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Effect of Nonlinear Four Wave (Fwm) Mixing in Fiber

KEYWORDS: Nonlinearity, degeneracy and waves

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ABSTRACT *Four Wave Mixing originate from the Kerr nonlinearity and strongly related to self-phase modulation and cross-phase modulation. Nonlinear effects differ only in terms of degeneracy of the involved waves.*

1.1.1: INTRODUCTION:

FWM is a nonlinear effect[4] arising from a third-order optical nonlinearity, as is described with a χ (3) coefficient. It can occur if at least two different frequency components propagate together in a nonlinear medium such as e.g. an optical fiber. Assuming just two input frequency components ω1 and ω2 (with ω2 > ω1), we obtain a refractive index modulation at the difference frequency, which again creates sidebands for each of the input in the figure below. In effect, two new frequency components are generated:

$\omega 3 = \omega 1 - (\omega 2 - \omega 1) = 2\ \omega 1 - \omega 2$

and $\omega 4 = \omega 2 + (\omega 2 - \omega 1) = 2\ \omega 2 - \omega 1$ [79].

FWM is also present if only three components interact. In this case the term f0 = 2f1 - f2 couples three components thereby generating Degenerate four wave mixing. In bulk media, phase matching may also be achieved by using appropriate angles between the beams. FWM in fibers is strongly related to self-phase modulation and cross-phase modulation: all these effects originate from the Kerr nonlinearity and differ only in terms of degeneracy of the involved waves.

FWM can have important deleterious effects in optical fiber communications, particularly in the context of wavelength division multiplexing where it can cause cross-talk between different wavelength channels, and/or an imbalance of channel powers [5]. One way to suppress this is avoiding equidistant channel spacing. FWM can transfer data to a different wavelength. A continuous wave pump beam is launched into the fiber together with the signal channel. Its wavelength is chosen half-way from the desired shift. FWM transfers the data from signal to the idler beam at the new wavelength [3].

Some of the advantages of FWM include parametric wavelength conversion, optical phase conjugation, demultiplexing of OTDM channels, wavelength conversion, and supercontinum generation. While some of its disadvantages are interchannel crosstalks, induction of noise and hence degrading the overall performance of the system.

1.1.2: Experimental Setup:

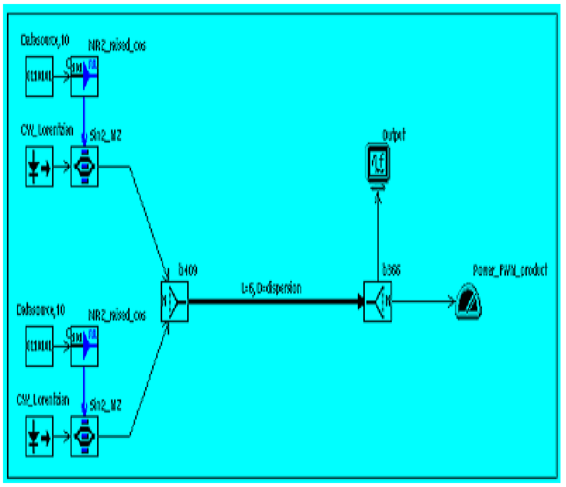

Fig.1: Experimental Setup

The experimental setup in Fig. 1 contains data source, Continuous wave laser source, Mach Zender modulator, driver, splitter, combiner, spectrum analyzer, and a power meter. The data source produces data at a rate of 10 GB/s or higher in the form of ones and zeroes. This data is then transferred to the driver which is a device that is used to convert the binary zeroes and ones into electrical format i.e. NRZ or RZ format. The signal is then passed on to Mach Zender modulator [2]. A modulator is a device that modulates carrier signal according to the modulating signal. Here the modulating signal is the one passed on from the driver and the carrier signal wavelength is provided by the continuous wave laser.

It must be noted that the optical signal is transmitted at a particular wavelength generated by the continuous wave laser and at a particular power level. The two optical signals of particular wavelength and power are multiplexed through combiner and are transmitted through the optical fiber cable[1]. The optical signal at the receiving end is passed on to splitter through which multiple analyzing components can be attached to make analysis of the received signal.

1.2.1: Result and Discussion:

In this experimental setup the two lasers are operating at center frequencies of 193.025 THz and 193.075 THz. Fig.

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2 shows the FWM cross products [7] and Fig. 3 shows plot of power vs. dispersion.

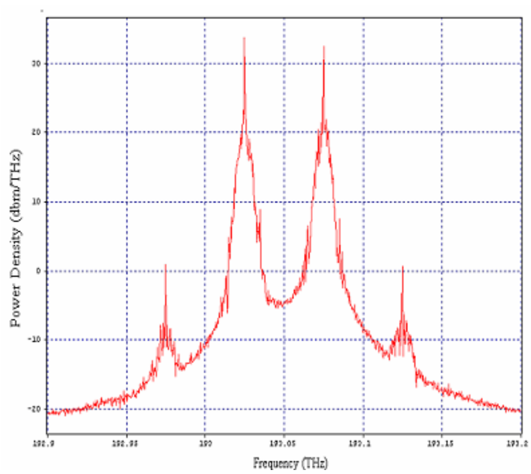

Fig. 2: Output Wavelengths (Power density vs. Frequency)

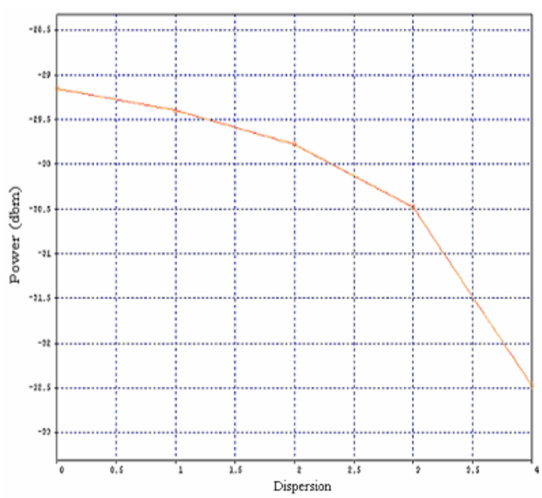

Fig.3: Power vs. Dispersion plot

CONCLUSIONS: Optical fibers exhibit a variety of nonlinear effects. Nonlinear effects are feared by telecom system designers because it can lead to transference of wrong or incorrect data to the receiving end due to interchannel mixing if the sideband wavelengths generated due to FWM coincide with the original wavelengths carrying data.

These nonlinear effects can be managed through proper system design. There are many ways by which these nonlinear effects can be reduced.

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