EPJ Web of Conferences **266**, 13027 (2022) https://doi.org/10.1051/epjconf/202226613027
EOSAM 2022

The effect of frequency modulation on the FSR of a Fabry-Perot cavity using an Optical Spectrum Analyser

João Reis[1,3], António V.Rodrigues[1,2], Paulo Robalinho[1,2], Susana Novais [1], João Maia[1], Paulo Marques[1,3], D. Roma[4,5], J. Salvans[4,5], M. Canal[4,5], J. Ramos[4,5], V. Gualani[4,5], S. Sisteré[4,5], V. Martín[4,5], M. Nofrarias[4,5], Susana Silva[1], Orlando Frazão[1]*

[1]INESC TEC, Rua do Campo Alegre s/n, 4169-007 Porto, Portugal
[2]Faculdade de Engenharia da Universidade do Porto, Rua Dr. Roberto Frias, s/n, 4200-465 Porto, Portugal
[3]Faculdade de Ciências da Universidade do Porto, Rua do Campo Alegre s/n, 4169-007 Porto, Portugal
[4]Institut de Ciències de l'Espai (ICE, CSIC), Campus UAB, Carrer de Can Magrans s/n, 08193 Cerdanyola del Vallès, Spain
[5]Institut d'Estudis Espacials de Catalunya (IEEC), Gran Capità, 2-4, Ed. Nexus, 08034 Barcelona, Spain

Abstract. It is presented a study of the dependence between the free spectral range (FSR) and the cavity length in Fabry-Perot interferometers. Furthermore, the effect of frequency modulation on the FSR is studied when an optical spectrum analyser (OSA) is used as an interrogator. For low frequency range it is possible to observe this behaviour in the OSA and using an appropriate processing signal it is possible to use the white light interferometry technique.

1 Introduction

The first Fabry-Perot interferometer was accomplished by the work of Charles Fabry and Alfred Perot in 1887 [1]. Essentially, a traditional Fabry-Perot (FP) interferometer consists in a cavity enclosed by two parallel reflecting surfaces. Since then, there has been a significant development of this interferometer and in 1993 after the invention of the optical fiber, the first in-fiber FP interferometer was demonstrated [2]. The importance and subsequent investigation of this type of structure is due to several features such as low cost, easy manufacturing, and immunity to electromagnetic interference.

The FP sensor can be used for many applications namely to measure strain [2-3], magnetic field [3-4], salinity or temperature [5]. Thus, in order to quantify the variation of the optical path length of the interferometer, which is defined as the product of the refractive index and the physical length of the cavity, the typical instrument used is an Optical Spectrum Analyzer (OSA).

In the present work, the study of the dependence of the FSR of an FP cavity with the frequency modulation is demonstrated. Also, the effect of frequency modulation observed in an OSA was explored using white light interferometry technique.

2 Free spectral range dependence with cavity length

The first test consists in the measurement of the optical spectrum of the FP cavity. An optical circulator was used to read the signal in reflection of the FP, using a broadband source (Optronics Tech ASE CL) with a bandwidth of 75 nm centred around 1565 nm to illuminate the fibre device.

Initially, the distance of the FP cavity was increased in the range of 50 to 600 μm by means of a micro-translation stage. An OSA (Yokogawa AQ6370C) was used to read the reflection spectrum of the increasing FP cavity and the correspondent FSR was measured. In Fig. 1 it is presented the optical spectrum of the FP cavity, with a cavity length of ~ 250 μm and high visibility.

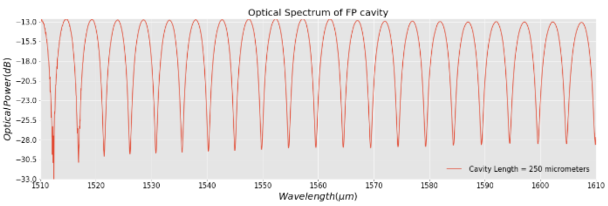

Fig. 1. Optical spectrum of the FP cavity.

In Fig. 2 it is observed the linear relationship between the FSR and the inverse of the cavity length, as predicted by the following equation [6]:

$$FSR = \frac{\lambda_0^2}{2\,n}\frac{1}{d} \qquad (1)$$

Where d is the cavity length, n is the refractive index of the air cavity ($n \approx 1$) and λ_0 is the operation wavelength. The slope obtained is of 1167.06±4.81 nm·μm^{-1}.

* Corresponding author: up201604696@edu.fc.up.pt

 https://doi.org/10.1051/epjconf/202226613027

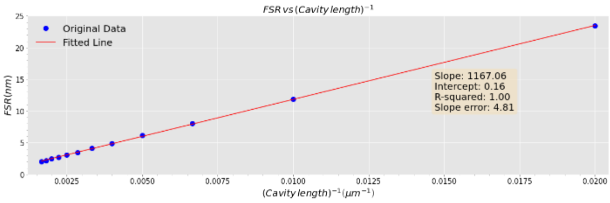

Fig. 2. FSR dependence with the inverse of the FP cavity length.

3 Frequency modulation of the correlation signal between two cascaded FP cavities

In this experiment, the setup (Fig. 3) relies on a broadband optical source with a bandwidth of 75 nm centered at 1565 nm and a four-port optical circulator. Two cascaded FP cavities are connected in independent ports of the optical circulator.

A piezoelectric stack (Thorlabs PK4GA7P1) was attached to one of the FP cavities and a high voltage amplifier (TEGAM Model 2350) was used to promote the mechanical variation of the PZT.

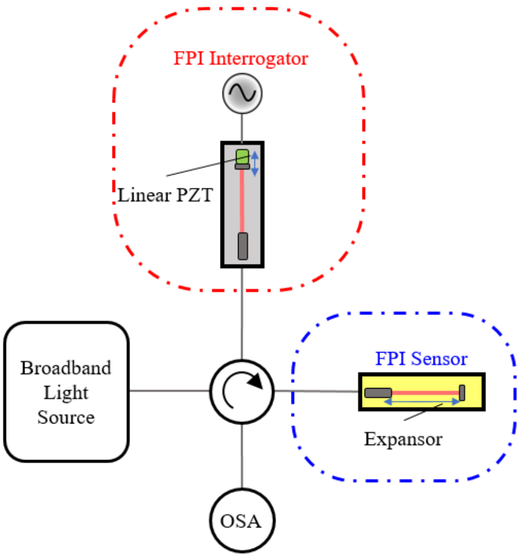

Fig. 3. Experimental setup for the characterization in frequency of the optical signal of two cascaded FP cavities.

An arbitrary wave function generator (Hewlett Packard 33120A) was used to apply a triangular electric signal to the linear PZT. The length of one cavity was continuously varied, while the other cavity length was kept constant. Therefore, the first cavity acted as an interrogator of the second cavity. The range of frequencies used was 0.5 Hz to 100 Hz and the reflected spectrum of the cascaded cavities was registered, for each frequency, in the OSA.

In Fig.4 it was observed the beat phenomenon, predicted by [7], for 0.5 Hz. When using low frequencies, the beat is generated between two cavities and the resulting modulation of the cavity variation is observed. In this case, the OSA has enough speed to keep track of the FP cavity length variation and a beat is observed (Fig.4a). However, when applying high frequency signals (above 5 Hz), the cavity length changes rapidly and the OSA is no longer able to keep track of this variation. In this case, the OSA reads the spectral response of the cavity with a background noise along the spectrum. Finally, with an appropriate signal processing it is possible to simulate the white light interferometry technique (see Fig. 4b).

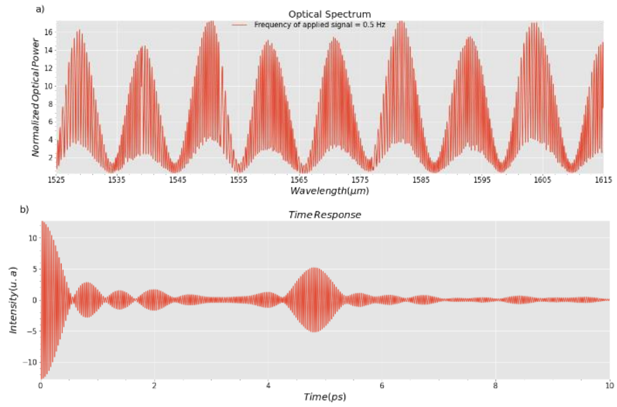

Fig. 4. Beat of the modulation signal of an FP cavity for 0.5 Hz: a) optical spectrum and b) time response.

4 Conclusion

In conclusion, it was determined that for low frequencies the OSA can be used to observe signal modulation, and with a suitable signal processing, it can been read by means of white light interferometry technique. Thus, in order to overcome this challenge for high frequency, an alternative solution involves the use of a fast detection system such as a single photodetector connected to an oscilloscope.

This work was realized with the financial support of the Lira Project in accordance with the terms of ESA Contract No. 4000135481/21/NL/AR.

References

1. M.R. Islam, M.M Ali, M. Lai, K.S. Lim, MDPI. Sens. **14**, 7451 – 7488 (2014).
2. J.S. Sirkis, D.D. Brennan, M.A. Putman, T.A. Berkoff, A.D. Kersey, E.J. Friebele, Opt. Lett. **18,** 1973 – 1975, (1993).
3. G.K.B. Costa, P.M.P. Gouvêa, L.M.B. Soares, J.M.B Pereira, F. Favero, A.M.B Braga, P. Palffy-Muhoray, A.C. Bruno, I.C.S Carvalho, Opt. Lett. **24**, 14690 – 14696, (2016).
4. K.D Oh, J. Ranade, V. Arya, A. Wang, R.O Claus, EPL, IEEE Photo. Tech. Lett. **9**, 797 – 799 (1997)
5. R. Flores, R. Janeiro, J. Viegas Scient. Repo. **9**, 9556 (2019).
6. M. Born, E. Wolf, *Principles of Optics Eletromagnetic Theory of Propagation, Interference and Diffraction of Light* (1999)
7. P. Robalinho, A. Gomes, O. Frazão, IEEE Sens. **21**, 4623 – 4627 (2021).