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ПЕРЕСТРАИВАЕМЫЕ ФИЛЬТРЫ ФАБРИ – ПЕРО

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Перестраиваемые светофильтры широко используются для перестройки длин волн в УФ, видимом и ИК диапазонах. Их преимущества заключаются в простоте, точности и высокой монохроматичности. Изменяя магнитное поле, можно перестраивать светофильтр и, при необходимости, выбрать желаемую длину волны. В статье представлены перестраиваемые светофильтры на основе интерферометра Фабри-Перо. Эти светофильтры могут перестраиваться в диапазоне длин волн от 400 нм до 1000 нм, в ИК-диапазоне от 8 мкм до 12 мкм, с шириной спектральной полосы пропускания от 0,5 мкм до 1 мкм, управляющее напряжение 0,5 – 1,5 мкВ.

Ключевые слова: перестраиваемые светофильтры, интерферометр Фабри–Перо, микроэлектромеханические системы (МЭМС), компоненты МЭМС

FABRY – PEROT TUNABLE FILTERS

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Tunable light filters are widely used for selecting different bands of wavelengths in the UV, visible and IR spectrum. Their advantages are simplicity, accuracy and high mono-chromaticity. By varying magnetic field it is possible to adjust the filter and select desired wavelength if necessary. In the paper a research on tunable light filters based on Fabry-Perot interferometer (FPI) is presented. These light filters can be tuned in the wavelength range from 400 nm to 1000 nm, in IR band of 8 – 12 μm, with spectral pass band width between 0.5 μm and 1 μm, out of band rejection than 10:1 with a resolution of 0.5 – 1.5μV.

Keywords: tunable light filters, Fabry-Perot interferometer, microelectromechanical systems (MEMS), MEMS components

Introduction

Over the past few years, network traffic has grown rapidly and the optical transport bandwidth has been continuously increasing. Optical networking using wavelength-division multiplexing (WDM) is the technology of choice for meeting these growing demands. Since in WDM systems each channel is related to a different wavelength, channel manipulations and particularly channel selection require optical wavelength selection (i.e., optical filtering). Single and multiple tunable Fabry-Perot interferometers have long been used as narrow-band commercial optical filters for WDM networks [1−3]. In this paper, a design of tunable light filter based on Fabry-Perot interferometer is proposed. The main advantage of the proposed architecture over the conventional tunable FPIs is its ability to provide high finesse with potentially low cost. Tunable optical filters are now the major key devices for many applications such as monitoring of different industrial processes, and dense wavelength division multiplexed networks (DWDM), environmental measurements, food/water quality analysis and monitoring.

Most of the works reported in the literature for achieving a tunable FPI involve either alteration of the length of the resonator cavity via a moveable mirror or by inducing change in the refractive index of the material inside the cavity via thermal, electrical, piezoelectric, or other means [4-6].

Fabry-Perot interferometer is an optical resonator which consists of two parallel mirrors. In addition the pass band wavelength of the tunable FPI can be controlled by adjusting the distance between the mirrors. Fabry-Perot interferometers can be made by silicon bulk [7, 8] or surface micromachining [9, 10]. The first commercially capitalized micromechanical FPIs were made for gas concentration measurements with traditional polycrystalline silicon based surface micromachining techniques [11].

Problem

In this paper, the expected characteristics of tunable light filters are considered. Two highly reflective mirrors are employed as bandpass filters.

Theory

With the use of two mirrors placed at a distance from each other the monochromaticity of radiation separated from the source spectrum with the width of the tunable range can be increased.

The Fabry-Perot interferometer is a typical multiple beam device. In Fig. 1 the interferometer has a substrate layer 10 wherein there may be layer with a hole 9 at the optical area of the interferometer providing an optical aperture for the interferometer. All the mirror layers are solid materials, mirror 1 and mirror 2 are silicon oxide and the layer 2 is doped in order to provide an electrically conducting electrode of the movable mirror with an air gap between them and layer 8 is a gap which includes vacuum, air and other transparent gases. The control is electrostatic. The interferometer is thus usable in shorter wavelegths of radiation. The Reflecting layers of the fixed mirror are provided by Layer 3 and Layer 4, Layer 5 serves as the gap between them. Layer 4 is a doped silicon and serves as a control electrode of the fixed mirror outside the optical area there is an air gap 6 which serves as the cavity of the interferometer. Layer 7 gives support of the mobile mirror bend with decreasing gap and streghtnen when it increases. Movable mirror area including air gap is made more flexible than the area with solid material. Therefore the stiffness of the moveable mirror is higher at the optical area than at the surrounding area. As a result, bending of the movable mirror mainly takes place outside the optical area, while the mirror area at the optical area remains substantially flat. Part of the light is transmitted each time the light reaches the second reflecting surface and the transmitted light rays interfere with each other to give rise to a maxima or minima depending on the path difference between them.

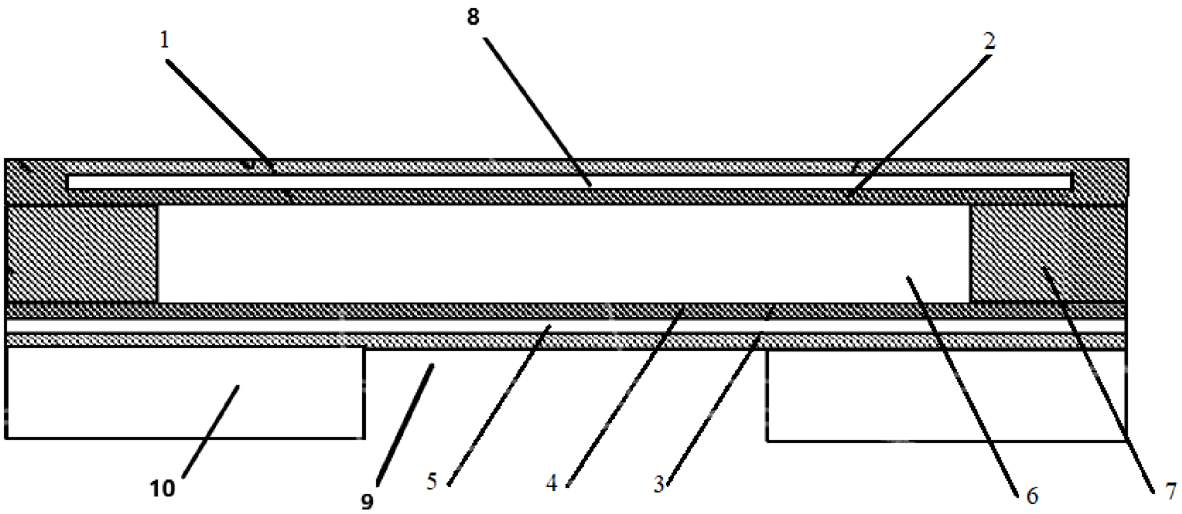

Fig. 1. Cross section of Fabry-Perot interferometer

Let us define possible parameters of Fabry-Perot interferometer.

In the interference pattern, the spectra of neighboring interference orders are superimposed.

The magnitude of the free spectral region (dispersion region) is equal to:

$$\Delta\lambda = \frac{\lambda^2}{2nL}, \tag{1}$$

where L is the distance travelled by light around the closed cavity.

The phase difference of the interfering beams is equal to:

$$\delta = \frac{2\pi}{\lambda}\Delta, \tag{2}$$

where, λ is the wavelength in vacuum, Δ is the optical path difference for any pair of adjacent beams.

$$\Delta = 2hn\cos\varphi, \tag{3}$$

where, h is the thickness of the layer between the interferometer mirrors, φ is the angle of incidence of light rays, n is the refractive index of the layer.

Condition for maximum and minimum of pattern interference:

$$2hn\cos\varphi = m\lambda; \tag{4}$$

$$2hn\cos\varphi = (2m+1)\frac{\lambda}{2}, \tag{5}$$

where m is the order of the interference.

The transparency of a Fabry-Perot interferometer for monochromatic radiation is expressed by the formula:

$$T_{FP} = \frac{T^2 T_{cp}}{(1-T_{cp}R)^2 + 4T_{cp}R\sin^2(\beta L)}, \tag{6}$$

where, T is the transmittance of the interferometer mirrors, R is the reflectance of the mirrors, T_{cp} is the power transparency between the mirrors, and βL is the phase difference between two adjacent beams.

Incident light is either reflected or transmitted by the first surface. Then it is bent according to refraction index of material in the gap. When it hits the second surface it is again, either reflected or transmitted. Light that is reflected back in to the gap travels to the other side and is either reflected or transmitted. Light that is reflected again may be transmitted when it again reaches the back of the etalon. Each transmitted wave has a slightly different phase than the other ones. The phase difference is due to the longer optical path length acquired through multiple bounces between the reflective surfaces. By tracing the light through the etalon mathematically the equation for the total transmission of the etalon is derived [12].

Conclusion

The tunable light filters based on Fabry-Perot interferometer can be applied in various fields of engineering and in analysis of various gases in research of harmful substances. And the major reason why the proposed Fabry-Perot interferometer is more adequate over conventional tunable FPIs is discussed.

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