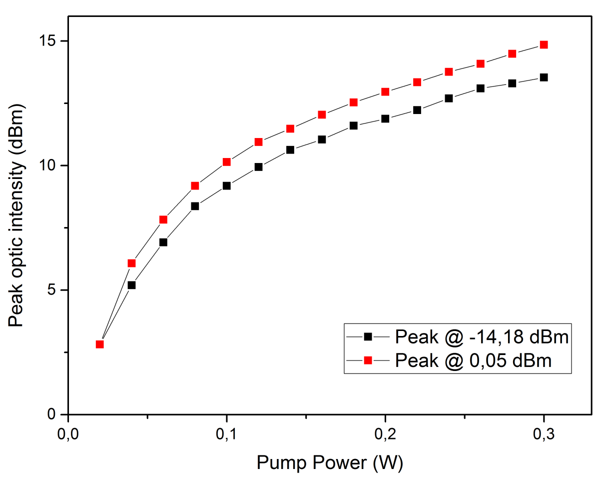

Figure 4. Optical power output as a function of the pump power.

For a higher pumping power it was observed (Figure 5) that the power output was also higher, as much expected. Between -30 dBm and -35dBm there seems to be some sort of irregularity in the measurements probably because the fiber was moved. It's also observable a output power plateau for lower input powers due to the lack of incident photons needed for the population inversion in the optical pumping.

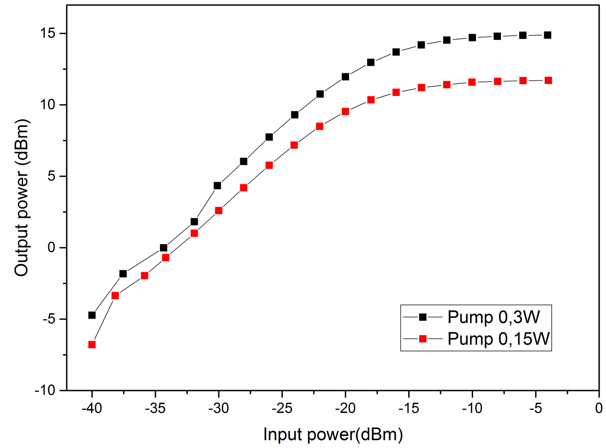

Figure 5. Optical power output as a function of the input power.

Using an erbium doped fiber in a Fabry-Pérot cavity it was put in a mismatched position of the Bragg gratings, stretching on of the grating to a position of 38.87*mm*. For this position it was obtained a slope of 0.0261*V* and a current threshold of 50.82*mA*. Although it wasn't possible to perform the two configurations (the tuned configuration and detuned) due to lack of time, comparing with the results of my college Luís Oliveira this value was in agree with this other work since it was obtained there a value of 0.02877*V, 52.657mA* for 38.80*mm* and 0.02464*V, 65.707mA* for 38.92*mm*.

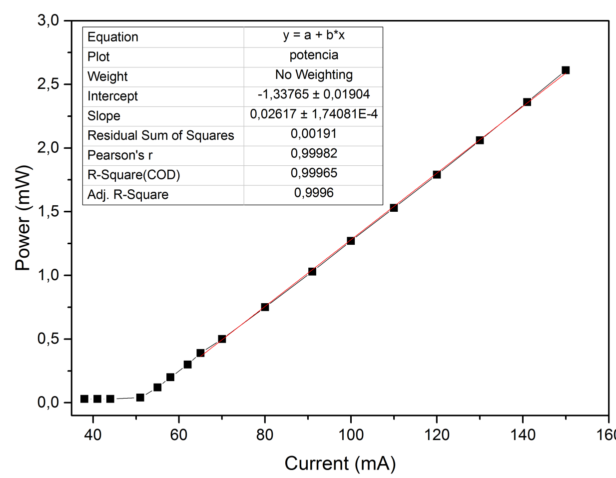

Figure 6. Power output as a function of the pump current.

IV. Conclusion

It was possible to evaluate how a three level pumping system can help to reduce signal losses in fiber communications and what's the response of the pump to different power input lasers. The results regarding to the EDFA are within the expected and observed by other colleges that performed the same experiment with the same fiber.

This experiment was very useful in order to get more experience using the OSA and working with optical set ups. In a next chance it would be

REFERENCES

[1] Marques, P. V. S.; Marques, M. B. & Rosa, C. C. Advanced experiments with an Erbium doped fiber laser 2011

[2] Quian, L. of Toronto, U. (Ed.) Experiment on Erbium-Doped Fiber Amplifiers 1998