A Cascaded Incoherent Spectrum Sliced Transversal Photonic Microwave Filters-An Analysis

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***Abstract---*An analysis of the performance of a simple, incoherent spectrum sliced microwave photonic filter is presented. This filter structure is based on cascading of two incoherent fiber Fabry -Pérot filters as a slicing element of a broadband optical source. The filter performance is studied by measuring the overall Free Spectral Range, 3dB Bandwidth, Quality factor and Main Lobe to Sidelobe Suppression level for different modes of connecting the filter in cascaded configuration. Also simulation results are presented. The Characteristics of cascaded FP filters with different configurations are tabulated. The estimated performances show that this cascaded filter combination can be tuned over the frequency from 4.6 GHz to 18 GHz with very good sidelobe suppression level.**

Keywords---- Fabry Perot filter, microwave photonics, photonic microwave filter, spectrum slicing, Q-factor.

I. INTRODUCTION

Microwave Photonics is an area in which the photonic devices and systems are used to generate, transport, process, and detect the microwave and milli-meter wave signals. It brings the unique advantages of photonic devices and waveguides to the processing of Radio Frequency (RF), microwave and millimeter wave signals. There are many advantages of processing microwave signals in optical domain are low loss, small size, light weight, broadband width, and immunity to Electromagnetic Interference(EMI) [1,2]. In addition to these advantages, microwave photonic filters also offer high dynamic range, high compactness and fast reconfiguration and wider tuning capabilities. It is very difficult to attain the reconfigured band pass transfer function of any filter with the traditional microstrip or waveguide RF technologies. This difficulty can be overcome by external on-line measures in spectrum sliced microwave photonic filters. Among various photonic microwave filter architectures, filters based on broadband optical spectrum slicing are simple and cost effective. Higher resolution, greater tunability and reconfigurability are achieved by this slicing method. The various techniques for spectral slicing of broadband source such as interferometers, fiber Fabry Perot (FP) filters, Fiber Bragg Gratings (FBG) are discussed [3]. Among various filter architectures, a low cost tunable periodic filter can be obtained by means of spectral slicing of LED spectrum with fiber FP filters. Because it can be used directly in optical domain. But the tuning capability of this filter is very restricted [4]. It has been proposed to use incoherent structures in cascade to obtain signal band pass transfer function with higher FSR [4]. The main idea is that carefully choosing two filter configurations, one with a lower FSR and selective resonances and a second with broader resonances and a higher FSR value. It will give the overall filter transfer function as the multiplication of individual filter transfer functions. It has the combined features of the resonance selectivity of the first filter and broad FSR value of the second.

In this paper, we have analyzed the performances of a simple, incoherent spectrum sliced transversal microwave photonic filter. The theoretical analysis of the proposed filter based on cascading of two fiber FP filters as a slicing element of a broadband source is discussed. The overall filter spectral response is theoretically simulated and obtained which gives high tunability in the frequency range from 4.6 GHz to 18 GHz with very good sidelobe suppression level. The Q-factor of the filter are also reported for different combinations of cascaded configuration. The characteristics of cascaded FP filters for different values incremental differential delay are tabulated and analysed.

II. ANALYSIS

The general layout of the proposed filter is shown in Fig. 1.The output light emitted from the unmodulated broadband source is fed to first fiber FP filter with smaller FSR. The spectrally sampled signal with equal spacing is applied to a second fiber FP filter with large FSR. This configuration gives much finer spectral slicing [5]. Then the output of the second fiber FP filter is externally modulated by RF input signal by means of external modulator. The modulated signal is fed to an optical dispersive fiber providing a linear group delay characteristics. The output signal from the dispersive fiber element is detected by photodetector and the RF output is obtained.

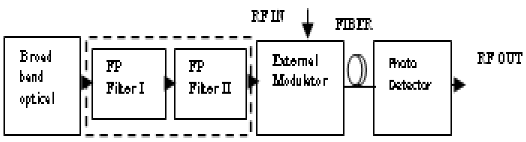

Fig.1. General Layout of the proposed configuration.

A. *Theory*

This configuration also gives resonance selectivity of the first filter and the broad FSR value of second one. The RF transfer function of the filter with single sideband (SSB) modulation is given by [6]

$$|H_{RF}(\Omega)| = R\left|\sum_{k=1}^{N} P_k e^{-j(\Omega(k-1)\Delta\tau)}\right| \qquad (1)$$

Where P_k represents the output power from the k^{th} slice of the broadband source, R is the receiver responsivity, Ω the RF frequency and $\Delta\tau=\beta_2\Delta\omega$ is the incremental differential delay experienced by two adjacent spectral slices of the broadband source, with β_2 represents the group delay slope of the dispersive element.Eqn.1represents the spectral response of a FIR filter where N is number of taps used in this filter. The number of taps gives the number of samples which is equal to the number of spectral slices generated by the optical filter.

The transfer function of first FP filter is $H_{RF1}(\Omega)$ and the second filter is $H_{RF2}(\Omega)$ respectively. Then the overall filter transfer function of cascaded configuration is given by the product of the transfer function of individual filter [7] using (1)

$$H_{overall}(f) = H_{RF1}(f)*H_{RF2}(f) \qquad (2)$$

$$= R\left|\sum_{m=1}^{N} P_m e^{-j[\Omega(m-1)\Delta\tau 1]} \sum_{n=1}^{N} P_n e^{-j[\Omega(n-1)\Delta\tau 2]}\right|$$

$$= R\left|\sum_{m=1}^{N}\sum_{n=1}^{N} P_m P_n e^{-j\Omega[(m-1)\Delta\tau 1+(n-1)\Delta\tau 2]}\right| \qquad (3)$$

where $\Delta\tau 1$ and $\Delta\tau 2$ are incremental differential delay of FP filter1 and FP filter2 respectively.

III. RESULTS AND DISCUSSION

The schematic diagram of two 34 tap cascaded incoherent spectrum sliced transversal microwave photonic filter is shown in Fig.2.

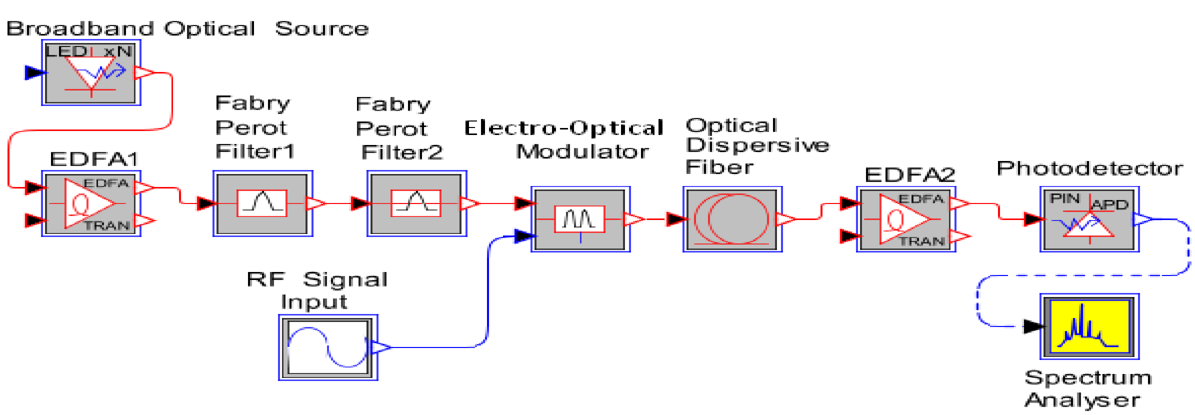

Fig.2.Proposed configuration using cascaded FP filters

The performance of the proposed filter has been analysed.This analysis was carried out by simulating the necessary data and experiments deploying Matlab. The broadband spectrum from the optical source is amplified by means of Amplified Spontaneous Emission (ASE) generated by Erbium-Doped Fiber Amplifier (EDFA). The ASE output from EDFA1 is centered at a wavelength of

1531.8nm is fed to first FP filter with34 tap and low FSR of 4.6GHz corresponds to differential delay between adjacent carriers of 219ps(= D x L x Δλ=17ps/km.nmx46kmx 0.28nm).A fiber FP filter with subnanometer (0.28nm)FSR was used. The optical dispersive coil of 46km standard single mode fiber with dispersion factor D=17ps/km.nm was used. It provides much finer and higher number of spectral slices signal samples. The sliced output signal is fed to second fiber FP filter of 34 tap with higher FSR of 6.097GHz corresponding to differential delay of 164ps.Higher FSR of (6.097GHz) is obtained by reducing the length of fiber (34.45km).The different FSR filters used in this configuration gives filter overall FSR of 18.28Ghz with very narrow and clear spectral slices. The 3dB BW of the filter 0.153GHz is obtained. This combination of the filter shows Q-factor of 119.A high overall filter FSR (18.28 GHz) with high Q-factor (119) and better sidelobe suppression level are obtained by carefully choosing individual filter FSRs of cascaded FP filter configuration. That is incremental differential delay of FP filter2 is one third of other filter. The EDFA2 is used to reduce losses due to the other components in the filter. Fig.3 (a) shows the overall spectral response of the filter for same FSR of two FP filters which is corresponding to differential delay of 219ps gives overall FSR is 4.6GHz, 3dB BW is 0.14 GHz and Q-factor is 33.Fig.3 (b) gives the overall spectral response of the filter for different FSR corresponding differential delay219ps and 109.5ps that is one half of the other filter. It gives overall FSR is 32GHz, 3dB BW is 0.17 GHz and Q-factor is 53. Fig 3(c) is the overall spectral response of the filter for different FSR corresponding to differential delay219ps &164ps which shows the overall FSR is 18.3GHz, 3dB BW is 0.153 GHz and Q-factor is 119.This is obtained by connecting the second filter is having differential delay as one third of the other. Table 1 gives the characteristics of the cascaded configurations of FP filters in terms of its overall FSR, 3dB BW and Q-factor. The high FSR of 18.28GHz, Q-factor of 119 and side lobe suppression of 37db were obtained by cascading with two incoherent filters of different differential delay, one of the filters with delay as one third of the other.

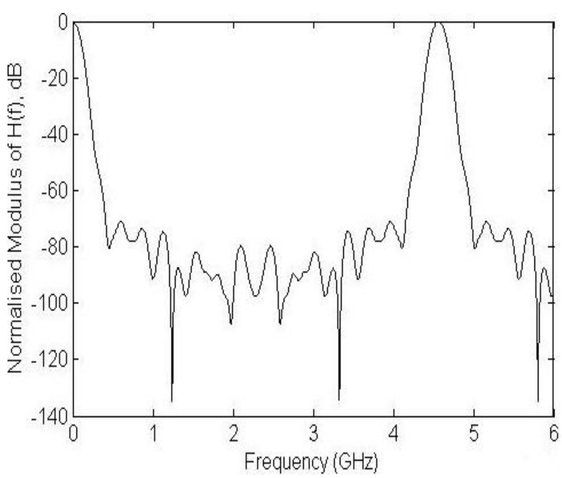

Fig.3 (a) Overall spectral response of the filter for same FSR corresponding to differential delay 219ps.

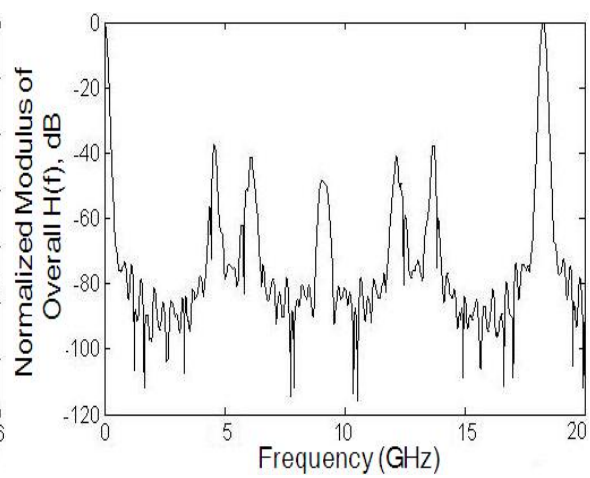

Fig3 (b) Overall spectral response of the filter for different FSR corresponding to differential delay219ps and 109.5ps.

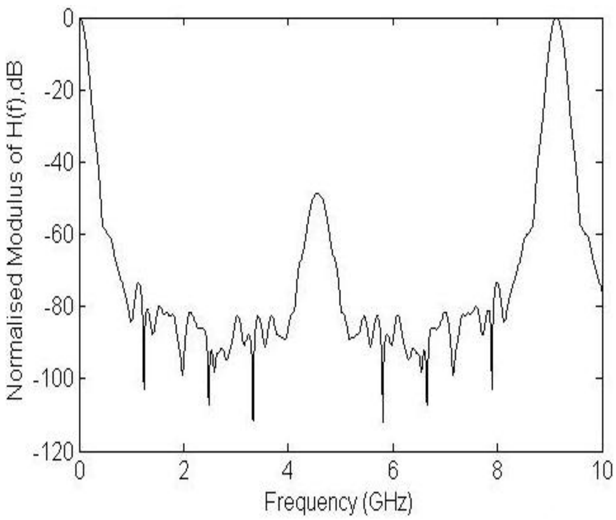

Fig.3.(c) Overall spectral response of the filter for different FSR corresponding differential delay219ps and 164ps.

S. No	Differential Delay (ps)	Overall FSR (GHz)	3db Bandwidth (GHz)	Q-Factor
1.	219,219	4.6	0.14	33
2.	219,109.5	32	0.17	53
3.	219,164	18.3	0.153	119

Table 1: Characteristics of the cascaded configurations of FP filters.

IV. CONCLUSION

We have analyzed the performance of a simple two 34 tap cascaded incoherent spectrum sliced transversal microwave photonic filter. Our proposed filter is composed of cascading two incoherent fiber Fabry Perot filters with different FSRs. We have considered three cases of filter configuration in terms of its incremental differential delay. The simulated results shows that the performance of this cascaded filter combination can be tuned over the frequency range from 4.6 GHz to 18 GHz with very good sidelobe suppression level. This was achieved by cascading two Fiber FP filters and by carefully choosing individual filters FSR. The future scope of this paper is by employing windowing technique to reconfigure the overall filter transfer function.

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BIOGRAPHY

R. K. Jeyachitra received her B.E. degree in Electronics and Communication Engineering, M.E. in Microwave and Optical Engineering from Madurai Kamaraj University, Madurai in 1995 and 1997 respectively. She is currently pursuing research in Microwave Photonics. From 1998 to 2004 she worked as lecturer and from 2004 to 2007 as assistant professor at J.J. College of Engineering and Technology, Tiruchirappalli. Now she is working as an Assistant Professor in the Department of ECE, National Institute of Technology, Tiruchirappalli. Her research interests are

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