Experimental analysis of polarization rotation sensitivity to temperature in commercial Faraday mirrors

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The objective of this work is to study the effect of temperature on the properties of Faraday mirrors. We conducted a series of experiments on several commercial mirrors using an optical vector analyzer. The results show the dependence of the optimal wavelength (showing the lowest detuning) on temperature.

Introduction

As shown in Figure 1, a Faraday mirror is a device, which consists of a Faraday rotator followed by a planar conventional mirror. When a Faraday mirror is placed at the end of a fiber link, the roundtrip light state of polarization is rotated by 90° compared to the input state of polarization. This feature is extremely useful for solving some polarization stability issues un fiber-based setups.

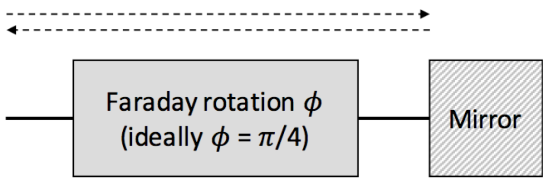

Figure 1. Internal schematic of the Faraday mirror.

The Faraday mirror (FM) is one of the key elements of a fiber-optic current sensor (FOCS) for plasma current measurement in the future international thermonuclear experimental reactor (ITER). It indeed allows partially compensating the intrinsic linear birefringence of the fiber that senses the current. As shown in [1], the limitations of the FOCS accuracy are related to the imperfection of the optical elements of the measurement setup. The FM detuning imperfection has not been considered so far. This imperfection is related to the fact that the polarization rotation induced by the FM is not exactly equal to 90 deg. Moreover, this detuning could depend on temperature. In this work, this temperature dependence is analyzed experimentally.

Measurement method

A Luna tech. Optical Vector Analyzer (OVA) was used to characterize the polarization properties of the FM. OVA measures the round-trip Jones matrix of the device under test (DUT) and using the Jones eigenanalysis method [2], it calculates the value of its Polarization Mode Dispersion (PMD). This parameter depends on several characteristics of the fiber, including its length. The longer the fiber section, the greater its PMD value. To determine the value of the polarization rotation angle induced by the FM, two measurements are required. First, we measure the value of PMD of a polarization maintaining fiber (PMF) terminated by reflector. This value will be denoted as PMD_{PMF}.

Figure 2 shows the scheme of this first measurement. Second, we measure the PMD value when the Faraday mirror is connected to the PMF. This value will be denoted as PMD_{FRM}. The scheme for this second measurement is shown on Figure 3. Finally, the value of the polarization rotation angle can be calculated from [3]:

$$\varepsilon = \arcsin\left(PMD_{FRM} / PMD_{PMF}\right) \tag{1}$$

where ε is the detuning angle of the Faraday mirror (equal to the roundtrip rotation angle minus 90 degrees). PMD_{PMF} can be measured once and used in (1) for each Faraday mirrors under test.

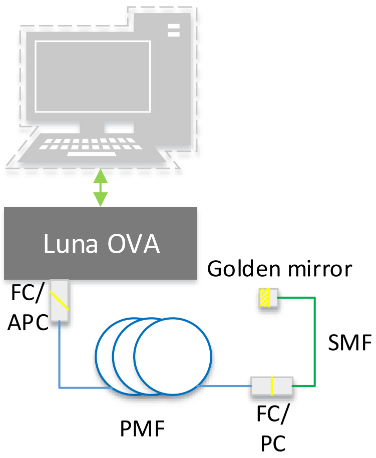

Figure 2. Scheme of the experimental setup to measure PMD_{PMF}.

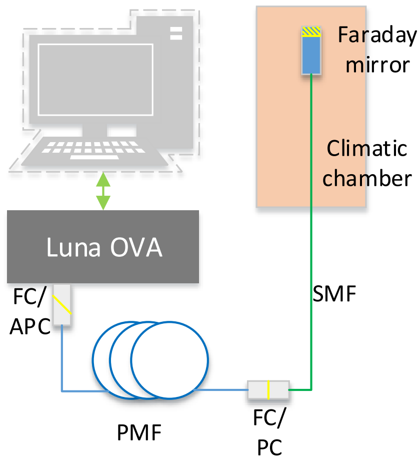

Figure 3. Scheme of the experimental setup to measure PMD_{FRM}.

For the measurements, we used a PMF patch cord with a length of 1.85 meters. The measured PMD_{PMF} averaged over the whole wavelength range was about 5 ps. The measurement temperature range was from 10^0C to 50^0C with a 5^0C step between 10^0C and 20^0C and a 10^0C step between 20^0C and 50^0C. The parameters of the OVA were set to have a measurement wavelength range from 1525nm to 1610 nm and to obtain an average curve obtained after 150 single measurements. Before measuring PMD_{FRM}, we taped the SMF pigtail of the Faraday mirror to the inside walls of the climatic chamber. The fan of the climatic chamber was turned off during the OVA operation to avoid undesirable vibration effects.

Data post processing

Figure 4 shows a typical measured dependence of the FM detuning angle on wavelength. This curve was obtained for 10^0C temperature. The obtained values agree with the results presented in [3].

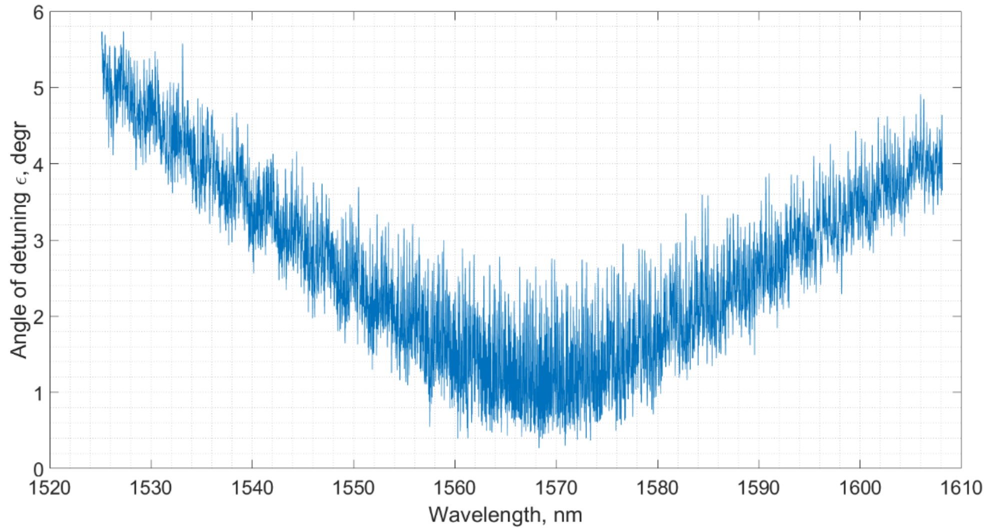

Figure 4. Typical measured curve showing the FM detuning angle versus wavelength.

As shown in Figure 4, the result is quite noisy. This is related to the small average value of PMD_{PMF} as explained in [3]. Nevertheless, from these data, it is possible to estimate the value of the wavelength at which we have a minimum of the detuning angle (optimum wavelength). To do so, an approximation by a 6th degree polynomial applied on the entre curve was performed and the x-coordinate of the optimum wavelength is that of the minimum ε value.

Results and conclusions

Figure 5 shows the measurement results, obtained for three different commercial mirrors. For each mirror, we made a linear approximation to estimate the value of the dependency slope.

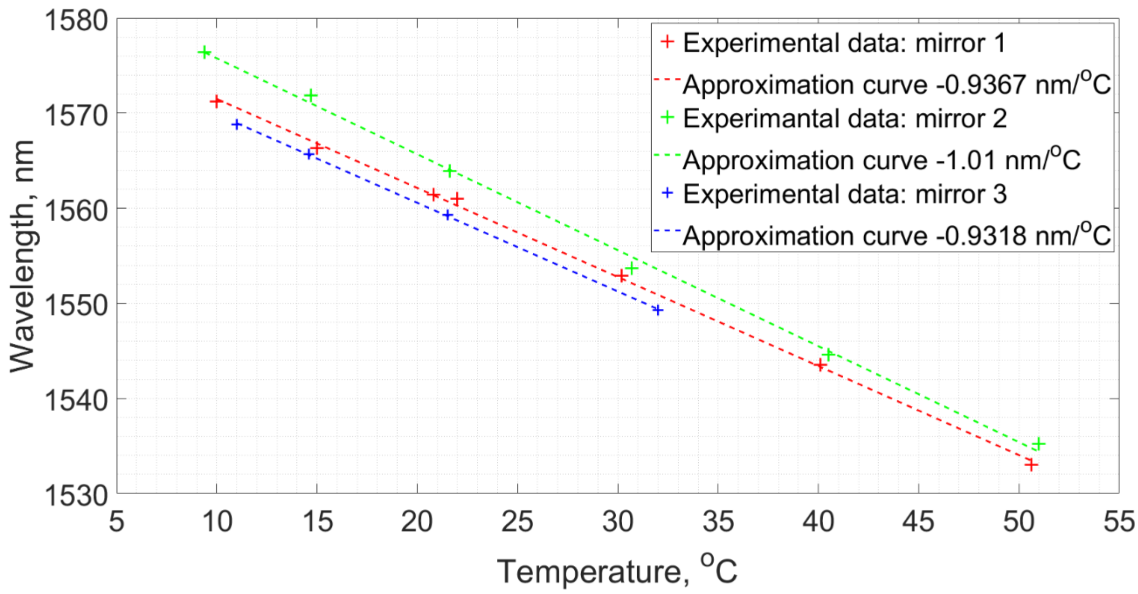

Figure 5. Dependency of the optimum wavelength on temperature for three different Faraday mirrors.

As it can be observed, all mirrors behavior shows a linear dependence on temperature with a slope of about -1 deg/nm. This means, that an increase of temperature by 10^0C leads to a decrease of the optimum wavelength by 10 nm. Most likely, the main reason of this observation is the temperature-dependent properties of Bismuth Iron Garnet (BIG) film used in the Faraday rotator (see Figure 1). The study of the Faraday rotation angle in BIG films indeed shows that they have a strong dependence on temperature [4].

Such a significant value of the temperature-induced wavelength drift will be considered for the design of FOCS applied to plasma current measurement in fusion nuclear reactors.

References

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