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Crosstalk Effect In A Transmission Line For Dense Wavelength Division Multiplexing (DWDM) System

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Abstract: This paper investigates the performance of a crosstalk analysis of an Acousto-Optic Tunable Filter based optical Multiplexer for Dense Wavelength Division Multiplexing (DWDM) system. Comparisons of wave length separation(m) over the signal power(dBm),crosstalk power(dBm), signal to crosstalk ratio(dB), signal to crosstalk noise ratio(dB) and power penalty(w) in Acousto-Optic Tunable-Filter based optical Multiplexer for DWDM system. This paper also investigates Bit Error Rate (BER) with respect to the signal power (dBm).

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

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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. 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]. 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].

2. THEORY

2.1 Transfer Function

The wavelength dependence of the fraction of the power transmitted by the AOTF [7] can be express as:

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

Here

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

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

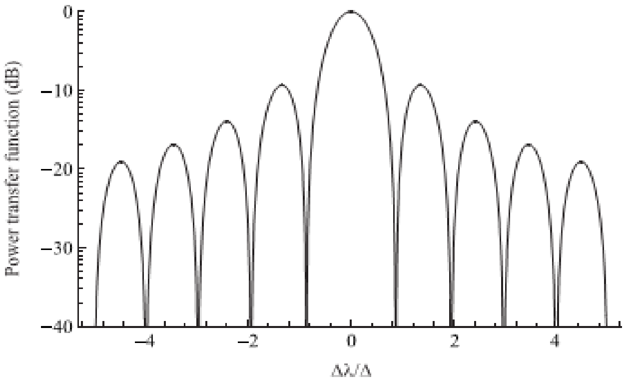

Figure-1: the power transfer function of the acousto-optic tunable filter

2.2 Signals to Crosstalk Ratio (SCR)

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

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

2.3 Signals to Crosstalk Noise Ratio (SCNR)

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

$$SCNR = P_{Sig} / P_c + P_N$$

$$= P_{sig} / \delta_C^2 + \delta_N^2 \qquad (5)$$

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

$$\delta_{Shot}^2 = \text{Shot Noise}$$

$$= 2eB(R_d * P_{Sig}) \qquad (7)$$

$$R_d = \eta e / hf$$

$$= \eta e \lambda_0 / hc \qquad (8)$$

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

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

$$P_{Sig} = \text{Signal Power}$$

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

Here parameters have their usual meanings.

2.4 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 express as,

$$BER = \frac{1}{2} erfc[\frac{\sqrt{SCNR}}{2\sqrt{2}}] \qquad (10)$$

Result and discussion:

Following the analytical approach presented in section 2, the signal power, crosstalk power, signal to crosstalk ratio, signal to crosstalk noise ratio, bit rate error and power penalty results are evaluated.

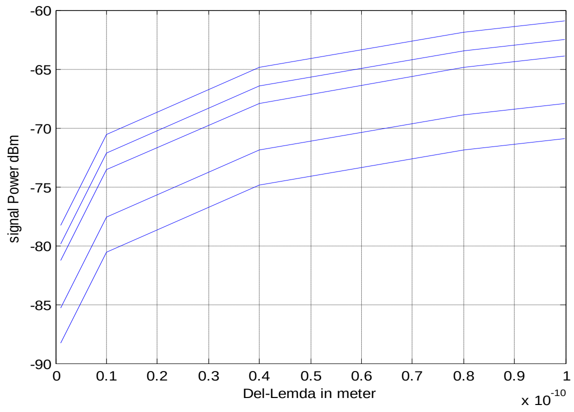

Fig 2.1: Plots of receive power sensitivity versus Channel wavelength separation (Δλ).

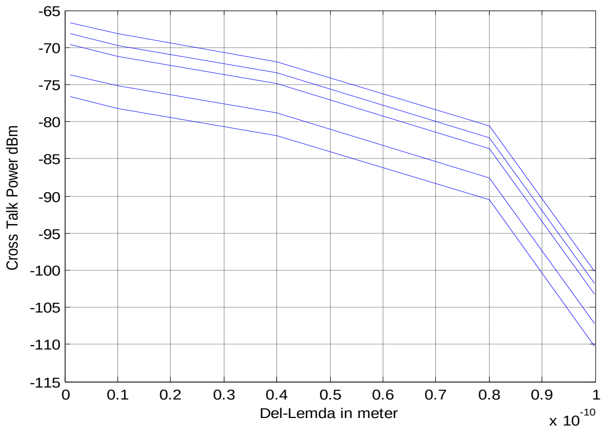

Fig 2.2: Plots of Crosstalk Power versus Channel wavelength separation (Δλ)

Plot of wave length separation vs. signal power is shown in fig.2.1.and wave length separation vs. crosstalk power in fig. 2.2.From the fig. 2.1,it is evident that the increase of wave length separation in the transmission line ,signal power increases but the crosstalk power decreases with respect the wave length separation ,it is shown in fig. 2.2.

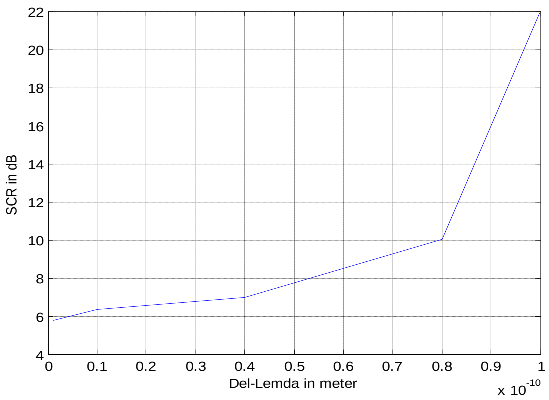

Fig 3.1: Plots of Signal to Crosstalk Ratio (SCR) versus Channel wavelength separation (Δλ).

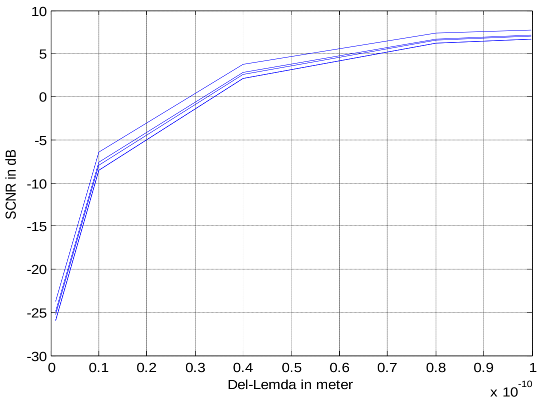

Fig 3.2: Plots of Signal to Crosstalk Noise Ratio (SCNR) versus Channel wavelength separation (Δλ)

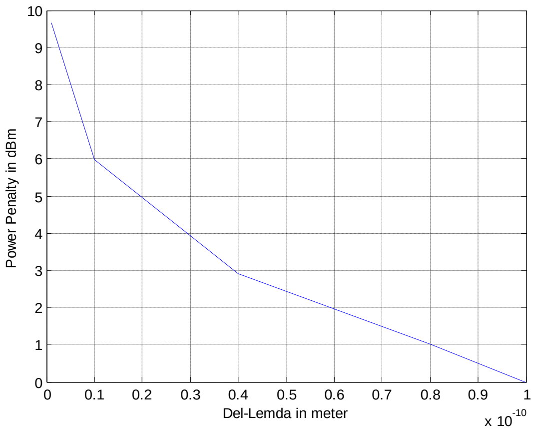

Fig 3.3: Plots of power penalty (dBm) versus channel wavelength separation (Δλ)

Plot of wave length separation vs. Signal to Crosstalk Ratio (SCR) is shown in fig.3.1.and wave length separation vs. Signal to Crosstalk Noise Ratio (SCNR) in fig. 3.2.From the fig. 3,it is evident that the increase of wave length separation in the transmission line , the SCR and SCNR performance gets better. That means the more we use spacing the more we get SCR and SCNR. Besides, it is observed that the increase of wave length separation in transmission line, signal power decrease at BER=10^-9. it is shown in fig 3.3.

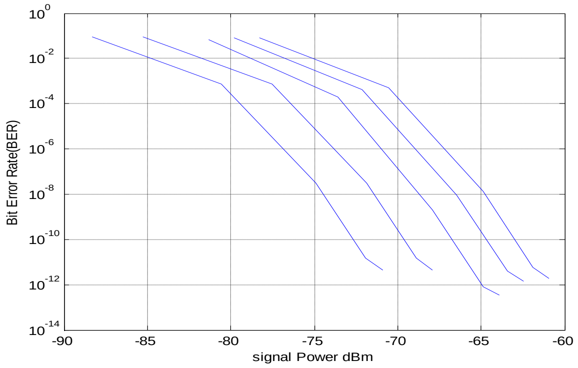

Fig 4: Plots of Bit Error Rate (BER) versus receive power sensitivity

We also observed that the performance Bit error rate vs. signal power in fig.4.From fig.4, 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.

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_o)	**1550**	**nm**
Length of the device (l)	**0.034**	**m**
Filter passband width (Δ)	**1**	**nm**

Conclusion:

We have observed the change in wave length separation in the transmission line over the signal power (dBm), crosstalk power (dBm), signal to crosstalk ratio (dB), signal to crosstalk noise ratio (dB) and power penalty (w). These observations are important in making the optical fiber transmission system more efficient and effective. Through the analysis we determined the performance of an Acousto-Optic Tunable Filter (AOTF) based optical add/drop multiplexer for DWDM system for different parameters values. We also found that BER decrease with the increase of SCNR. This will help us to design a DWDM system.

Acronyms:

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

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