Fiber Optics

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I. PURPOSE

An optical fiber is one of the most widely implemented optical systems threw out research and the communication industry. The main interest in optical fibers really in its ability to capture light and guide it with minimal loss per kilometer. A fiber can capture light by exploiting total internal reflection, for this lab we are not as interested in its reflection properties as we are in coupling light inside this system and observing how the light get absorbed by the fibre and its attenuation after propagating threw a reasonable length of fiber.

In this lab's purpose is to get some experience in the handling of optical fibers. A general over view of the physics need to handle this system is given and a basic poetical hands-on is also done. The general goal of this lab is to acquire practical knowledge on what one should keep ion mind when working with fiber from the deployment to the physical constraints that this system has. Our main task where to measure the numerical aperture (NA), the attenuation spectrum and preform basic light coupling in multi and single mode fibers.

II. THEORY

First lets consider the coupling of light, to understand this we need to study the Numerical aperture of the fiber which is a dimensionless number that that characterizes the range of angles over which the system can accept or emit light.

$$NA = \sqrt{n_{core}^2 - n_{clad}^2} \approx \frac{Spot}{2 \cdot f} \tag{1}$$

Where n is the refractive index, Spot is the spot size of the out coupled beam form the fiber and f is the focal length.With this we can find what type of optics we need to use to couple the most amount of light into the fibre. This can also be verified experimentally since we can make a basic measurement of the divergence of the light coming out of a coupled fibre. In general we know that the most effective optical array to couple light is one that matches the NA op the fibre. For a single mode fibre it's more complicated and in general more power is lost while coupling this is due to the since of the core which is usually around 8 μm and for a multi-mode fiber the inner core is around 65 μm.

An other interesting property of a fiber is its absorption over distance. Since we want to have the lowest possible absorption so out signal can propagate for long distance without needing constant amplification. theoretically we expect a absorption signal as the one seen in Fig,1 where the least attenuated signal would be around 1.5 μm

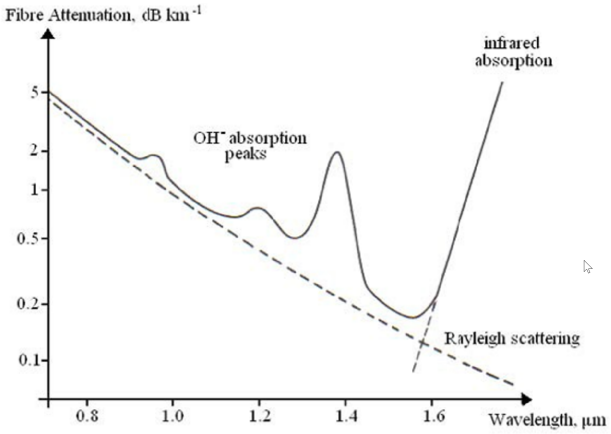


FIG. 1: Expected absorption signal for a optical fiber

III. EXPERIMENTAL SETUP

This laboratory exercise was comprised of three different measurements and setups. The first was aligning and coupling light into fibers, where a He-Ne laser was used together with two turning mirrors and a setup to align the fiber itself. In the aligning setup, an aperture together with a x-y-z translation was used to match that of the fiber being used. In Fig.2 below, the schematic setup for the first exercise is shown.

In the second exercise, white-light spectroscopy of fiber optics where measurements of the attenuation of the fiber optics was performed. In this setup a halogen lamp, a coupling lens, an equi-mode fiber, reference fiber coupled with fiber optics connectors and a CCD spectrometer was used. The spectrum was then presented in a computer program. The schematic of the setup is shown below in Fig.3.

In third and last exercise the fiber Bragg grating was to be performed. In this setup various components is being used, such as splitters, circulators, couplers and a fiber Bragg grating together with a temperature and current

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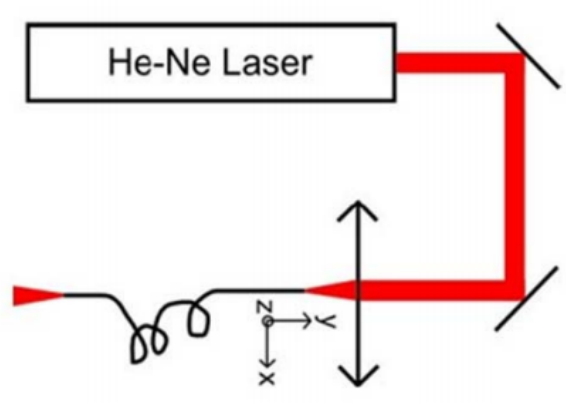


FIG. 2: Setup schematic of the first exercise of the laboratory

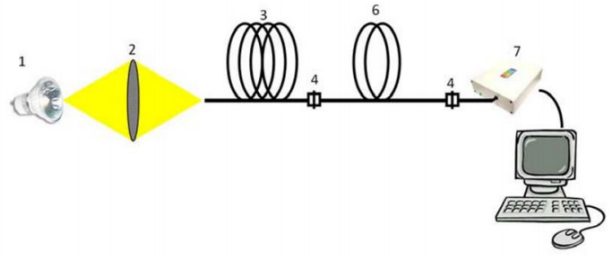


FIG. 3: Setup schematic of the second exercise of the laboratory.

controlled laser, photo detectors and a multimeter. The experimental setup is shown in Fig.4 below.

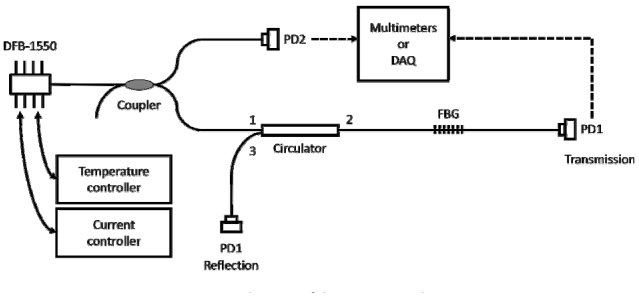


FIG. 4: Setup schematic of the third exercise of the laboratory

IV. METHOD

In this experiment we conducted three different set of measurements, first we coupled light into a optical fiber by mean of setting a lens with a matching NA than the fiber we were using and then measure the NA of the fiber by looking at the out going light and rectifying whats given by the manufacture. After this we looked at how white light is absorbed by the fiber of different lengths and comparing with what is theoretically expected to show up.

This accomplished this measurement by illuminating two fiber with different lengths and measuring with a spectrometer the out coming signal in intensity. We measured also the dark current to clean our signal form noise and then executed our measurements. With this then we finally wanted to study how a Bragg grating reflected and transmitted signal looked by modulating the wavelength of the illuminating light source.The wave length was modulated by changing the resistance of the diode laser,

V. RESULTS

In Fig. 5 the absorption of the fiber is shown, which it's theoretical expected counter part was shown in Fig.1. In general one can observe that it dose follow the same trend, where one can see the absorption signal of OH absorption and there is a minimum at $\lambda \approx 1548$ nm which is close to what is expected 1500 nm and use in optical communications.

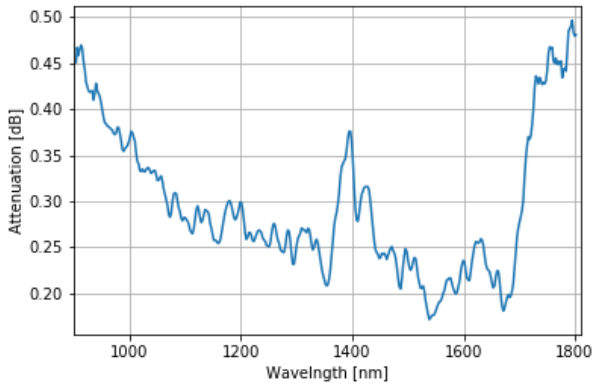


FIG. 5: Attenuation of the fiber for different wavelengths calculated from the relative intensity of three meter and hundred meter fibers.

A Bragg grating was also studied by looking at the transmitted and reflected signal scanning threw a wavelength range and recording its intensity. In Fig.6 we show the recorded signal where we can see the grating is centred for a wavelength of 1550.4 nm with side bands of around 0.1 nm which shows it accomplishes high selection.

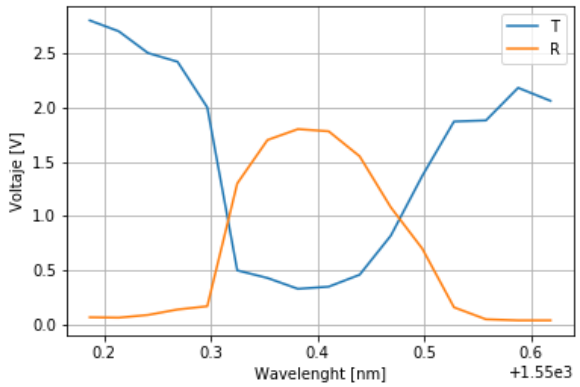


FIG. 6: Brag grating transmitted and reflected signals in function of wavelength

VI. DISCUSSION

In the first exercise the coupling of the light into single- and multimode fibers showed a big difference between the two types. Where the singlemode fiber was very sensitive to the aligning process with the efficiency only going up to a few percent. Where as the multimode fiber showed much better result between 60-70% efficiency. The numerical aperture (NA) matching of the fiber and coupling optics did also have a big efficiency dependence, since the spot size need to match the size of the fibers. If there is a big difference a large percent of the light will not reach the fiber core. This is what makes the multimode fibers much easier to couple since the core is much bigger and the NA will have the same effect.

In the second exercise where the attenuation where to be measured, a clear similarity between the measured spectra and the expected absorption can be seen. There is a large and distinct CO-peak in both and it is also clear that the infrared absorption is present as well.

In the FBG experiment, maximum reflection occurred at $\lambda_b = 1550.4\ nm$ as can be seen in FIG.6. The half maximum width can be determined to be about 0.18 nm wide, which is to be expected in a FBG experiment. Knowing the centered wavelength we can find the spacing $\lambda_b = 2n\Lambda$ and its known that the average refractive index is $n = 1.47$ giving off a spacing $\Lambda = 527.347\ nm$

VII. CONCLUSIONS

In conclusion, the different experiments showed rather expected result, with a few complications with some of the setup before correct measurement could be made. In the first exercise the aligning process showed the importance of correct NA and the size of the fiber core.

The attentuation spectra was also expected in its shape, however not precisely in the numbers which could be due to other reflections and losses in the fiber.

In the last exercise there were some problems with the FBG fiber, which first did not show any reflection. This was later corrected with another FBG which presented the expected results.

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