COMPARISON BETWEEN DC AND AC SOURCE TO CONTROL FABRY-PEROT OPTICAL FILTER

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ABSTRACT

This research presents an actuation method for the Fabry-Perot optical filter (Micro Electromechanical System) using the electrostatic force in order to get the desired wavelengths. DC source is conventionally used to actuate to control this force, but the stability is not high. To overcome this problem, we apply an AC actuation at several frequencies and study the effect of the frequencies to control quality. Experimental results with high accuracy are performed to evaluate the quality criteria of the system.

Keyword: *MEMS, FP, DC source, AC source.*

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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, 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 MEMS devices used in optical communications, medical and analytical engineering. In the field of optical communication, 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 in order for the light having the desired wavelength to goes through.

2. STRUCTURE AND CONTROL TECHNIQUES FOR FP OPTICAL FILTER

2.1. The structure of the optical filter

A 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

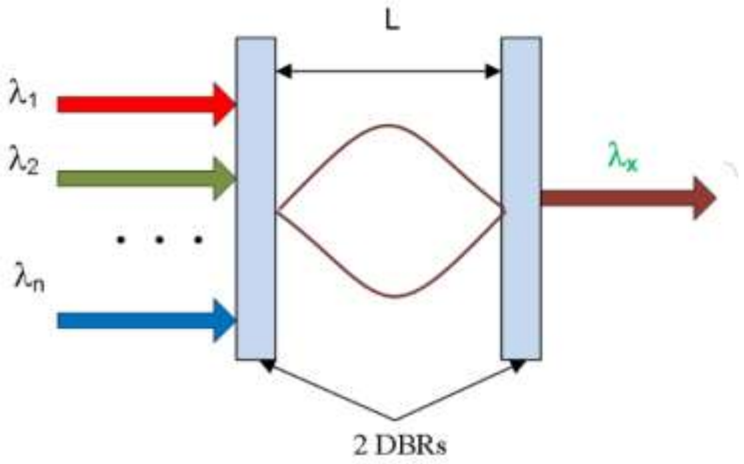


Fig -1: The structure of the FP optical filter

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.

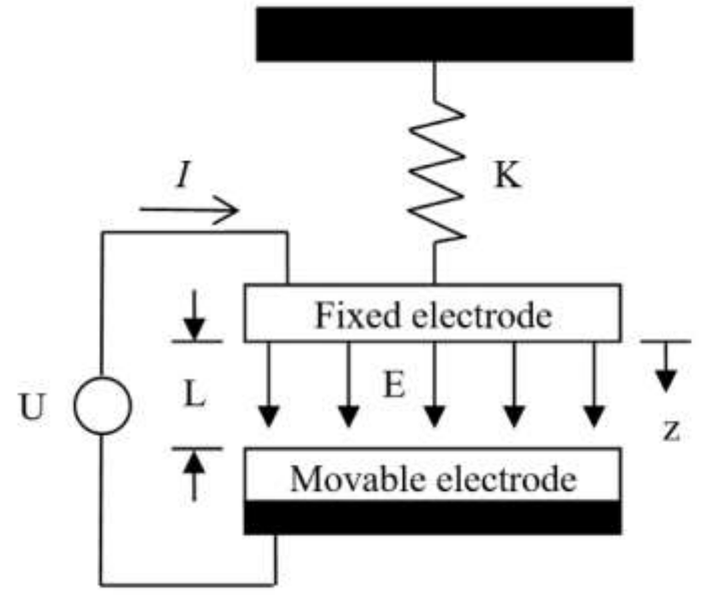


Fig -2: FP optical filter model in the form of two parallel electrodes

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:

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

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 a DC power supply.

The electrostatic force F_E is opposite to the elastic force F_M. When the DC voltage is set to the two electrodes, the electrostatic force is determined:

$$F_E = -\frac{d}{dz}\left(\frac{1}{2}CU^2\right) = \frac{\varepsilon\ AU^2}{2(L-z)^2} \tag{2}$$

ε: Dielectric constant
C: Capacitance of the capacitor
A: The area between two electrodes
L: Initial air gap between two electrodes
U- Input voltage set to two electrodes

Thus, according to (2), when U changes, F_E will change causing the distance between the two electrodes to change as well.

Assume that the AC source is in the sinusoidal waveform and the current in the optical filter can be calculated in Eq.3, with the angular frequency ω and the effective current value I_{RMS}

$$I(t) = I\sin(\omega t) = \sqrt{2}I_{RMS}\sin(\omega t) \tag{3}$$

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:

$$F_E = -\frac{d}{d_z}\left(\frac{q^2(t)}{2C}\right) = \frac{I^2}{2\varepsilon A\omega^2}\cos^2(\omega t) \tag{4}$$

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

Thus, according to Eq.4 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.

The experimental results performed with DC and AC sources were performed in [10,11]. We make the following comparisons:

The first comparison: the stability of the transmitted spectrum through the filter at certain voltages

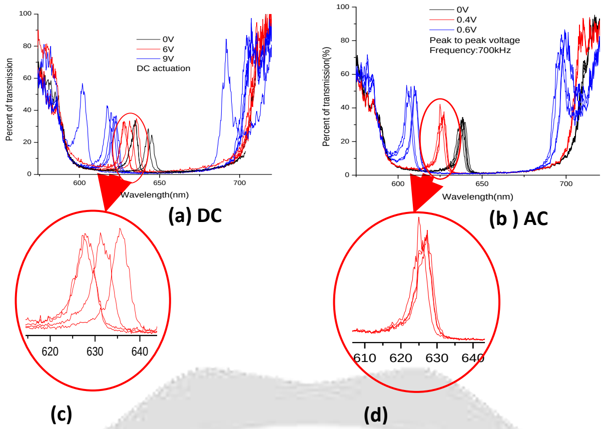
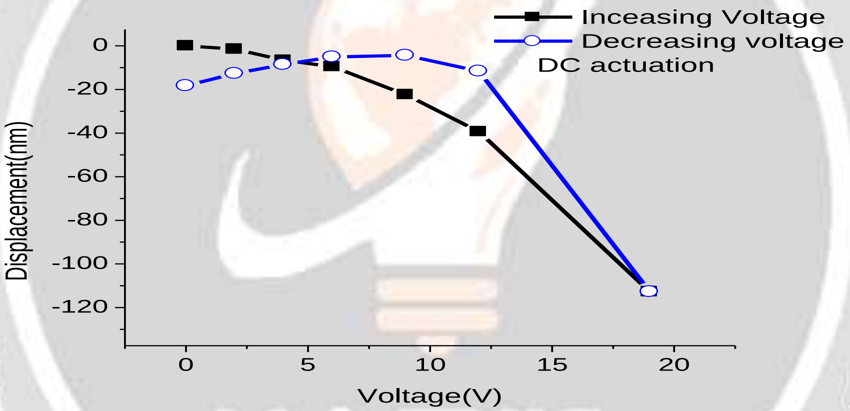


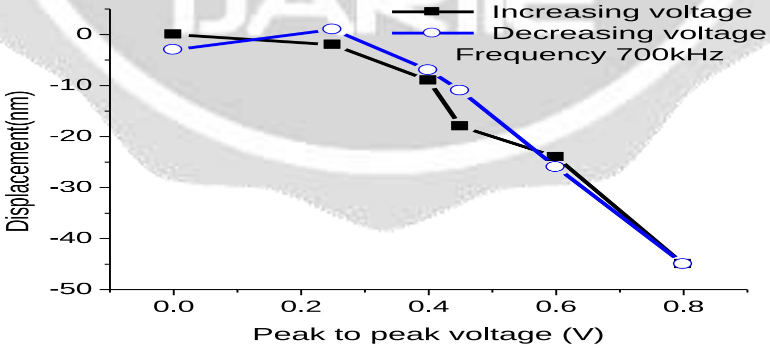
Fig -3 Transmitted spectrum when controlled with DC and AC sources

Fig -3 shows the difference of transmitted spectra when the filter is controlled by DC and AC source.

The second comparison: the result of the actual displacement of the Bragg reflector when the voltage increases or decreases.



(a) DC source control



(b) AC source control

Fig -4 Displacement of the upper Bragg reflector.

Fig -4 (a) and (b) illustrate the displacement of the Bragg reflector and compare two cases: control with a DC source and an AC source. The coincidence of the two lines during the increase and decrease of the voltage indicates the stability of the control. Control with a 700 kHz AC source indicates that the two lines are almost identical, while that with a DC source indicates a significant difference.

4. CONCLUSIONS

From the experimental results on the Fabry-Perot optical filter, we have the conclusion. The response time when controlled with an AC source is faster than with a DC one when the set voltage changes to a new value. The stability of the AC control has been proven to be better than of the DC one because the AC control is not affected by the distance parameter between the two capacitor (the distance between two reflectors) and the residual charge parameter of the capacitor.

5. ACKNOWLEDGEMENT

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