

Crosstalk Analysis of an Acousto-Optic Tunable Filter Based Optical Add/Drop Multiplexer for DWDM System

Md. Saiduzzaman, Imtiaz Ahmed, Kowshik Mushfiq-ur-Rahman

Abstract— Dense Wavelength Division Multiplexing (DWDM) system is limited by different impairments like optical attenuation, crosstalk, chromatic dispersion, polarization mode dispersion, Scattering etc. All of these impairments restrict the transmission distance and bandwidth. In the Present Scenario the DWDM system needs significant improvement, where analyzing the crosstalk of an Acousto-Optic Tunable Filter (AOTF) based Optical Add/Drop Multiplexer (OADM). This paper conducts a comprehensive study of DWDM system and extracts the optimum performance of the overall system by increasing the channel spacing of the AOTF with a significant improvement of signal to crosstalk ratio with channel spacing and reduced bit error rate as the bandwidth of the channel is increased accordingly.

Index Terms— Acousto-Optic Tunable Filter (AOTF), Bit Error Rate (BER), Crosstalk, Dense Wavelength Division Multiplexing (DWDM), Optical Add/Drop Multiplexer (OADM), Optical cross connect (OXC), Signal to Crosstalk Ratio (SCR), Wavelength Division Multiplexing (WDM)

1 INTRODUCTION

The popularity of Dense Wavelength Division Multiplexing (DWDM) is increasing extensively for long-haul optical communication due to its high cost effectiveness. Closely spaced channels within the same window makes the system easy to manage and provides increased flexibility, but the requirement of very narrow spectral-width laser sources, this technique also needs very low loss optical add/drop multiplexer (OADM) with minimum fluctuations. Acousto-Optic Tunable Filter (AOTF) is a potential solution to this problem. Several papers have been published in the area of An OADM design based on fiber Bragg gratings [1], Interferometric cross talk-free OADM using cascaded Mach-Zehnder fiber gratings [2]. But most of these researchers have focused their work from the optical signal processing point of view and not from tunable MUX/DEMUX aspect, especially using acousto-optic concept. However several authors have discussed about acousto-optic wavelength tunable switches and filters (AOTF) but as a simple OADM with limited tenability. In this paper the basic concept and thorough analysis of an acousto-optic tunable filter based OADM system has been presented, where we simulated the filter transfer function from a very narrow channel spacing of 0.1nm up to as wide as 1nm, which shows a significant improvement of SCNR. Result also shows that increasing the bandwidth within the cost effective range of 10GHz to 250GHz causes a significant improvement in BER.

2 THE OADM FUNCTION

The main function of an optical multiplexer is to couple two or more wavelengths into the same fiber. If a demultiplexer is placed and properly aligned back-to-back with a multiplexer, it is clear that in the area between them, two individual wavelengths exist.

This presents an opportunity for an enhanced function, one in which individual wavelengths could be removed and also inserted. Such a function would be called an optical wavelength drop and add demultiplexer/multiplexer-and for brevity, optical add/drop multiplexer. OADM is still evolving, and although these components are relatively small, in the future, integration will play a key role in producing compact, monolithic and cost-effective devices [3].

3 NECESSITY OF AOTF

Regarding the architecture of dynamic OADM configurations, there are two types [4]. One is the SW type with a back-to-back multiplexer/ demultiplexer, and the other is the AOTF type. Figure 1 shows these configurations. One of the technical difficulties in using the SW type for OADM is that for limited channels in a WDM system, a non optical switch will be required on the drop and add sides to accomplish a dynamic capability. This can be extremely expensive and cumbersome. Other problems such as channel passband narrowing due to concatenation of multiplexers/demultiplexers for a channel spacing of 0.8 nm or less can also create major problems in a long-distance network. The AOTF type holds a lot of promise for providing a cost-effective solution for a static as well as dynamic OADM and presents no passband narrowing prob-

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lem. We have therefore been developing dynamic OADM systems using AOTF.

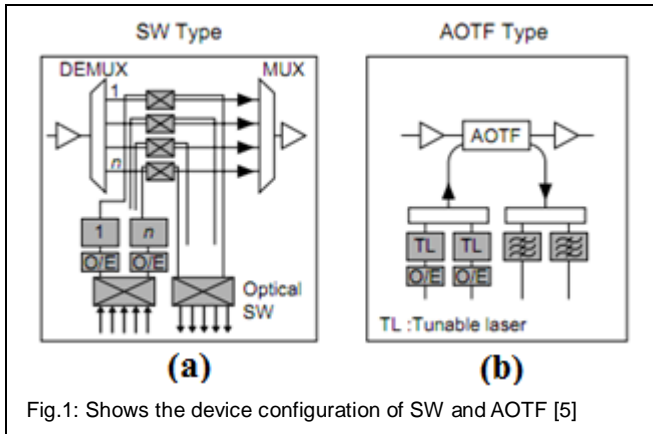


Fig.1: Shows the device configuration of SW and AOTF [5]

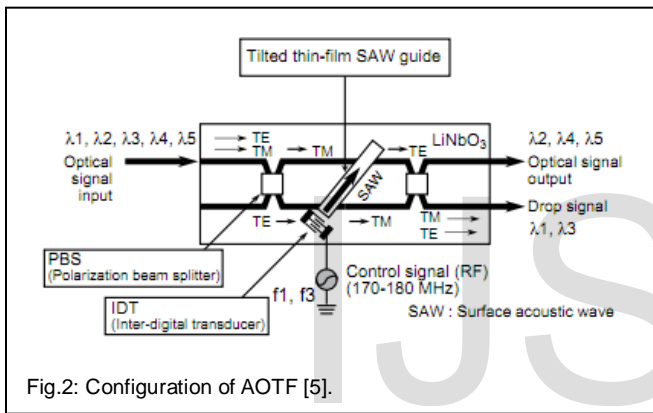


Fig.2: Configuration of AOTF [5].

4 ACOUSTO-OPTIC TUNABLE FILTER

The acousto-optic tunable filter is a versatile device. It is probably the only known tunable filter that is capable of selecting several wavelengths simultaneously. This capability can be used to construct an optical cross connect (OXC).

The theory is based on utilizing diffraction of light by the refractive index gratings generated by the acoustic waves. The acoustic source which is usually an inter-digital transducer is electronically controlled leading to an electronically tunable filter. An oscillating electric signal drives the transducer to vibrate, which creates sound waves in the glass. These can be thought of as moving periodic planes of expansion and compression that change the index of refraction. Incoming light scatters off the resulting periodic index modulation and interference occurs similar to in Bragg diffraction.

Changing the driving acoustic frequency changes the band of optical frequencies that the filter passes (selects). Changing the power of the acoustic wave changes the length required for complete diffraction of the input wave [6], [7].

5 THEORY

5.1 Transfer Function

The wavelength dependence of the fraction of the power

transmitted by the AOTF [7] can be express as:

$$T(\lambda) = \frac{\sin^2((\Pi / 2)\sqrt{1 + (2\Delta\lambda / \Delta)^2}}{1 + (2\Delta\lambda / \Delta)^2} \quad (1)$$

Here

$$\Delta\lambda = \lambda - \lambda_0 \quad (2)$$

$$\Delta = \lambda_0^2 / 1 * \Delta n \quad (3)$$

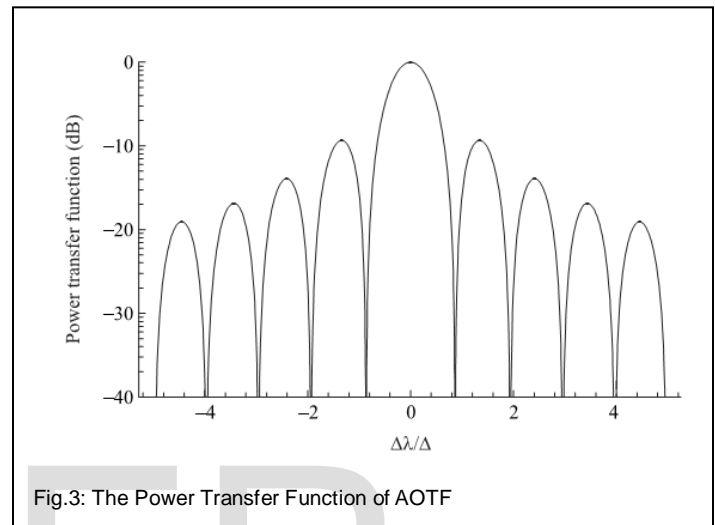


Fig.3: The Power Transfer Function of AOTF

5.2 Signal to Crosstalk Ratio (SCR)

The Ratio between signal power and Crosstalk power is called signal to Crosstalk Ratio (SCR).

$$SCR = \sum P_{sig} / \sum P_C \quad (4)$$

5.3 Signal to Crosstalk Noise Ratio (SCNR)

The Ratio between signal power and to Crosstalk power with noise power is called signal to Crosstalk Noise Ratio (SCNR).

$$SCNR = P_{sig} / P_C + P_N = P_{sig} / \delta_C^2 + \delta_N^2 \quad (5)$$

$$\delta_N^2 = \delta_{Shot}^2 + \delta_{Thermal}^2 \quad (6)$$

$$\delta_{Shot}^2 = \text{Shot Noise} = 2eB(R_d * P_{sig}) \quad (7)$$

$$R_d = \eta e / hf = \eta e \lambda_0 / hc \quad (8)$$

$$\delta_{Thermal}^2 = \text{Thermal Noise} = 4kTB / R_L \quad (9)$$

$$P_C = \delta_C^2 = \text{Crosstalk Power}$$

$$P_{sig} =$$

Signal Power

$$P_N = \delta_N^2 = \text{Noise Power}$$

Here parameters have their usual meanings.

5.4 Bit Error Rate

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage. The expression [8] can be expressed as,

$$BER = \frac{1}{2} \operatorname{erfc}\left[\frac{\sqrt{SCNR}}{2\sqrt{2}}\right] \quad (10)$$

6 RESULT AND DISCUSSION

Following the analytical approach presented in section 5, the Signal power, Cross-talk power, Signal to Crosstalk Ratio, Signal to Crosstalk -Noise Ratio, Bit Rate Error and Power penalty results are evaluated

Plot of Signal Power vs. Wave length Separation ($\Delta\lambda$) is shown in Fig. 4. From the fig, it is evident that the increase of $\Delta\lambda$ in the transmission line, Signal Power increases.

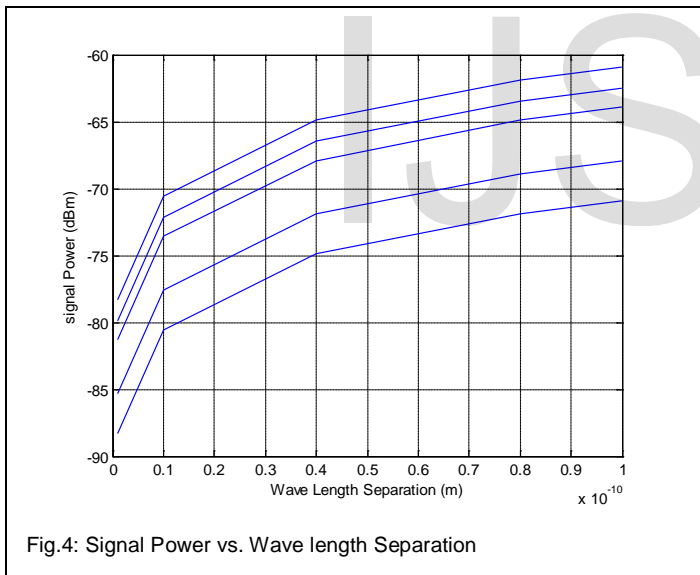


Fig.4: Signal Power vs. Wave length Separation

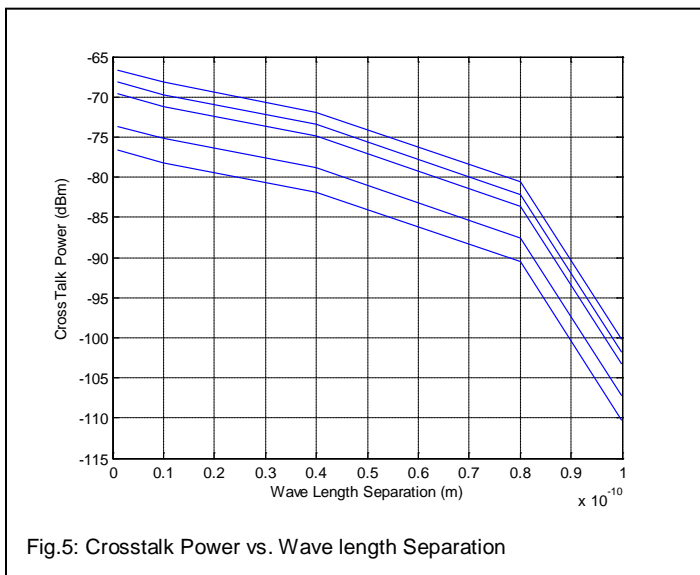


Fig.5: Crosstalk Power vs. Wave length Separation

Plot of Crosstalk Power vs. Wave length Separation ($\Delta\lambda$) is shown in Fig. 5. From the fig, it is evident that the increase of $\Delta\lambda$ in the transmission line, Crosstalk Power decreases.

Plot of Signal to Crosstalk Ratio vs. Wave length Separation ($\Delta\lambda$) is shown in Fig. 6. From the fig, it is evident that the increase of $\Delta\lambda$ in the transmission line, the SCR performance gets better. That means the more we use spacing the more we get SCR.

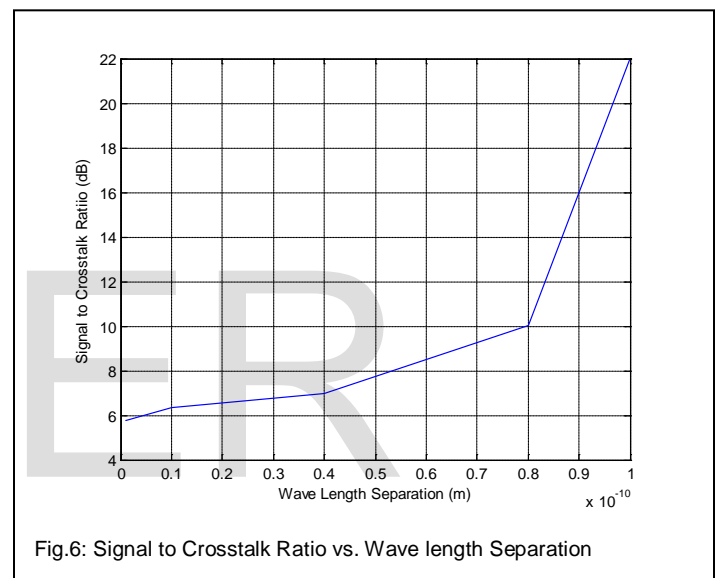


Fig.6: Signal to Crosstalk Ratio vs. Wave length Separation

Plot of Signal to Crosstalk Noise Ratio vs. Wave length Separation ($\Delta\lambda$) is shown in Fig. 7. From the fig, it is evident that the increase of $\Delta\lambda$ in the transmission line, the SCNR performance gets better. That means the more we use spacing the more we get SCNR.

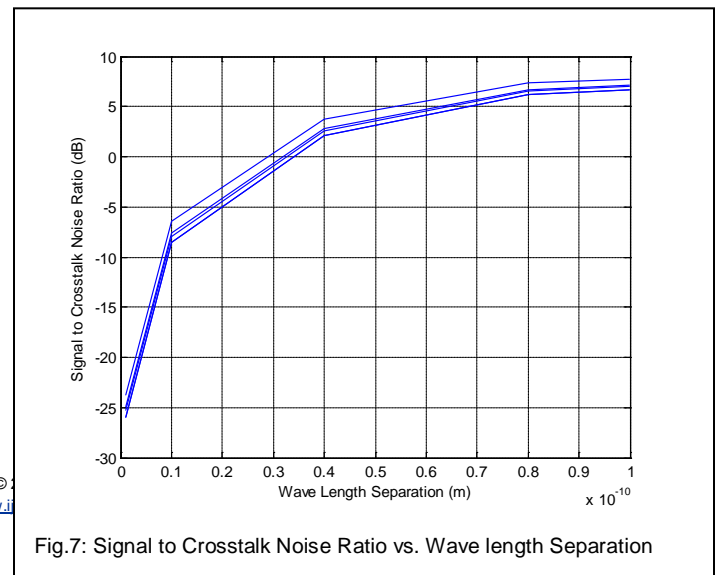


Fig.7: Signal to Crosstalk Noise Ratio vs. Wave length Separation

TABLE 1
ASSUMPTION PARAMETERS

Parameters	Values	Units
Temperature (T)	300	K
Load Resistance (R_L)	50	Ω
Bandwidth (B)	10 to 250	GB
Operating Wavelength (λ_0)	1550	nm
Length of the device (l)	0.034	m
Filter passband width (Δ)	1	nm

Plot of Bit Error Rate vs. Signal Power is shown in Fig. 8. From the fig, it is evident that the increase of Signal Power in the transmission line, Bit Error Rate decreases. That means we get more accurate data transmission through optical link. Also from the fig, we see that BER is decreasing with the increase of received power.

The Assumption parameters are as shown in Table 1

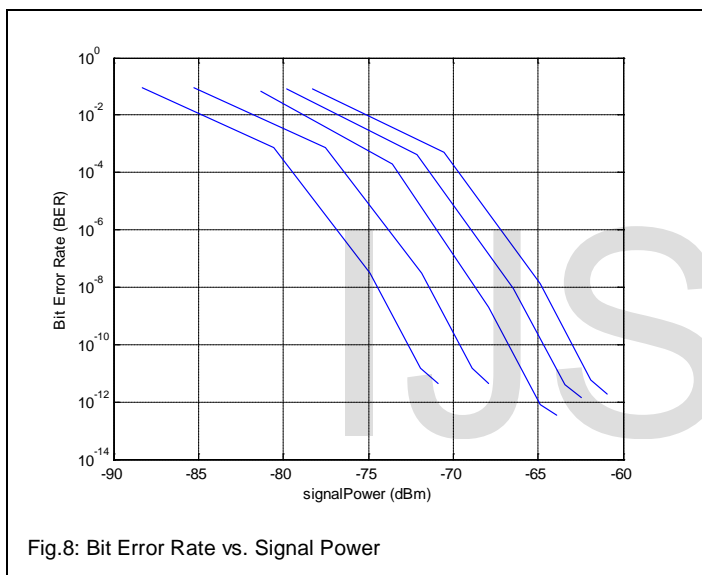


Fig.8: Bit Error Rate vs. Signal Power

Plot of Power Penalty vs. Wave length Separation ($\Delta\lambda$) is shown in Fig. 9. From the fig, it is observed that the increase of $\Delta\lambda$ in the transmission line, Signal Power decreases at $BER=10^{-9}$.

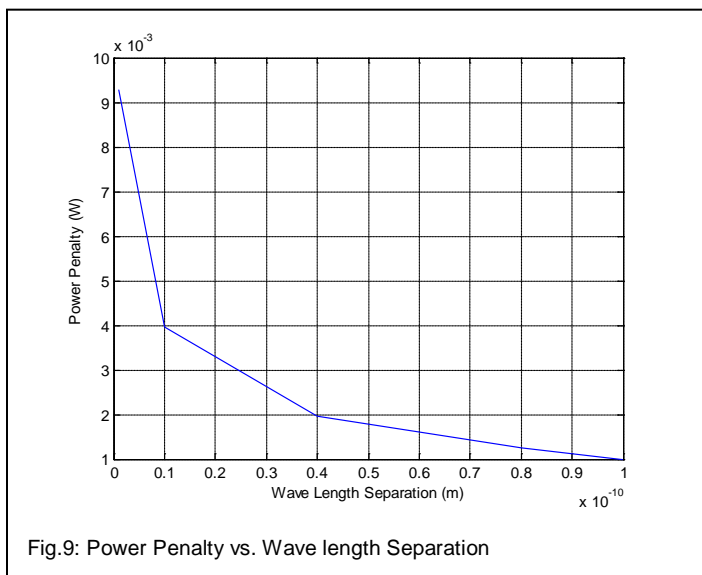


Fig.9: Power Penalty vs. Wave length Separation

7 CONCLUSION

OADM is essential part of DWDM system and for narrower channel spacing we use AOTF in the OADM instead of SW. But the main drawback in Acousto-Optic tunable Filter is the secondary maxima (sidelobes) in its optical transmission spectrum. This results in interchannel crosstalk in dense WDM systems which may lead to a bit error rate (BER) penalty. In this paper we are making sure that a narrow bandwidth was achieved and the sidelobe suppressed as far as possible. The sidelobes are suppressed by using optimum value of passband width.

Through the analysis we determined the performance of an Acousto-Optic Tunable Filter (AOTF) based optical add/drop multiplexer for DWDM system for different parameter values. We found that BER decrease with the increase of SCNR. Thus, from that figures, we can determine the value of BER for any given SCNR. Now we can easily find out the received power, SCNR, input power, penalty power of a DWDM system. This will certainly help us to designing a DWDM system.

8 ACRONYMS

- AOTF - Acousto-Optic Tunable Filter
- BER - Bit Error Rate
- DWDM - Dense Wavelength Division Multiplexing
- OADM - Optical Add/Drop Multiplexer
- OXC - optical cross connect
- SCR - Signal to Crosstalk Ratio
- SCNR - Signal to Crosstalk Noise Ratio
- WDM - Wavelength Division Multiplexing

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