THE EFFECT OF AC SOURCE TO FABRY-PEROT OPTICAL FILTER

Nguyen Thi Thu Linh[1], Nguyen Thi Xuan Mai[2,*]

[1] *Faculty of International Training (FIT), Thai Nguyen University of Technology, Vietnam*
[2]*Faculty of Fundamental Science, Thai Nguyen University of Technology, Vietnam*

ABSTRACT

This paper presents an actuation method for the Fabry-Perot (FP) optical filter (Micro Electromechanical System) using the electrostatic force to get the desired wavelengths. The AC source is conventionally used to actuate. High precision experimental results were performed to clarify these effects of AC power frequency.

Keyword: *MEMS, FP, AC source.*

1. INTRODUCTION

MEMS (Micro-Electro-Mechanical System) consists of mechanical actuators, sensors, and other devices at micrometer size[1-5]. The principle of operation of these devices is based on physical phenomena such as: thermal expansion, mechanical force, the electromagnetic force, and electrostatic force [6-8]. MEMS devices based on electrostatic resistivity have many advantages in micrometer and nanometer dimensions.
FP optical filter is one of the MEMS devices used in optical communications, medical and analytical engineering. In optical communication, an FP optical filter is used to adjust and follow the WDM signal [9]. In this paper, the micro FP optical filter is an actuator and is controlled to have the desired wavelength to go through.

2. STRUCTURE AND CONTROL TECHNIQUES FOR FP OPTICAL FILTER

2.1. The structure of the optical filter

An FP optical filter, as shown in Fig. -1, consists of two Bragg reflectors (DBRs) with high reflectivity, the distance between the two Bragg reflectors will determine the output wavelength

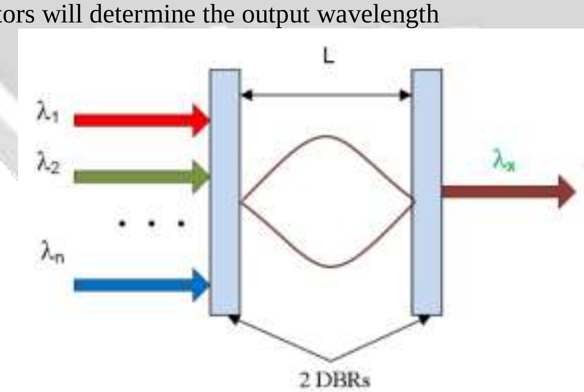


Fig -1: The structure of the FP optical filter

The beams of light to the FP optical filter consist of different wavelengths, but the filter's output only captures the light of a certain wavelength. The electrostatic force will determine the distance between these two reflectors.
The use of electrostatic force for MEMS equipment is appropriate because of the energy density and the feasibility of the electromechanical devices. In many actuators, the balance between the electrostatic attraction and the elastic force will determine the positions of the electrodes. The wide range of electrode placement is extremely useful for various applications of microelectromechanical systems.

An FP optical filter with two reflectors can be considered two electrodes of a parallel capacitor. An electrode is fixed on the base, and the other is movable, as shown in Fig -2.

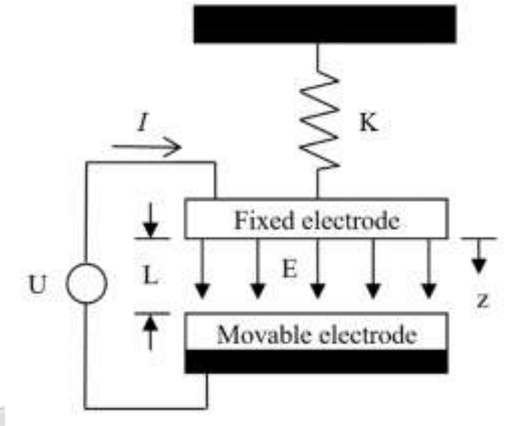


Fig -2: FP optical filter model in the form of two parallel electrodes

2.2. Adjust the distance between two electrodes

As shown in Fig. 2, the movable electrode is connected to a spring with the elastic force F_M, calculated as follows:

$$F_M = Kz \quad (1)$$

z - vertical displacement,
K – elastic coefficient of the spring.

The distance between the two electrodes depends on the elastic force F_M and the electromagnetic force. In order to produce electromagnetic force and to control the distance between these two electrodes, we use an AC power supply.

Assume that the AC source is in the sinusoidal waveform and the current in the optical filter can be calculated in Eq.2, with the angular frequency ω and the effective current value I_{RMS}

$$I(t) = I\sin(\omega t) = \sqrt{2} I_{RMS}\sin(\omega t) \quad (2)$$

If the angular frequency ω of the AC source I (t) is higher than the mechanical resonance frequency, the electrostatic force can be calculated as follows:

$$F_E = -\frac{d}{d_z}\left(\frac{q^2(t)}{2C}\right) = \frac{I^2}{2\varepsilon A\omega^2}\cos^2(\omega t) \quad (3)$$

with $q(t) = \int I(t)dt = \int I\sin(\omega t)dt$ is the charge of the capacitor.

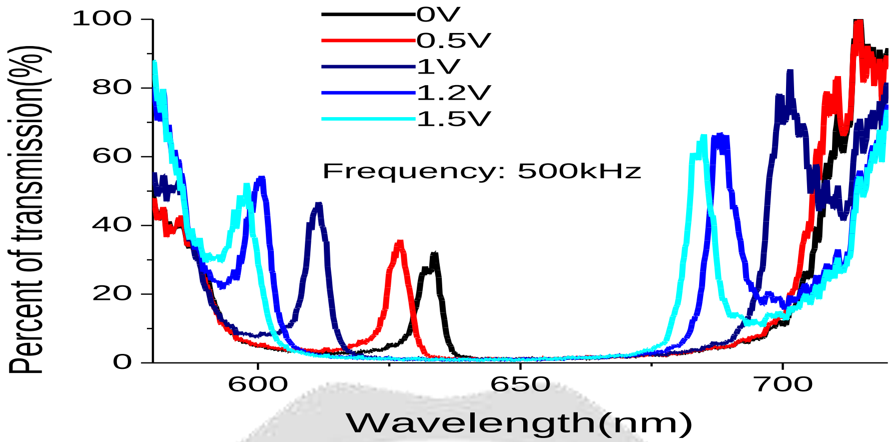
Thus, according to Eq.3 when we change the amplitude and frequency of the current source, the distance between the two electrodes will change.

3. RESULTS AND EXPERIMENTS

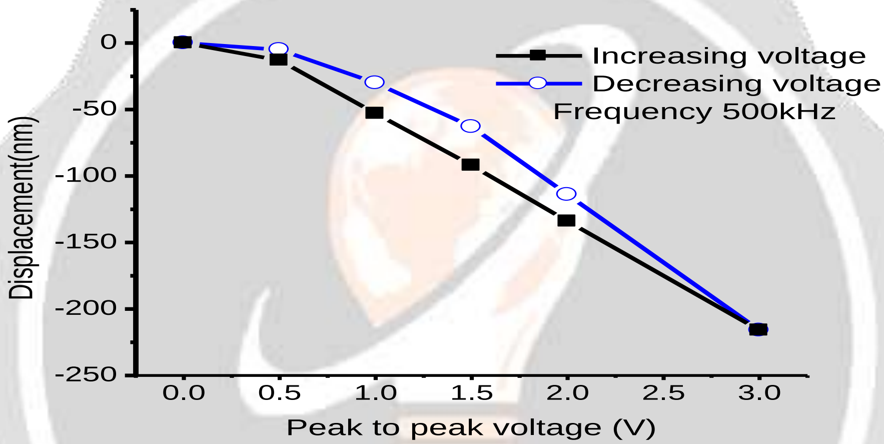
Measure the actual displacement of the electrode in the FP optical filter, a white light interferometer made by Zygo company. In this paper, the spectra filtered by the FP were measured by the spectrum analyzer, version HR2000, made by Ocean Optics. The data measured by New View 5000 were analyzed by MetroPro software to produce the results of the measurements.

3.1 At 500 kHz frequency

The spectral output transmitted through the filter and the actual displacement of the Bragg reflector at 500 kHz, as shown in Fig. -3.



(a) Transmitted spectrum



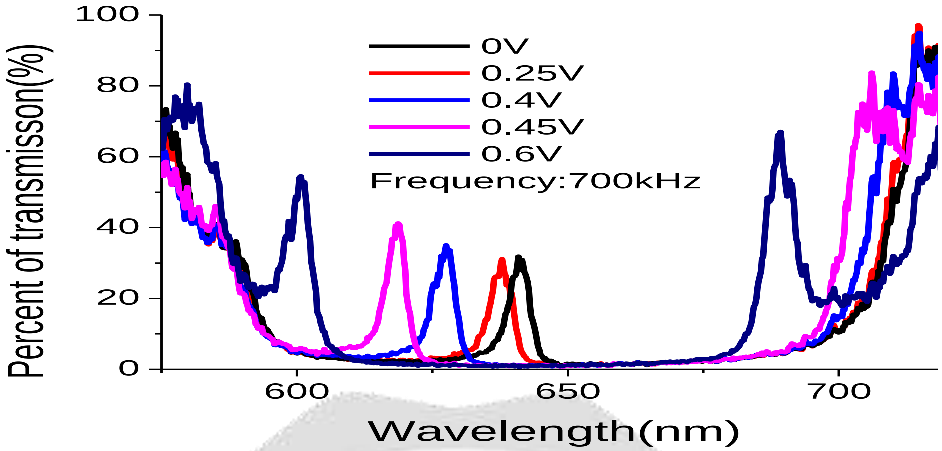
(b) Reflector displacement

Fig -3: Control at 500Khz frequency

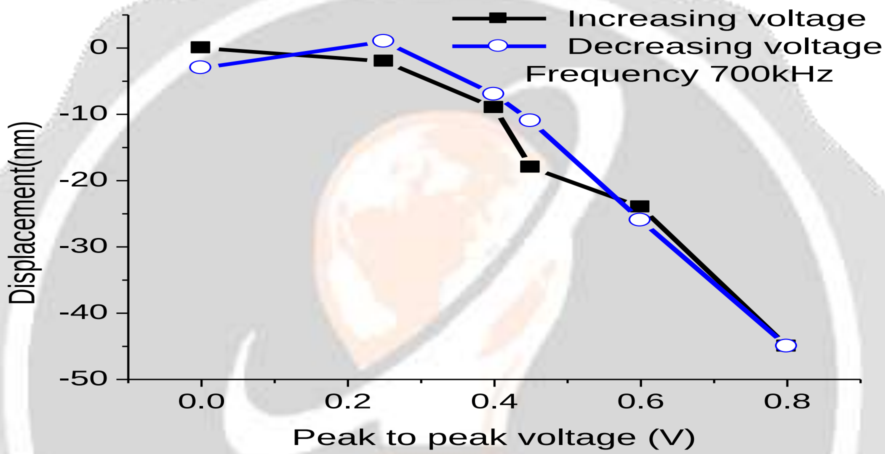
The results in Fig. -3a show that, in the transmitted spectrum, the applied peak voltage varies from 0 to 1,5v, and the transmitted spectrum moves to the left compared to the central wavelength. In Fig. -3b, the voltage varies from 0 to 3v.

3.2. At 700 kHz frequency

The spectral output transmitted through the filter and the actual displacement of the Bragg reflector at 700 kHz as shown in Fig. -4



(a) Transmitted spectrum



(b) Reflector displacement

Fig -4: Control at 700Khz frequency

When the voltage varies from 0 to 0,6v, the transmitted spectra move to the left of the central wavelength. In Fig. -4b the voltage varies from 0 to 0,8v.

4. CONCLUSIONS

In this study, the different frequencies of 100 kHz, 500 kHz, and 700 kHz were studied. For frequencies below 100 kHz, the transmitted spectra through the filter have a reduced amplitude, so there is no practical significance. For frequencies above 700 kHz, accurate measurement of both the amplitude of the voltage and the frequencies on oscilloscopes are much more complex. At 500 kHz frequency, the displacement of the Bragg reflector varies in a range of 0 to 225 nm. However, there is a slight bias between the increased voltage and the decreased one. At 700 kHz frequency, The displacement of the Bragg reflector on the expanded voltage line.

5. ACKNOWLEDGEMENT

This work is supported by Thai Nguyen University of Technology, Vietnam

6. REFERENCES

[1]. Younis, M. I. (2011). MEMS linear and nonlinear statics and dynamics (Vol. 20). Springer Science & Business Media.

[2]. Judy, J. W. (2001). Microelectromechanical systems (MEMS): fabrication, design and applications. Smart materials and Structures, 10(6), 1115.

[3]. Grayson, A. C. R., Shawgo, R. S., Johnson, A. M., Flynn, N. T., Li, Y., Cima, M. J., & Langer, R. (2004). A BioMEMS review: MEMS technology for physiologically integrated devices. Proceedings of the IEEE, 92(1), 6-21.
[4]. Spearing, S. M. (2000). Materials issues in microelectromechanical systems (MEMS). Acta materialia, 48(1), 179-196.
[5]. Niarchos, D. (2003). Magnetic MEMS: key issues and some applications. Sensors and Actuators A: Physical, 109(1-2), 166-173.
[6]. Girbau, D., Pradell, L., Lázaro, A., & Nebot, A. (2007). Electrothermally actuated RF MEMS switches suspended on a low-resistivity substrate. Journal of microelectromechanical systems, 16(5), 1061-1070.
[7]. Ollier, E. (2002). Optical MEMS devices based on moving waveguides. IEEE Journal of selected topics in quantum electronics, 8(1), 155-162.
[8]. Versaci, M., Jannelli, A., & Angiulli, G. (2020). Electrostatic micro-electro-mechanical-systems (MEMS) devices: a comparison among numerical techniques for recovering the membrane profile. IEEE Access, 8, 125874-125886.
[9]. Patterson, J. D. (1997). Micro-mechanical voltage-tunable Fabry-Perot filters formed in (111) silicon. *Ph. D. Thesis*, 1449.