MEMS actuated integrated, tunable optical filter's based on micro Ring Resonator

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Abstract: ***In the recent years optical networks has been proved out to be very efficient and faster compared to traditional satellite and wired network. Optical filters are needed for dynamic allocation and bandwidth selectivity of input signals in these networks. For filtering microring Resonators are considered best due to their various advantages such as small size, light weight, effective operational capability and inexpensiveness. Integrated ring resonators are compact, integrated micro structures which can be used for Multiplexing/Demultiplexing, Modulation/Demodulation, Switching and filtering of optical signals. This paper gives an overview of applications of Ring Resonators in modern optical communication system especially with Microelectromechanical systems (MEMS). We have focused this study in the field of optical filters. Basic structure and characteristics along with recent inventions and works done in this field has been summarized.***

Keywords: Integrated Ring Resonators, Optical filters, WDM, MEMS.

1. Introduction

Optical filter is essentially same as the traditional electrical filter in the sense they allow a particular signal to pass through it and block others. Optical filter is an optical structure which applies a designed amplitude and phase to the incident light signal. This paper gives an overview about optical filter which uses ring resonators. Ring resonator is an integrated microstructure made by silicon which consists of a circular waveguide and one or more straight waveguides. It's operating principle is similar to that of whispering galleries but instead of sound waves. Optical signal is used and they obey properties behind constructive interference and total internal reflection. It has four ports which are Input, Throughput, Add and Drop ports. When the light of resonant wavelength is supplied at the input waveguide it builds up in intensity due to repeated round trip in circular ring and comes out at the output waveguide. Light wave couples from one waveguide to another by evanescent fields. Gap and coupling length between waveguide determines how much power is coupled from straight to circular waveguide and vice versa.Fig.1 shows the basic structure of ring resonator.

A single waveguide with one ring acts as a notch filter and if use two parallel straight waveguide than it acts as an add/drop filter.

A. Single Ring Resonators:

Single ring resonator consists of unidirectional coupling between a ring resonator with radius r and a waveguide, is described in Fig. 2. Defining that a single unidirectional mode of the resonator is excited, the coupling is lossless, single polarization is considered, none of the waveguide segments and coupler elements couple waves of different polarization, the various kinds of losses occurring along the propagation of light in the ring resonator filter are incorporated in the attenuation constant .Fig. 3 shows its characteristics.

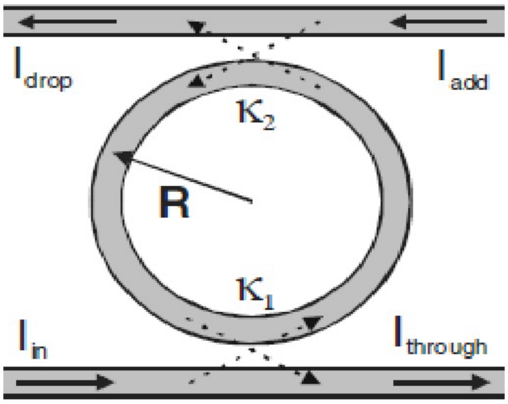

Figure 1: Basic structure of optical ring resonator

B. Double Ring Resonators:

Double ring resonators offer the possibility of realizing a box-like filter characteristic which is favorably used in optical networks. This is not the only advantage, but also from the point of characterization, two rings if coupled in series have the drop port in the same direction as the input port, which is also convenient for interconnection of many 2 cross 2 devices. Ring resonators can be connected in serial and parallel configuration.

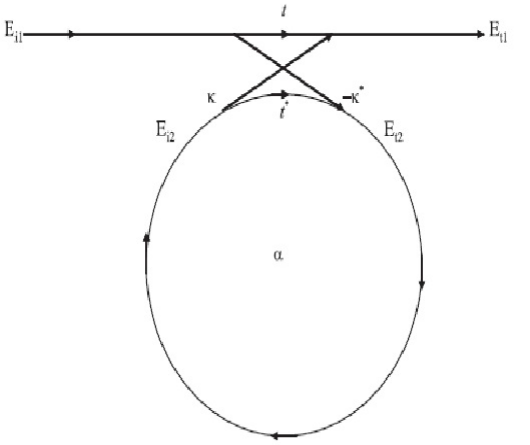

Figure 2: Model of a single ring resonator with one waveguide

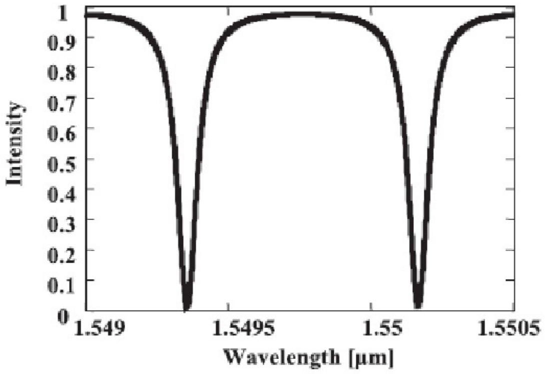

Figure 3: Notch type ring resonator filter characteristic

In the serially coupled configuration, each ring resonator is coupled to one another, and a signal that is to be dropped from the input port to the drop port must pass sequentially through each resonator. Because of this sequential power transfer, all resonators must be precisely resonant at a common wavelength. The resulting resonant line shape in the series configuration is determined physically by the separations between the ring resonators.

In the parallel-coupled configuration, all resonators are coupled to both the input and drop port waveguides, but usually not directly to one another (the resonators can also be coupled to one another resulting in a wavelength selective reflector. The resonators are instead indirectly coupled to each other by the optical path lengths along the input and output waveguides that interconnect them. These lengths determine the details of the resonant line shapes. An optical signal in the parallel configuration passes through all ring resonators simultaneously. This softens the requirement that the resonances of each ring have to be precisely identical. Nonaligned resonant frequencies instead lead to multiple peaks, or ripple in the line shape.

(1*). Serially coupled Double ring resonator*:

Schematic of serially coupled ring resonator is shown in Fig 4. Here one ring is coupled with another and optical signal has to travel from both the rings to go to different ports. Coupling between the rings is affected by separation between them.

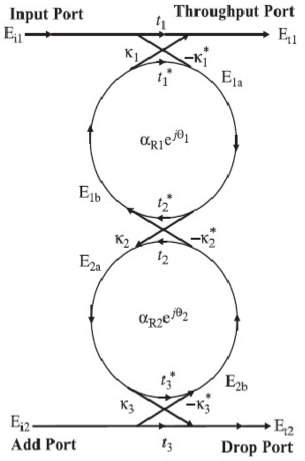

Figure 4:Two ring resonators coupled in series

(2) *Parallel coupled Double ring resonator*:

In parallel coupled connection both the rings will be connected to both waveguides and any input signal will enter to both the rings simultaneously. Parallel coupled ring resonator is shown in fig.5.

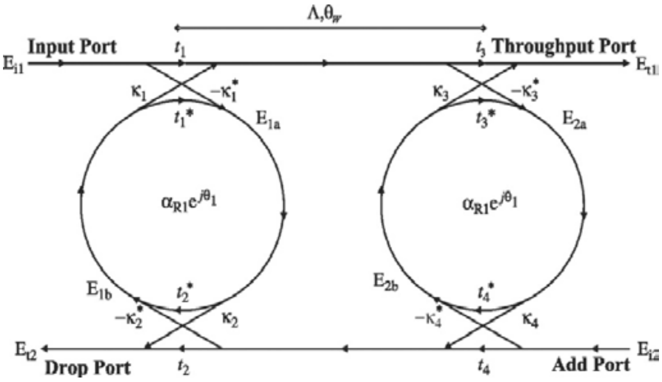

Figure 5: Parallel coupled double ring resonator

C. Multiple Coupled Resonators:

The use of multiple vertical or lateral coupled ring resonator configurations opens up the possibility to realize custom designed transmission functions and thus is suitable for a wide variety of device implementations. Vertical and lateral ring resonator architectures where the rings are either coupled in series or in parallel have been implemented in the past. The use of multiple coupled ring resonator configurations together with other photonic devices like grating couplers or Mach Zehnder interferometers increases the functionality and transmission characteristic even further. One of the main targets of realizing optical filters is to tailor the pass band shape.

(1) *Serially Coupled Ring Resonators*:

Serially coupled Ring resonators (as shown in fig. 6) are also referred to as coupled-resonator optical waveguides (CROW).

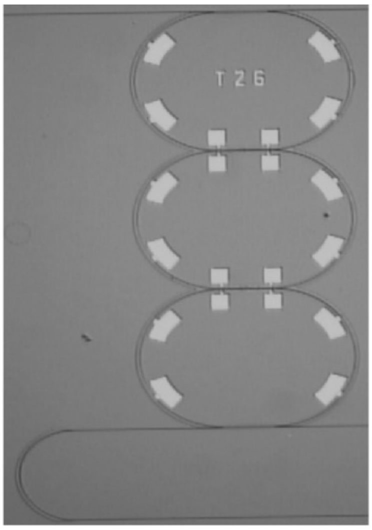

Figure 6: Photograph of a serially coupled triple ring resonator

(2) *Parallel Coupled Ring Resonators*:

One of the advantages of parallel coupled ring resonators(as shown in fig.7) over serially coupled ring resonators is that their transfer functions are less sensitive to fabrication tolerances, as each ring resonator can compensate errors in any of the others.

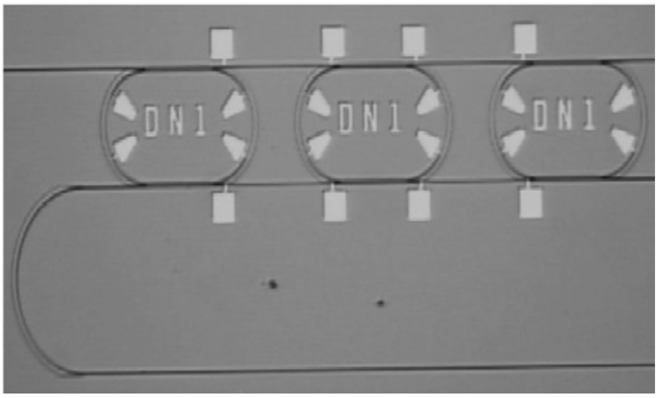

Figure 7: Photograph of a Parallel coupled triple ring resonator

D. Ring Resonator Parameters:

Ring resonator filters can be described by certain figures of merit which are also generally used to describe optical filters

(1) *Free Spectral Range*: Optical resonators provide transmission spectra that are periodic in the frequency domain. They demonstrate narrow peaks followed by broad low transmission minima. We therefore need a measure of the frequency interval between the peaks and this is the free spectral range (FSR).The FSR for any resonator is the reciprocal round trip time of a photon in the cavity.

$$\Delta\nu = c / n_{\text{eff}}.L_{\text{ring}} \qquad (1)$$

(2) *Full width at half maximum (FWHM) or 3 dB bandwidth:*

It is the width of a spectrum curve measured between those points on the y-axis which are half the maximum amplitude. Fig. 8 shows relationship between FSR and FWHM.

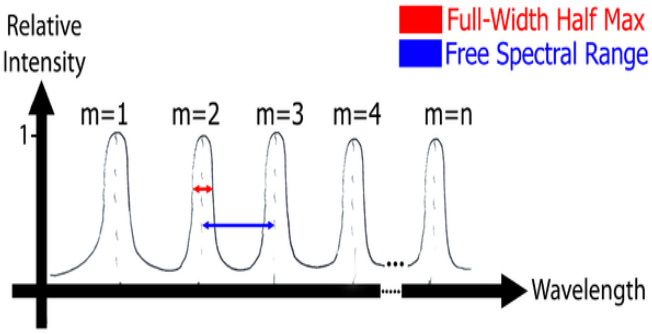

Figure 8: FSR and FWHM

(3) *Finesse (related to Q factor):*

The finesse is a measure of the resonators frequency selectivity. Generally, finesse is more commonly used in optics than in microwaves and electronic circuits, where the quality factor (Q-value) is preferred. It can be expressed as the ratio of Free Spectral Range and Full width at half maximum.

$$F = \frac{FSR}{FWHM} \qquad (2)$$

(4) *Intensity enhancement or Buildup factor (B):*

The intensity in the ring resonator can be much higher than that in the bus waveguides, as the traveling wave in the ring resonator interferes constructively at resonance with the input wave and thus the amplitude builds up. In addition to this intensity increase, the field also experiences a phase-shift of an integral multiple of 2 in one round trip. The intensity enhancement or buildup factor B is given by

$$B = \frac{E2}{E1} \qquad (3)$$

(5) *Depth of Modulation*:

$$M\,(\text{dB}) = 10.\log\,[K] \qquad (4)$$

$$K = \frac{Y_{max}}{Y_{min}} \qquad (5)$$

Where Ymax is relative peak intensity and Ymin is relative minimum intensity.

E. Wavelength tuning in Optical Filter:

Tunability is essential for the system application of optical filters. In the case of periodic filters, like ring resonators, it is important to fit the transmission curve to the defined channel spacing. Three tunability methods exist either for trimming the center wavelength of the filter after processing or for tuning the resonance wavelength when the ring resonator add drop filter is in operation. These methods are as following

(1) *Thermo-optic tuning*: In this method of tuning the filter component is heated by electric heater which is fabricated along with the waveguide and due to the application of heat the refractive index of the material changes which in turn

shifts the resonances. This method is fairly slow and require significant amount of power.

(2) *Electro Optic tuning*: In this method electric field is applied to change either the refractive index or absorption of the material. Effect produced by this method is quite small compared to thermo optic method but on the other hand this method is faster and consumes significantly less power than thermo optic method.

(3) *Carrier Injection Method*: It is another mean by which we can change refractive index, gain or absorption of the component. Introducing gain is an advantage of using carrier injection and resonance can be changed by it.

F. Applications of Ring Resonator in Optical Communications:

- Dispersion compensators
- Modulator/Demodulator
- Multiplexer/Demultiplexer
- Optical delay lines
- In Optical Signal Processing

II. MEMS (MICROOPTOELECTROMECHANICAL SYSTEMS):

Micro-Electro-Mechanical Systems, or MEMS, is a technology that in its most general form can be defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of micro fabrication.

The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters.

Likewise, the types of MEMS devices can vary from relatively simple structures having no moving elements, to extremely complex electromechanical systems with multiple moving elements under the control of integrated microelectronics. The one main criterion of MEMS is that there are at least some elements having some sort of mechanical functionality whether or not these elements can move.

While the functional elements of MEMS are miniaturized structures, sensors, actuators, and microelectronics, the most notable (and perhaps most interesting) elements are the micro sensors and micro actuators. Micro sensors and micro actuators are appropriately categorized as transducers, which are defined as devices that convert energy from one form to another. In the case of micro sensors, the device typically converts a measured mechanical signal into an electrical signal.

Components of MEMS are shown in fig.9.

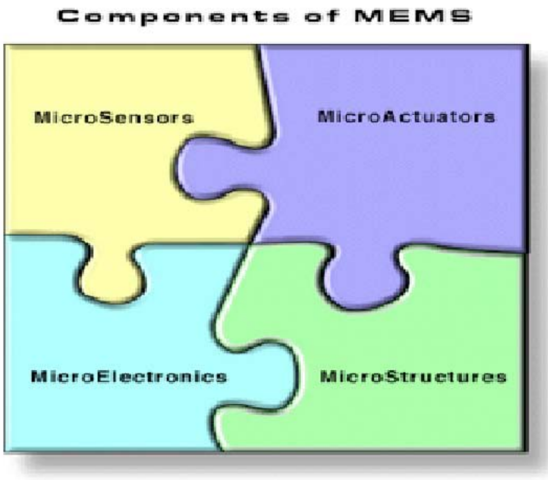

Figure 9: Components of MEMS

III. DISCUSSION:

1. A. Multiple-Channel Piezoelectric Actuated Tunable Optical Filter for WDM Application [1]

A new eight channel piezoelectric actuated tunable optical filter has been designed on a suspended silicon beam using race track shaped ring resonators. Piezoelectric material is sandwiched between two layers of silicon. When DC electric field is applied to the beam due to the piezoelectric effect the beam will elongate in horizontal and vertical direction, because of this the perimeter and refractive index of the of the rings will change and tenability can be obtained. Channel spacing is 1.6 nm between the channels.

- Center wavelength (nm) - 1547.3028 to 1557.1194
- 1 dB bandwidth (nm) - 0.5205 to 0.5240
- 3 dB bandwidth (nm) - 0.8974 to 0.9037
- Tunability (pm/V) - 45.42- 45.70
- Spacing (nm) - 1.598
- Loss difference (dB) - 0.2218
- Band rejection ratio (dB) - 35
- Channel crosstalk (dB) - 30
- Tuning Range (nm) - 3.45

2. Integrated Wavelength-Selective Optical MEMS Switching Using Ring Resonator Filters [2]

A fully integrated wavelength selective MEMS (Micro opto electro mechanical system) actuated optical switch using ring resonators has been designed. This filter is compatible with CMOS and consumes very low power. For actuation it uses a parallel metal plate to move lossy aluminum membrane to move in and out of the ring resonators evanescent field.

The lossy membrane absorbs the optical power and spoils the resonance and all the optical power passes through ring unaffected at throughput port. By this loss can be controlled and thus the cavity quality factor and resonant wavelength can be shifted between add and drop ports.

Fig. 10 and 11 shows the characteristics of this device.

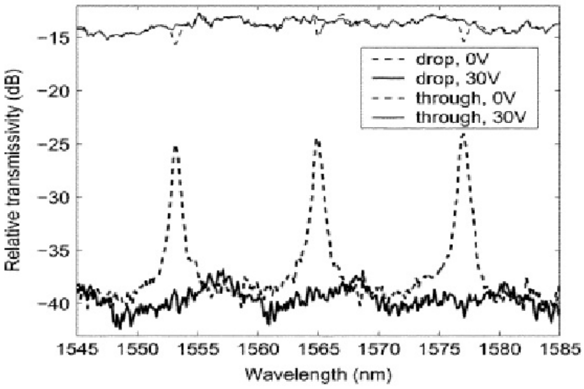

Figure 10: Spectral results of the integrated wavelength selective optical switch

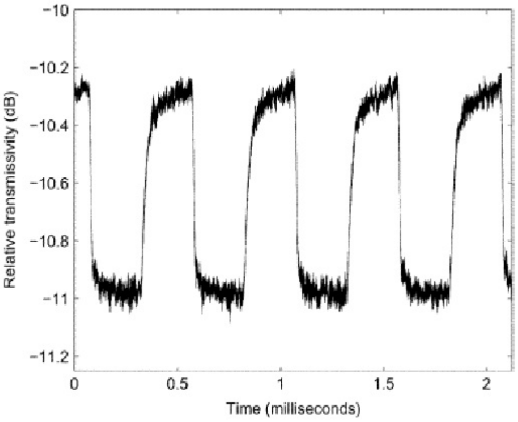

Figure 11:Through-port temporal switching results

3. MEMS-Actuated Microdisk Resonators with Variable Power Coupling Ratios [3]

This device is a basic building blocks many WDM systems. The ability to change coupling ratio between the ring and microdisk allows us operate it under critical and over critical conditions. This microdisk resonator can be used to construct tunable optical delays and dynamic dispersion Compensators. In this device optical resonance can be continuously tuned by voltage. Fig 12 and 13 shows the device characteristics.

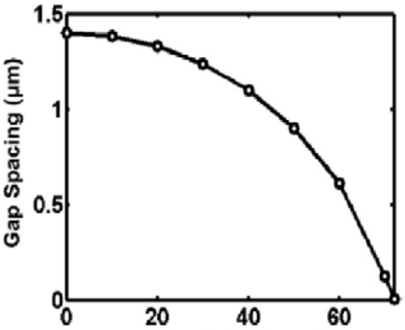

Figure 12: Simulated transfer curve of the deformable waveguide

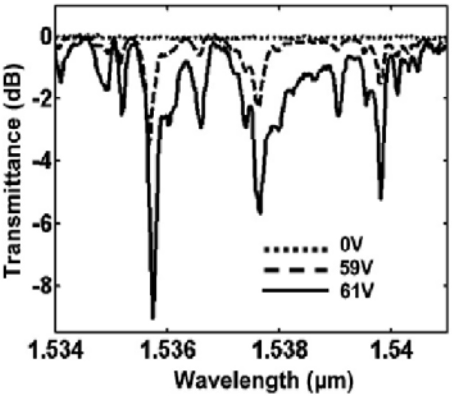

Figure 13: Measured spectral responses of the MEMS-actuated microresonator at various bias conditions

4. Wavelength and Bandwidth-Tunable Filters Based on MEMS-actuated Microdisk Resonators [4]

MEMS actuated micro ring resonators which can be used WDM networks for multiple applications such as adding, dropping, switching, and multiplexing/demultiplexing of optical signals. For actuation a micro heater is built alongside the resonator and with the application of heat refractive index of the ring changes and subsequently resonance frequency can be shifted. Fig 14 and Fig 15 shows the characteristics of this device.

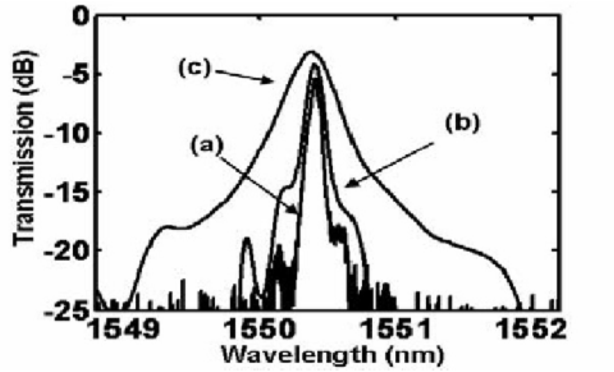

Figure 14:The measured full-width at half-maximum (FWHM) spectra at the drop port with different actuation bias.

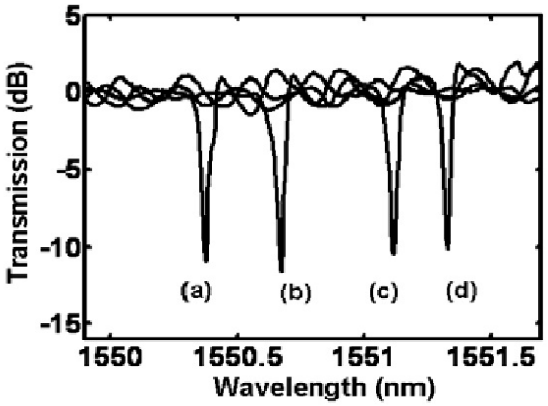

Figure 15: Measured Spectra at the through port with different applied currents through on-chip microheater.

5. An Integrated, Silica-Based, MEMS-Actuated, Tunable- Bandwidth Optical Filter with Low Minimum

Bandwidth [5]

This is a MEMS actuated tunable optical filter which is suitable for wavelength and bandwidth selective operations. This device is fabricated using PSG (Phosphosilicate Glass) made ring resonators. It has achieved a tuning range of 0.8 to 805 GHz and low minimum bandwidth as low as 30 MHz. Fig 16 shows the characteristics of the device.

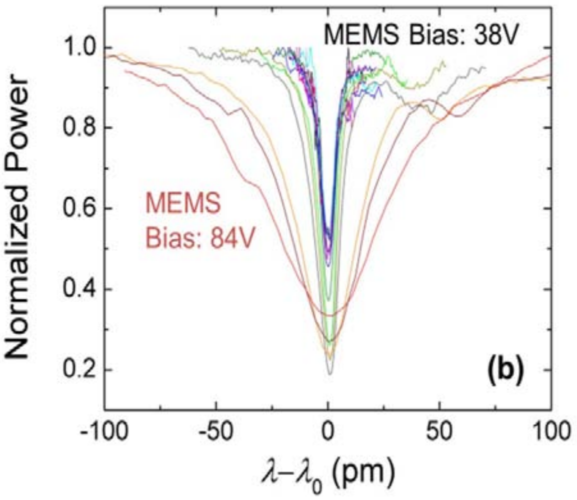

Figure 16: Demonstration of bandwidth tuning as MEMS bias is varied from 84 to 38V.

6. Optical Transmission Characteristics of Fiber Ring Resonators [6]

Transfer characteristics of optical ring resonators vary with different values of finesse. By systematic study it has been shown phase shift and intensity of optical signals for under coupled, critically coupled and over coupled conditions are different. Tunable true time delay lines can be made using ring resonators.

7. Transmission Characteristics of Tuneable Optical Filters Using Optical Ring Resonator with PCF Resonance Loop [7]

A theoretical analysis of a tuneable optical filter is presented by proposing an optical ring resonator (ORR) using photonic crystal fiber (PCF) as the resonance loop. The influences of the characteristic parameters of the PCF on the filter response have been analyzed under steady-state condition of the ORR. It is shown that the tunability of the filter is mainly achieved by changing the modulation frequency of the light signal applied to the resonator. The analyses have shown that the sharpness and the depth of the filter response are controlled by parameters such as amplitude modulation index of applied field, the coupling coefficient of the ORR, and hole-spacing and air-filling ratio of the PCF, respectively. When transmission coefficient of the loop approaches the coupling coefficient, the filter response enhances sharply with PCF parameters. The depth and the full-width half-maximum (FWHM) of the response strongly depends on the number of field circulations in the resonator loop.

8. Highly dispersive micro-ring resonator based on One dimensional photonic crystal waveguide design and analysis [8]

This device is based on a micro-ring resonator with the addition of a series of periodic defects that are introduced to the microring. When the wavelength of operation approaches the band-gap of the periodic structure, the modal dispersion is significantly increased. The huge dispersion leads to narrowing of the spectral line width of the resonator. This leads to an order of magnitude line width narrowing for a microring radius of the order of 10m. The proposed hybrid device is analyzed theoretically and numerically using finite-elements calculations and finite-difference-time-domain calculations.

9. On cascades of resonators for high-bandwidth integrated optical interconnection networks [9]

Power penalty is generally not prohibitive but if very complex interconnected filters and switches are going to be designed by ring resonators then we have to take this into consideration. Here power penalty characteristics of various devices made by ring resonators are studied and analyzed. Butterworth and Chebyshev filters which are connected with optical devices are also studied.

10. Tunable optical filter based on Sagnac phase shift using single optical ring resonator [10]

A single optical ring resonator connected to a Sagnac loop is used to demonstrate theoretically a novel narrow band optical filter response that is based on Sagnac phase-shift Df. The given filter structure permits the Sagnac rotation to control the filter response. It is shown that by changing the Sagnac rotation rate, we can tune the filter response for desired bandwidths. To increase the wavelength selectivity of the filter, the Sagnac phase-shift should be as small as possible that is limited by the loop length. For Df 0.1 rad, the obtained FWHM is 2.63MHz for tuning loop length of 2 m.

11. Tuning a racetrack ring resonator by an integrated dielectric MEMS cantilever [11]

A MEMS actuated tunable optical filter which is designed by racetrack shaped ring resonator is simulated and its characteristics are studied here. Electrostatic actuation is used to move the cantilever beam in and out of the evanescent field of the waveguides and thus tuning of wavelength and bandwidth is achieved.

12. Optical Fiber Sensor Technologies: Opportunities and Perhaps Pitfalls [12]

Modern optical fiber sensor technology has influenced modern world in a very large scale. Fiber optic sensing and practical problems associated with it in structural monitoring, electromagnetic measurements, and environmental sensing is discussed.

13. A MEMS TUNABLE PHOTONIC RING RESONATOR WITH SMALL FOOTPRINT AND LARGE FREE SPECTRAL RANGE [13]

This device is a MEMS actuated tunable optical ring resonator which has a very small footprint and a large spectral range. It can be used in reconfigurable optical networks for wavelength selectivity. Fig 17 and 18 shows the characteristics of the device.

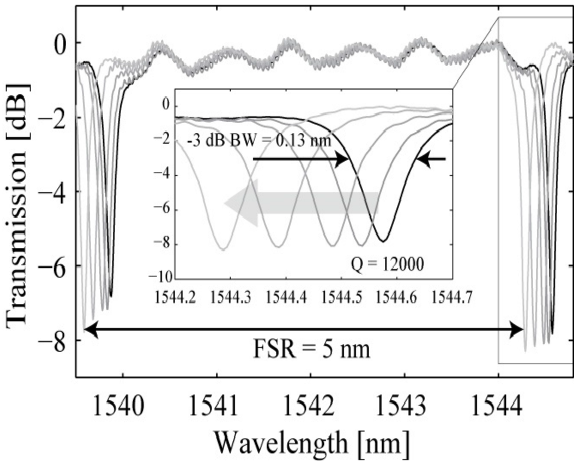

Figure 17: Transmission spectra for the device.

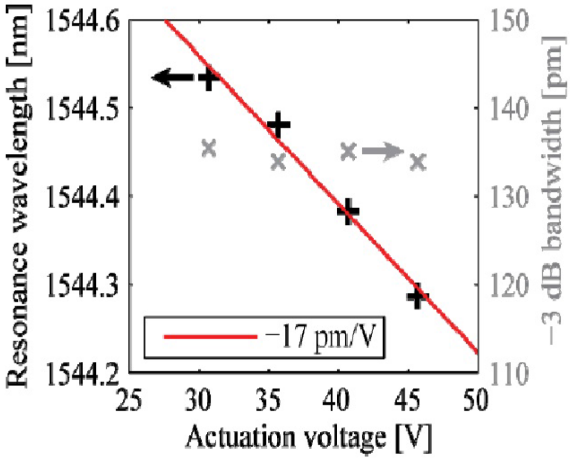

Figure 18:Tunability of the filter

IV. DESIGNING OF TUNABLE OPTICAL FILTER BASED ON MOEMS ACTUATED OPTICAL RING RESONATOR

After going through the recent work done in the field of optical filtering we are going to design an optical filter which will be MOEMS (Micro-opto-electro-mechanical systems) actuated. MOEMS is a combination of MEMS merged with Micro-optics. This filter will be designed on a suspended beam of silicon and it will consist of eight channels. Each channel will have its own set of optical filters which will be made of Ring Resonators. Piezoelectric effect will be used for actuation and allocation of wavelength of input optical filter. We will bury the piezoelectric material between two layers of silicon. Filters for each channel will be placed in the middle of beam to attain uniform longitudinal stress and strain. When a DC voltage will be applied to the beam it expand on longitudinal direction and due to which perimeter and refractive index of rings will change and it will only allow resonance wavelength to pass through it and block the rest. Fig. 19 shows the tunability of single ring resonator notch filter

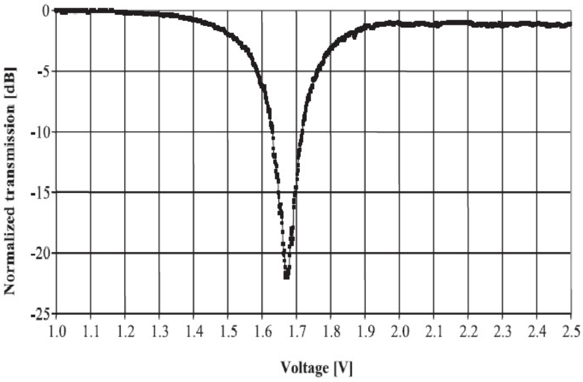

Figure 19: Tunability of single ring resonator notch filter

The filter we will be designing will have a better tenability, sensitivity and improved mechanical strength.

This filter has enormous potential in the WDM networks. It can be used for wavelength multiplexing/ Demultiplexing, Switching, Modulation/Demodulation. It can also be used for dispersion monitoring and with slight modification it can be used as sensors which can be in sensing of force, pressure, vibration etc

V. CONCLUDING OBSERVATIONS

The aim of this paper is to outline role of ring resonators and its use in optical filters and sensors. Ring resonator due to its integrated design, small compact size and footprint and extremely low power consumption has been proved very revolutionary. Most advantageous thing about ring resonator is that it can be customized according to need of the application. Ring resonators are compatible with existing CMOS and FET technology. These filters can be designed to very small size devices ranging to micrometer and nanometer range and they can be actuated using Microelectromechanical system (MEMS).Focus of this paper is to summarize what work has already been done on optical filter actuated by MEMS and explore new possibilities of this technique for optical filters. Extremely small and efficient optical filters with very small footprint and low power consumption had been made and they still hold the potential for new research and invention in the same field. MEMS actuated filters and sensors can be made in suspended or cantilever beams made by silicon, polymers or semiconductor materials. Ring Resonators aren’t necessarily be of circular in shape and we can use Racetrack, square, hexagon or elliptical in shape and their characteristics vary accordingly. This very fact gives us a lot of liberty to explore this field even further.

REFERENCES

[1] Hailu Dessalegn, T. Srinivas (2015),”Multiple-Channel Piezoelectric Actuated Tunable Optical Filter for WDM Application”, World Academy of Science, Engineering and Technology International Journal of Mathematical, Computational, Physical, Electrical and Computer Engineering Vol: 9, No: 7

[2] Gregory N. Nielson, Dilan Seneviratne, Francisco Lopez-Royo, Peter T. Rakich, Ytshak Avrahami, Michael R. Watts, Hermann A. Haus, Harry L. Tuller and George

Barbastathis(2005), "Integrated Wavelength-Selective Optical MEMS Switching Using Ring Resonator Filters", IEEE PHOTONICS TECHNOLOGY LET-TERS, VOL. 17, NO. 6, Digital Object Identifier 10.1109/LPT.2005.846951

[3] Ming-Chang M. Lee, Ming C. Wu (2005),"MEMS-Actuated Microdisk Resonators with Variable Power Coupling Ratios", IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 17, NO. 5, DOI: 10.1109/LPT.2005.845772

[4] Jin Yao, Ming-Chang M. Lee, David Leuenberger and Ming C. Wu (2005),"Wavelength- and Bandwidth-Tunable Filters Based on MEMS actuated Micro disk Resonators", Optical Society of America, ISBN: 1-55752-802-0

[5] Karen E. Grutter, Anthony M. Yeh, Alejandro Grine, Ming C. Wu (2013),"An Integrated, Silica-Based, MEMS-Actuated, Tunable- Bandwidth Optical Filter with Low Minimum Bandwidth", Optical Society of America, ISBN: 978-1-55752-972-5

[6] John E. Heebner, Vincent Wong, Aaron Schweinsberg, Robert W. Boyd, and Deborah J. Jackson (2004),"Optical Transmission Characteristics of Fiber Ring Resonators", IEEE JOURNAL OF QUANTUM ELECTRONICS, VOL. 40, NO. 6

[7] Kazhal Shalmashi, Faramarz E. Seraji, Mansur Rezaei Mersagh(2011),"Transmission Characteristics of Tuneable Optical Filters Using Optical Ring Resonator with PCF Resonance Loop", Optics and Photonics Journal, 1, 172-178,doi:10.4236/opj.2011.14028

[8] Damian Goldring, Uriel Levy and David Mendlovic (2007),"Highly dispersive micro-ring resonator based on One dimensional photonic crystal waveguide design and analysis", Optical Society of America, doi:10.1364/OE.15.003156

[9] Benjamin A. Small, Benjamin G. Lee, and Keren Bergman (2006),"On cascades of resonators for high-bandwidth integrated optical interconnection networks", science direct journal, Optical Society of America, doi: 10.1364/OE.14.010811

[10] Faramarz E. Seraji, Fatemeh Asghari (2010),"Tunable optical filter based on Sagnac phase shift using single optical ring resonator", Optics and Laser Technology 42, 115119, DOI: 10.1016/j.optlastec.2009.05.008

[11] S.M.C. Abdulla,L.J. Kauppinen, M. Dijkstra, M.J. de Boer, E. Berenschot, H.V. Jansen, R.M. de Ridder, and G.J.M. Krijnen(2011), "Tuning a racetrack ring resonator by an integrated dielectric MEMS cantilever", OSA ,15 August 2011 / Vol. 19, No. 17 / OPTICS EXPRESS 15864,doi: 10.1364/OE.19.015864

[12] Brian Culshaw (2004),"Optical Fiber Sensor Technologies: Opportunities and Perhaps Pitfalls", JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 22, NO. 1, Digital Object Identifier 10.1109/JLT.2003.822139

[13] Carlos Errando-Herranz, Frank Niklaus, Gran Stemme, and Kristinn B. Gylfason (2015),"A MEMS TUNABLE PHOTONIC RING RESONATOR WITH SMALL FOOTPRINT AND LARGE FREE SPECTRAL RANGE", IEEE (ed.), Proceedings of the 18th International Conference on Solid-State Sensors, Actuators and Microsystems Transducers, DOI: 10.1109/TRANSDUCERS.2015.7181094

[14] D.G. Rabus (2007),"Integrated Ring Resonators the Compendium", Springer.

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