Experiments on an erbium doped fiber laser

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Abstract

In this project we will study an Erbium doped fiber laser where the cavity is built with two Bragg grattings. We will begin by characterizing the grattings, starting with studying the reflectivity of the gratting under stress and, when both are aligned, the laser characteristics. In the first place we saw the changes on the spectrum and measured optical power variations with pump current changes. We determinined the laser's slope efficiency to be 0.013 *W/A* and it's threshold pump current to be 53.14 mA.

I. Theoretical introduction

i. Erbium doped fibers

Erbium doped fiber amplifiers (EDFA) are vastly used in optical communication networks thanks to its properties: they can work in the 1.5 μm wavelength region, in which telecom fibers have the minimum losses [1].

They work on the principle of the three level pumping scheme (Figure 1).

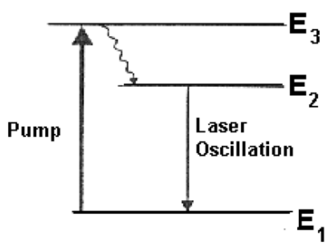

Figure 1: *Three level pumping scheme.*

When the Erbium ions are pumped to Energy level E_3 and then quickly relax to a lower state (E_2) a storage of energy occurs, which is used to amplify an incident beam. However, with the increase of the incident signal amplitude the gain diminishes, since the high number of incident photons lead to quicker depopulation of the E_2 level, which can not be matched by the pumping population of the level.

Optical amplifiers, similar to lasers, amplify incident light through stimulated emission [2]. In this experiment we will use an Erbium doped fiber, where the optical gain appears due to the excited Erbium ions released when the amplifier is pumped to achieve population inversion.

ii. Bragg gratings

A Bragg grating is a periodic perturbation of the refractive index along the waveguide and is created trough exposure to an intense UV periodic light patern.

When characterizing a Bragg grating we will see a reflection peak that appears due to the successive reflections on the different refractive index regions, allowing maximum reflection for a well defined wavelength (Λ_B), known as Bragg's wavelength - Eq 1.

$$\lambda_B = 2n_{eff}\Lambda \quad (1)$$

where n_{eff} is the effective index of the propagating mode and Λ is the spatial period of the index modulation.

However, by fixating one end of the grating it is possible to change the lenght between perturbations [1], and switching the Bragg wavelenght on which it works. If we connect two gratings we can align them so we have an overlap of the reflectivity peaks, creating a *Fabry-Perot* cavity on the Erbium doped fiber, allowing for an amplification of the signal.

II. Experimental Procedures

In this section we will do a brief overview of the experimental procedures and the main considerations to take into account.

The experimental setup (Figure 2) is almost the same troughout the entire experience, only switching the Optical Spectrum Analyser (OSA) for an optical power meter on the later stages.

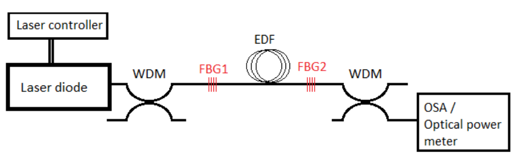

Figure 2: *Experimental setup schematics.*

In this setup we use an WDM near the OSA so we can filter out the non absorbed pump (980 nm). Otherwise we would still see it in the OSA screen.

i. Bragg Gratings characterization

In this part of the work we connect an Optical Spectrum Analyser (OSA) and measure the fluorescence that appears due to the doped fiber. It is important to note that in the case of a detuned cavity there will be different Bragg peaks for each Bragg grating.

In the first place we will glue the cladding (if we glue the casing then the cladding will slip inside it) of the fiber to a carriage (Figure 3) and stretch it to change the position of the positive peak, taking values from the OSA for each distance.

Before taking measurements we found the stage position for which we saw a sharp peak on the OSA and used that position as the origin of our positions measurements.

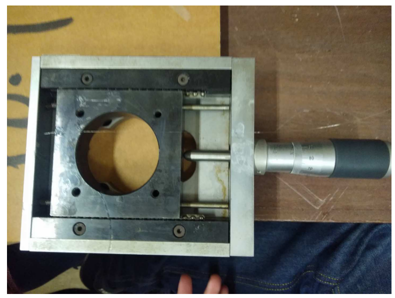

Figure 3: *Carriage used to stretch the fiber.*

It's important to take into consideration that if we stretch too much the fiber then it may break due to the tension applied to it. If it breaks near the grating we will need to splice both ends, as long as we have an working margin. Otherwise we will have to replace the grating with a new one.

ii. Laser characterization

In this second part we begin by making sure that the Bragg peaks of both gratings are overlapping and then study the laser spectrum for increasing values of pump current. After this we can obtain the threshold current and slope efficiency, by connecting an optical powermeter instead of the OSA and changing the pump power.

III. Results and Analysis

Before the start of this section it's important to note that this work incurred many problems, especially during the gluing the fiber to the carriage, and also during the process of saving the data provenient from the OSA we encountered problems with the choice of the correct data channel.

[1] by stretching it.

Troughout the entire analysis process we used a pump wavelength of 980 nm and a signal of 1550 nm.

i. Bragg gratings stretching

As expected we can see (Fig 4) that the position of the peak changes with different stretch values of the grating. In the used configuration, an increase in the stage position translates to a greater stretch of the fiber.

When the two gratings are aligned we see, as expected, the sharp peak that appears and the lack of the negative peak seen on the other measurements.

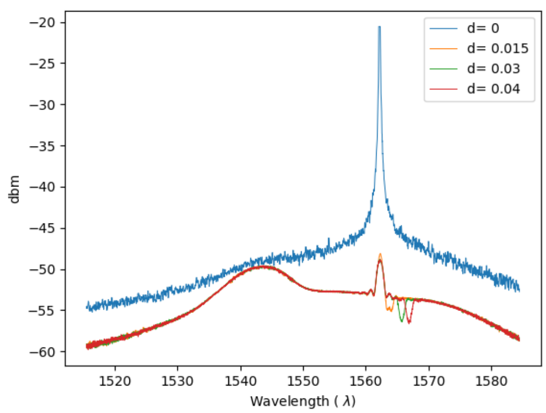

Figure 4: *Spectrum from the fiber laser with the carriage in different positions.*

We can now analyse the spectral attenuation for the second Bragg grating. We could analyse the grating reflectivity by studying the attenuation of the negative peak with the wavelength as in [3] but, due to a low sampling pool and two measurements being almost similar, we can't extract the necessary data for further analysis.

ii. Laser characterization

In the first place we will start with the study of the laser spectrum with different pump powers.

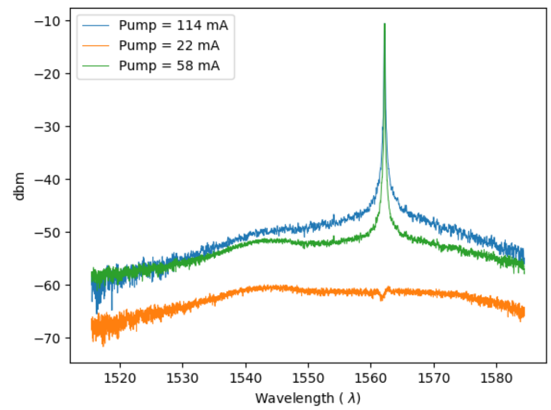

Figure 5: *Spectrum changes with the increase of the pump power. In this case, with an increase of its current.*

In Figure 5 we can see the laser spectrum bellow the threshold current (lower curve), with a behaviour close to the ones seen on Figure 4. The other two measurements were clearly above the threshold current, since we can see the sharp peaks around similar wavelengths.

Switching to a powermeter we measured the optical power for different values of pump intensity (Figure 6).

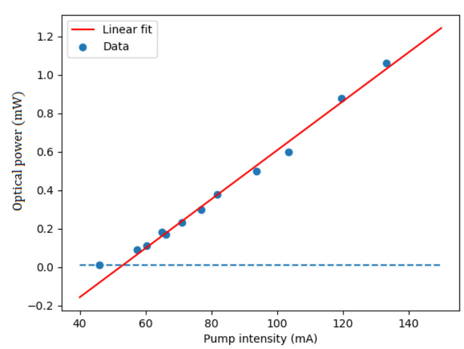

Figure 6: *Optical power readings with variations of pump with a linear fit yielding r^2 of 0,989.*

By doing a linear fit of the data, excluding the first point since it belongs to the under threshold region, we find a slope of 0,013 W/A and a threshold pump current of 53,14 mA.

After this analysis we left, for future work, the study of the threshold pump current with the stage position and characterizing the laser with different wavelengths.

IV. Conclusion

In this work we aligned two Bragg gratings by stretching them to change their spatial period. As expected we saw a sharp peak when they were aligned and otherwise we saw two different peaks that were on different positions for different stage positions. Afterwards we saw the effect of the change of the pump current on the laser spectrum, for values of current over and under the treshold.

By studying this effect with an optical powermeter we determined the laser's slope efficiency to be 0.013 *W/A* and it's threshold pump current to be 53.14 mA.

References

[1] https://www.rp-photonics.com/ erbium _doped_fiber_amplifiers.html.

[2] L. Qian, "Experiment on erbium-doped fiber amplifiers," *University of Toronto*, 1998.

[3] P. V. S. Marques, M. B. Marques, and C. C.Rosa, "Advanced experiments with an erbium doped fiber laser," *Optical Society of America*, 2013.