INTRODUCTION

The sensitivity of optical ellipsometers is in general limited, at least in the low frequency domain, by the 1/f noise. The origin of this noise is not yet well understood. Experiments searching for extremely small values of birefringences, arising for instance in the presence of an external magnetic field (PVLAS) \[1, 2\], would have a strong benefit from the comprehension and reduction of this technical noise. We have performed a study aimed at investigating the effect of a finite size optical beam on this noise.

The highest sensitivity for optical ellipsometers is normally obtained by using the heterodyne detection technique. A laser beam, with a time variable polarization state, is shined through the measuring sample. If the index of refraction of the sample is frequency modulated, a beat signal will be produced. This signal can be extracted by means of an analyzing prism. With a suitable laser power available, shot noise level can normally be reached only at a frequency of modulation in the sample of several tens of Hz. At lower frequencies, other noise sources become predominant: amplitude noise of the laser, thermal noise, vibration noise and flicker (1/f) noise. Flicker noise is probably the most subtle one, since up to now its origin has not been clearly identified. Thermal noise is perhaps more clear, however the mechanism producing 'ellipsometric noise' in the sample is again not fully understood. To try to shed some light on the mechanisms generating noise in the ellipsometer, a table-top apparatus has been realized with the aim of studying in particular the spatial correlation of the noise.

The laser beam of a standard heterodyne ellipsometer is separated into two identical beams, one of which is then split into two spatial parts, left and right. The three beams constitute three separate ellipsometers acting on the same sample under measurement, thus allowing for a study of the spatial correlations in both signal and noise of the system. In PVLAS-like optical ellipsometry, a high finesse optical Fabry-Perot cavity is also used to amplify the signal to be measured.

In the PVLAS laboratory, located within the Laboratori Nazionali di Legnaro, we have realized a small scale facility where short length optical cavities can be assembled inside the ellipsometer in order to study their characteristic. The possibility of using short cavities allows for a much faster operation.
measured. We can then identify three lock-in outputs quantities: i) \( V_a(t) \), coming from the photodiode \( \Phi_T \), proportional to the birefringence signal \( S_a(t) \) of the complete beam; ii) \( V_L(t) \), coming from the photodiode \( \Phi_L \), proportional to the birefringence signal of the left half of the beam; and iii) \( V_R(t) \), coming from the photodiode \( \Phi_R \), proportional to the birefringence signal of the right half of the beam. By using a summing amplifier it is then possible to obtain a voltage \( V_+(t) = \frac{1}{2} [V_L(t) + V_R(t)] \), which is related to a signal \( S_+(t) \) resulting from the average of the left and right halves.

![Fig. 2. Splitting of the laser beam into two geometrical separated parts left and right. Each halves is then analysed independently and the results are combined in order to eliminate uncorrelated noise.](image)

Our aim is to compare the SNR ratio between the two signals \( S_a(t) \) and \( S_+(t) \). If uncorrelated noise between the two halves is present, an increase of the SNR of a factor \( \sqrt{2} \) would be possible.

In order to have a very sensitive ellipsometer a very high finesse optical cavity is mounted between the polarizer \( P_1 \) and the SOM. The cavity is placed inside a vacuum chamber and the access is done with two optical windows. Although this facility is not housed in a clean environment, the special design of the cavity allows for a safer mounting procedure (see figure 3) [3].

![Fig. 3. The cavity assembly. The spacer and the cavity container are made of MACOR.](image)

**RESULTS**

We mounted the cavity with good quality mirrors and the measured finesse was about 10 000. The cavity showed a large birefringence and we had to align the polarization along one of the cavity birefringence axis.

It was then possible to turn on the SOM and perform a measurement of the birefringence noise. By using the Faraday Cell, a calibration signal was introduced in the system at the frequency of 4 Hz.

![Fig. 4. Frequency spectrum of the two signals \( S_a(t) \) (dotted red line) and \( S_+(t) \) (continuous black line). The peak at 4 Hz is a calibration peak generated with the Faraday cell FC.](image)

Figure 4 shows the frequency spectrum of the birefringence for the two signals \( S_a(t) \) and \( S_+(t) \). As can be seen, the height of the calibration peak is the same in the two channels, indicating a good balance between the different detection lines.

If we now compare the noise curves for the two signals we can see that no appreciable difference is present. This is a strong indication that there is no uncorrelated noise between the left and right halves of the beam. This is true over the complete band of studied frequencies, and in particular for frequencies below 2 Hz where a 1/f noise is clearly present.

This can be then stated as: 1/f noise in optical system shows correlations in the spatial distribution of the optical beams.