Erbium doped fiber lasers

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***Abstract*—This report discusses the implementation of an Erbium doped fiber laser made with a cavity built with two tunable Bragg gratings. An analysis is made of several spectra for different pump currents, both below and over the threshold, using an OSA. Replacing the OSA with a power meter and using different pump currents we obtain a threshold pump current of 42.92mA and a slope efficiency: 0.0013mW/mA. We did not study the response of the gratings under mechanical tension, this was due to their fragility, they break easily.**

FBG: Fibre Bragg Grating
OSA: Optical Spectrum Analyzer
EDF: Erbium doped fiber

I. Introduction

Erbium-doped fiber amplifiers are by far the most important fiber amplifiers in the context of longe-range optical fiber communications; they can efficiently amplify light in the 1.5μm wavelength region, where telecom fibers have their loss minimum. The fiber laser market is growing due to its many advantages over conventional lasers[1]. By using the knowledge acquired during the current and previous semester in handling optical fibers, cleaving, splicing and spectroscopic characterization, a setup was implemented with the aim of achieving a laser system. Our approach to fiber lasers is based on a Fabry-Perot cavity built with two fiber Bragg gratings (FBG) with a small mismatch in the Bragg wavelength. The laser emission is achieved when this mismatch is reduced through longitudinal stress applied to one of the gratings. By following this approach we can gain some sensitivity to the laser characteristics as a function of the cavity parameters, in particular mirror reflectivity(total losses) in what concerns both threshold and slope efficiency.

A. Laser

The LASER emits light through a process of optical amplification, based on the stimulated emission of electromagnetic radiation. The source of light is coherent, spatially and temporally, it's widespread application in technology shaped the technological progress of the twentieth century. Fundamentally, a laser consists of a gain medium, a mechanism to energize it, and something to provide optical feedback. The gain medium is made up of a material with properties that allow it to amplify light by stimulated emission, light of a specific wavelength that passes through this medium is amplified, increases in power. For this medium to amplify light, it needs to be supplied with energy in a process called pumping, this energy is typically supplied as an electric current or as light at different wavelength.

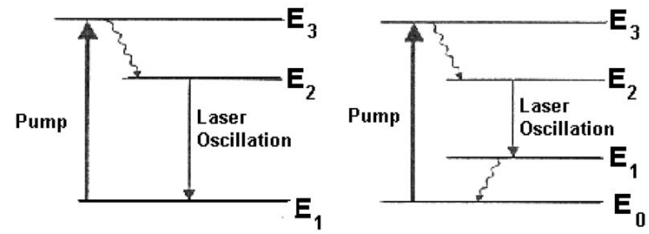

Figure 1. Left: 3 level laser, Right: 4 level laser. The wavy lines represent fast relaxation of the level population, by nonradiative processes.

The main difference between the 3 and 4 level laser pumping schemes is related to the energy state occupied by the dopant after the stimulated-emission event. In a 3-level system, the lower level is the ground state, whereas it is an excited state with a fast relaxation time in the 4 level system. This difference dictates that a stronger pumping is needed with the 3 level system in order to achieve population inversion.[3] The EDF system we will study is a 3-level system, the optical gain will appear due to the excited erbium ions released when the amplifier is pumped after achieving population inversion.

B. Bragg gratings

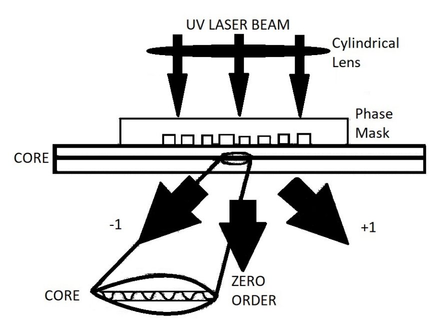

Figure 2. Schematic illustration of the phase mask technique for Bragg grating photo-inscription.[1] Techniques such as this one were mentioned in a 1st semester course on micro and nano fabrication in a clean room.

A Bragg grating is a periodic perturbation of the refractive index along the waveguide, and is formed by exposing it to an intense UV periodic light pattern created by the interference of two light beams at the same wavelength.[1] A common method to fabricate Bragg gratings is based on a diffractive optical element, and usually referred as a phase mask method, we can see a illustration of this in Fig.2. To fabricate Bragg gratings it is essential that the waveguide materials, within the core media are photosensitive, i.e., that its refractive index can be permanently changed through UV exposure. This property can usually be found in optical fibers doped with germanium. The refractive index perturbation usually consists of a core geometry variation and/or of a core index perturbation, both inducing an effective index perturbation. The resulting uniform sinusoidal Bragg index grating along the core of the waveguide can be expressed as:

$$n(z) = n_0 + \Delta n \cos(\frac{2\pi z}{\Lambda}) \tag{1}$$

where n_0 is the average index, Δn the UV induced refractive index perturbation, z the distance along the longitudinal axis and Λ the spacial period of the index modulation. For this periodic modulation the central Bragg resonant wavelength is given by:

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

with n_{eff} the effective index of the propagating mode. Therefore, the Bragg wavelength can be changed by varying the period, such as by stretching or compressing the fiber, or by affecting the modal effective index such as by temperature change.

II. Experimental setup and procedures

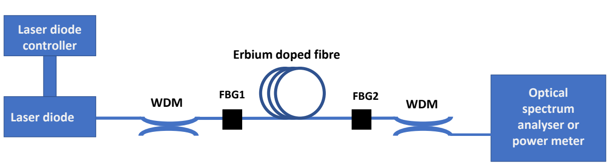

Figure 3. Experimental setup.

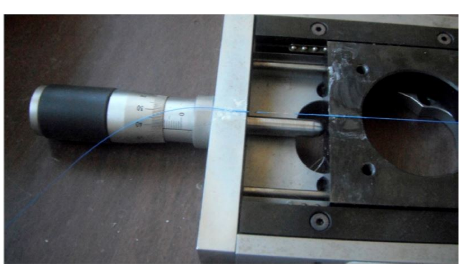

Figure 4. Platform to stetch the fiber with the FBG.

Our experimental setup can be seen in Fig.3, and we maintain it throughout our experiment, the only variation is in the last section, we change the OSA to a power meter. The WDM on the right is used to filter the non absorbed pump and to keep it from showing up on the OSA screen. If we were to use the stretching we would glue the fiber to the stage frame and at the moving block, allowing the stretching of the FBG1 that is positioned between those points. That would be made using a platform like the one in Fig.4. Experimentally we would see different Bragg peaks for each Bragg grating if the cavity were detuned. To characterize the laser we study the spectrum for increasing values of the pump current, and by doing so the threshold current and slope efficiency can be found. In this last part we use a power meter instead of an OSA.

III. Data

A. Spectra obtained

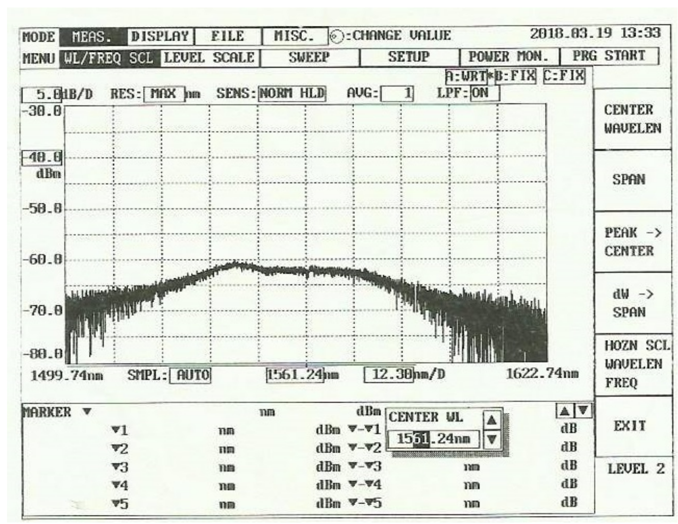

Figure 5. pump current: 24.91mA

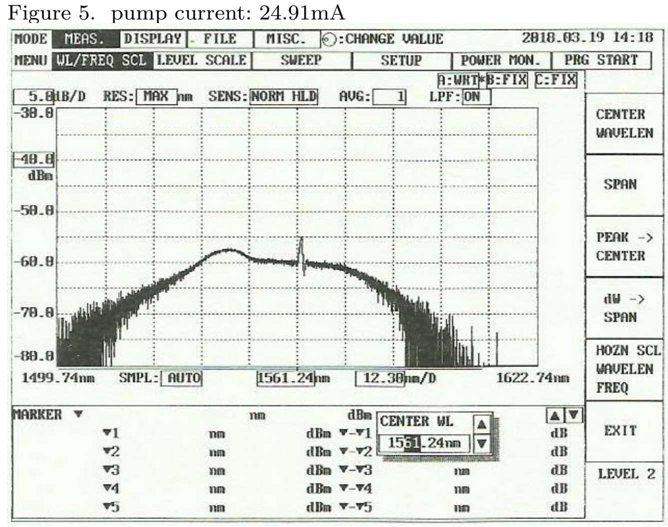

Figure 6. pump current: 39.22mA

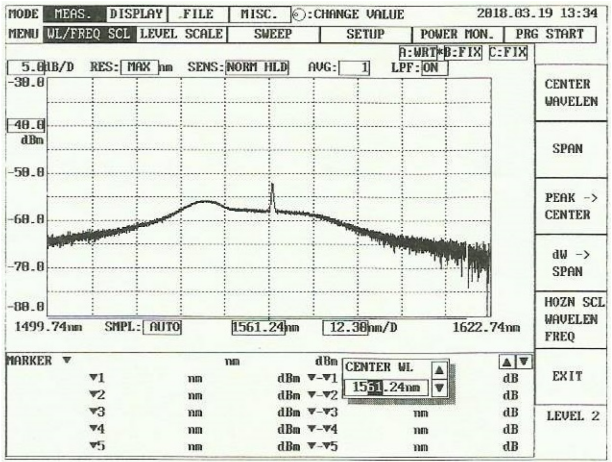

Figure 7. pump current: 40.88mA

By looking at Fig.5, 6 and 7 we can see the spectral emission characteristics obtained with increasing pump power below threshold. In Fig.8 and 9 we can see a pronounced peak, telling us we are now above threshold.

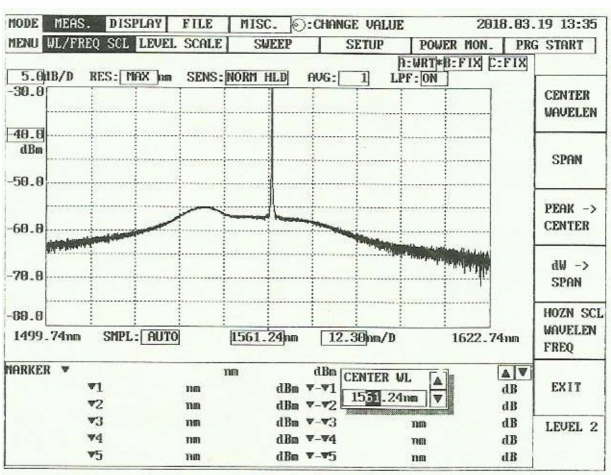

Figure 8. pump current: 47.04mA

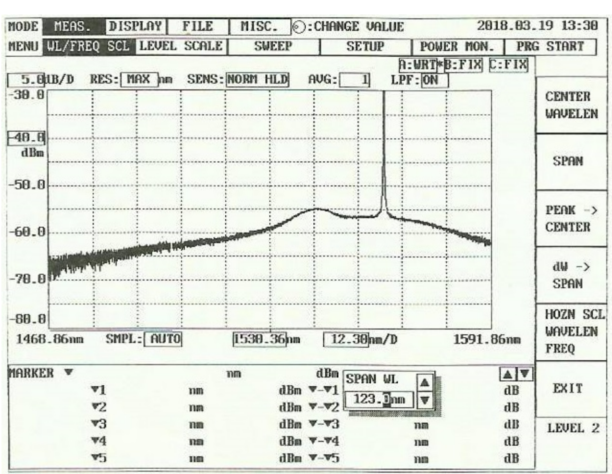

Figure 9. pump current: 49.53mA

B. Laser power and threshold

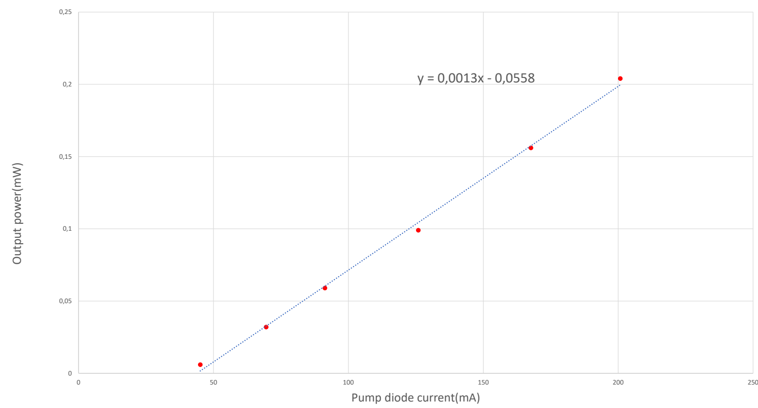

Figure 10. Output power versus Pump diode current. A linear fit was performed on the data(red dots), giving us an $r^2$of 0,99687. The slope efficiency and threshold pump current can be obtained.

In order to study the dependence of laser output power as a function of pump power, we replace the OSA by an optical power meter. We then measured the laser output power for a set of pump diode current. Due to experimental constraints, we were not able to obtain data from different stage positions. This was due to the sensitivity of the gratings, they could easily break by applying too much strain. The results can be seen in Fig.9, where we plot output power(mW) versus pump diode current(mA). By doing a linear fit we can extrapolate the threshold pump current to be: 42.92mA and the slope efficiency: 0.0013mW/mA. This lasing threshold is the lowest excitation level at which a laser's output is dominated by stimulated emission rather than by spontaneous emission.

IV. Conclusion

We were able to obtain several spectra for our erbium doped laser, using the OSA, both below and above the threshold pump current. After replacing the OSA by a power meter we obtained a good linear relation between output power and pump diode current, for different pump currents. That allowed us to extrapolate threshold current and slope efficiency. This part of the project was very satisfactory, however, a more extensive study on how the position of the peaks change with respect to different stage positions for the stretching of the fiber would be interesting, such as a plot similar to Fig.9 for different positions.

We obtained a threshold pump current of 42.92mA and a slope efficiency of 0.0013mW/mA.

References

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