Fiber optics communications using liquid crystal based Fourier optical spectrum analyzer without moving parts

Jitendra Gothwal [1], Manish Kumar Agarwal[2]

[1]M.Tech Research Scholar, ECE Department, Bhagwant University, Ajmer, Rajasthan
[2]Assistant Professor, ECE Department, Bhagwant University, Ajmer, Rajasthan

ABSTRACT

Wavelength division multiplexing (WDM) corresponds to the scheme in which multiple optical carriers at different wavelengths are modulated by using independent electrical bit streams and are then transmitted over the same fiber. The optical signal at the receiver is demultiplexed into separate channels by their wavelengths. WDM has the potential for exploiting the large bandwidth offered by the optical fiber. In this thesis, a method of Fourier analysis of multi-beam interference is developed. It is shown that the total electric field and relative phase delay of each beam form a Fourier transform pair. Thus methods and properties of Fourier analysis are applicable in multi-beam interference analysis and design. Fourier transform based design is presented. Novel devices that apply such design principles are introduced. Principles and structures of novel adaptive attenuators based on various technologies such as segment deformable mirror, liquid crystal, phase modulation array are given. Simulation results for segment deformable mirror based adaptive attenuator are presented. In wavelength division multiplexed (WDM) optical communication networks, signals are amplified periodically by optical amplifiers. Since the gain profiles of optical amplifiers are not flat, equalizers are usually used to maintain signal powers at different wavelengths in equal to avoid crosstalk and data loss. However, fixed attenuation can only compensate fixed input power and amplification. In active network, input power and amplifier gain change with time. Active level compensation at each wavelength is needed. An adaptive attenuator is a device with a chromatically variable transitivity used to equalize channel powers in wavelength-division Multiplexing (WDM) fiber-optic communication lines. We propose and demonstrate a liquid-crystal (LC)-based Fourier optical spectrum analyzer (FOSA). The FOSA consists of a birefringent filter array with an embedded LC phase modulator. The LC phase modulator is used to control the phase difference between two orthogonally polarized beams to avoid mechanical movement in conventional Fourier transform spectrometers. The detailed operation principle of this FOSA is described. A single-LC-based 6-stage FOSA is experimentally demonstrated, and the results obtained using such a FOSA show good agreement with the results measured using a reference spectrometer. We propose a liquid crystal (LC)-based cost-effective Fourier optical spectrum analyzer (FOSA) without moving parts. Unlike normal spectrometers, the LC FOSA retrieves the spectrum's Fourier coefficients instead of the direct spectrum measurement by changing different LC states in a number of stages. Besides the common applications, the LC FOSA can precisely read and recover the envelope of a dense wavelength-division-multiplexing spectrum to act as a spectral monitor and then work with a gain-flattening device to control the optical network instantly and dynamically.

Keyword : - *Fiber , Liquid, Parts, and Optical Spectrum etc.*

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1. INTRODUCTION

Electrical tuning of the photonic band gap is achieved with the infiltration of smectic liquid crystal and an all-fiber tunable notch filter is displayed for applications in optical communication. A novel technology for all-fiber based electric field sensing was developed with the use of photonic crystal fibers infiltrated by nematic liquid crystal. A simple and compact all-fiber sensor head is displayed, which allows accurate measurement of electric field intensity, as well as detecting and measuring electric field signal parameters such as frequency, amplitude and direction of the electric field. Studies on the sensor's transmission and reflection responses demonstrate the capability of a simple and compact all-fiber electric field sensor to operate in in-line and end-point type configurations. The effect of the applied electric field frequency frequency on the propagation properties of the liquid crystal infiltrated photonic crystal fiber ranges from 50 Hz to 1 kHz. It has been proven that the parameters of the applied electric field, such as frequency and amplitude, can be measured by using the appropriate fitting function for the transmission response time of the fiber. Selected infiltrated photonic crystal fibers are studied in a polarized electric field sensing scheme and an electric field range is given which allows to obtain a linear transmission response for the optimization sensor of the length of the infiltrated section of the photonic crystal fiber subject to electric field. The directional electric field sensitivity of the elliptical core photonic crystal fiber penetrated by the liquid crystal is studied and a true all-fiber directional electric field sensor is displayed, capable of simultaneously detecting and measuring the amplitude and direction of the applied electric field. The use of optical fibers in telecommunications has become of great importance in recent years because such technology allows high rate and low attenuation. The geometry of the optical fiber with special attention to the physical phenomena that provide the optical transmission of the signal. Of great importance is the phenomenon of scattering, attenuation and nonlinear effects, which often result in loss of function. The most important submicron electronic devices that allow electro-optical (vice versa) communication are also active and passive optical components such as lasers (exploiting the excited emissions of radiation) or photodiodes to understand the emission phenomenon of photons. In recent years, commercial solutions for optical transceivers have had great success in the market. The optical transceiver module, i.e., from a physical point of view, is an integrated circuit that allows both the transmission and the reception of the optical signal. The study of the performance of a transmitted or received optical signal depends on the optical medium and the definition of the signal transmission on the receipt. Soon, the proposed metrics will be based on the study of confusion, delay or errors in the generation and signal reception (BER and sensitivity) of eye diagrams that provide an overall focus of transmission goodness. The most important optical fiber communication standard that allows optical fiber transmission with bit rates ranging from 4Gbps to 10Gbps.

2. Wavelength Division multiplexing (WDM)

The achievable transmission bandwidth of optical fiber exceeds Tbps. However, such performance is not possible these days due to the limited number of electrical components available. The current maximum transmission speed is single channel 40 Gbit / s (with multilevel modulation). It is possible to use multichannel systems to capture the enormous potential of fiber, where each transmission channel is transmitted independently from the others, modulating the carrier at a certain wavelength. This leads to the wavelength section multiplexing 41 (WDM) system as shown in the following figure:

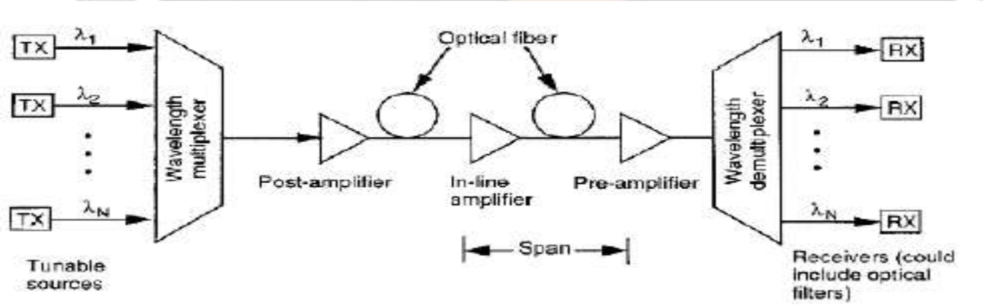


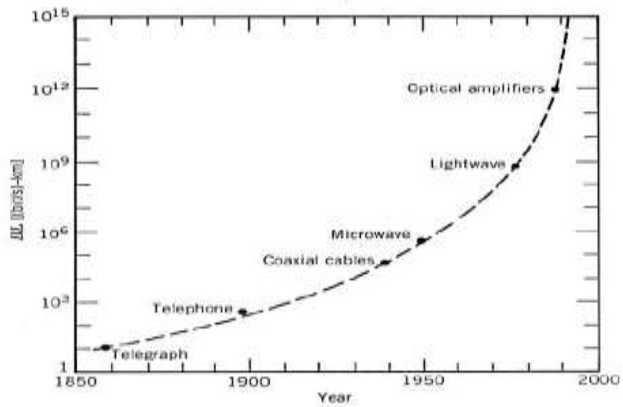
Figure 1.1: Wavelength Division Multiplexing scheme

The components comprising a typical WDM system are:
Transmitter: DFB laser, Lithium niobate external modulators;
Optical multiplexers and de-multiplexers: AWG filters;
Optical In-line amplifier: EDFA;
The receiver: Photodiodes PINFET broadband networks;
Optical transmissions typically represent the WDM distance between carriers at> 100 GHz (or 1 nm), whereas DWDM (dense WDM) for dense WDM-space refers to 42, where the order of magnitude of the gap between words is the bandwidth of the coarse wavelength of the coefficient of bandwidth (CWDM) 43 is the combination of several optical channels into a single fiber. CWDM technology uses the ITU standard 20nm spacing between wavelengths from 1310nm to 1610nm. With CWDM technology, transponders, lasers and filters are generally not too expensive as the wavelengths are far apart (compared to DWDM).

3. Need for Fiber Optic Communications

The advent of telegraphy in the 1830s ushered in the era of electronic communication.
The bit rate can be increased to b10b / sec using new coding methods such as Morse code. The use of intermediate relay stations allowed for long distance (k 1000 km) communication. The first successful Atlantic telegraph cable was launched in 1866. The invention of the telephone in 1876 underwent a major change, with electrical signals being transmitted in various forms in analog form. For more than a century, analog electrical techniques have dominated communication systems.

Figure 1.2: Increase in bit rate-distance product BL during the period 1850-2000



4. LITERATURE REVIEW

Due to its large bandwidth and dielectric resistance, the fiber optic communication network is primarily used for distribution automation systems (DAS).
Hwang and Choi [2] proposed a complex network where WLANs are connected to a fiber-optic network to extend DAS across distribution paths. They designed the DAS wireless bridge for a specific communication network using IEEE 802.11, effectively testing WLN technology and feasibility in terms of transmission speed and the sensitivity of the received signal.
Malachia et al. [3] Optical back propagation (OBP) technology was evaluated using high non-linear two fibers to compensate for the transmission fiber non-linear effects.
Shengley [4] reviewed emerging technology for developing fiber-optic data communication bandwidth for next-generation broadband networks.
Al Najjar et al. [5] A station based on the Smart Communication Platform System (SCPS) has been proposed to test the performance of the system used to maintain and support the communication network in disaster areas.
Bhosal and Dioscorker [6] analyzed the performance of a spectral phase encoding optical coding multiple access scheme based on wavelength / time (W / T) signals and random phase signals.
Wool et al suggested new technology. [7] Modulation format-transparent polarization tracking and demultiplexing to determine polarization status independently of the modulation format.
Li et al. [8] The millimeter-wave (MM-wave) generation of the e-band (71–76 GHz, 81–86 GHz) was first tested based on the Photonics generation technique. Sue et al.
[9] A simple low-cost, high-sensitivity fiber optical sensor system was used to measure the refractive index (RI).

5. RESEARCH METHODOLOGY

For an actual digitally controlled adaptive attenuator, there are fundamental limits for device performance. They are: relative delay range $|\Delta T|$max number of bits of control b and number of mirrors N. Since the relative delay components {DT} the device can provide is discrete and limited, the methodology developed in Chapter 5 is no longer suitable. The theory of attenuation spectrum design based on discrete relative delay spectrum is discussed below. From Fourier transform theory we know that a discrete periodic time signal x(nTs) has discrete periodic spectrum X(kf1) as shown in Fig 1.4.

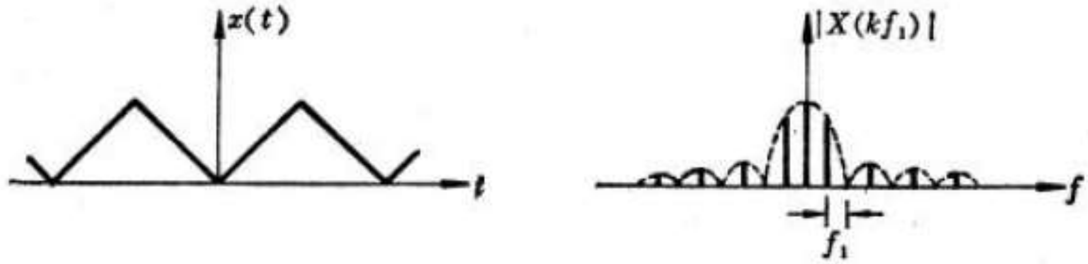


Figure 1.3: Time signal and its spectrum

Where $f1=1/T1$, and T1, is t he period of the time varying signal: $x(t+T1) = x(t)$

It is the same in the optical spectrum and relative delay spectrum as shown in Figure 1.3.

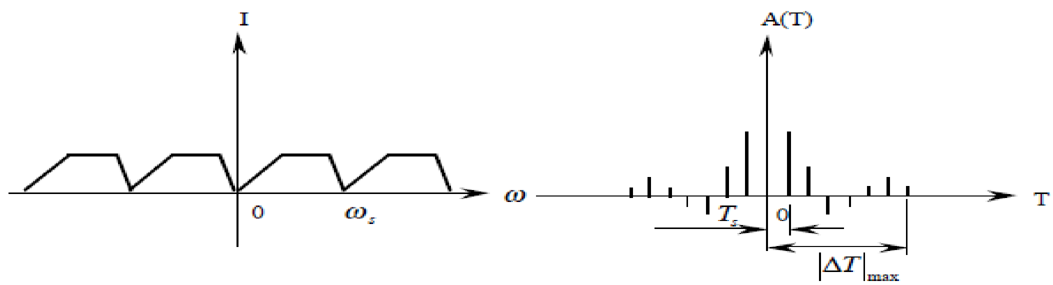


Figure 1.4: optical spectrum and its relative delay spectrum

Where $T_s = 2\pi/\omega_s = |\Delta T|max/\ 2b-1$ The step of spectrum design for the deformable mirror based adaptive attenutor is:

Calculate the quantization step $T_s = 2\pi/\omega_s = |\Delta T|max/\ 2b-1$ where $|\Delta T|max= (2\cos\theta\ \Delta Lmax/2\ )/c$, $\Delta Lmax$ is the maximum vertical movable range that the deformable mirror can cover.

Calculate $\omega s= 2\pi/\ Ts$

Expand the desired attenuation spectrum $I(\omega)$ with period ωs and get $Ip\ (\omega)$

Fourier transform of $Ip\ (\omega)$ gives discrete spectrum components that the device can provide

This is a transmission kind adaptive attenuator. A airplane wave is incident upon the liquid crystal based totally segment modulator array. Refractive index of every unit of the array can be managed electronically. The mild via every unit is deemed as one beam. The beams that go via the array will intrude with every different after the 2nd center of attention lens. By altering the refractive index of every unit of the array so as to allocate the segment difference, we can use a pc to arbitrarily allocate {T} amongst the beams. Group ok unit into m groups. Among every group, $\Delta T=0$ {A(T)} allocation is achieved. allocation is achieved. When the range of unit is large, power allocation and section allocation can be modified individually. The machine deployment is plotted in Figure 1.5.

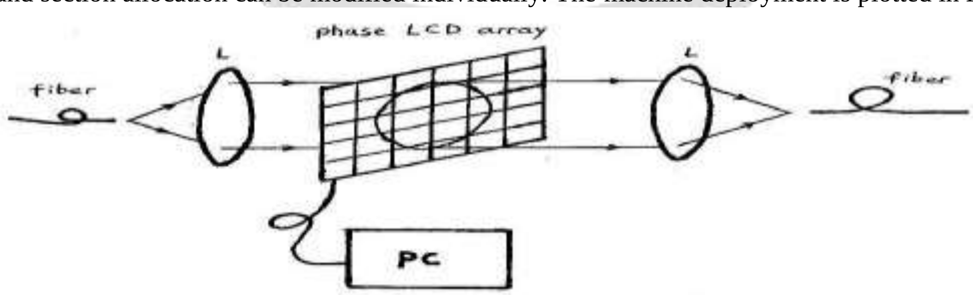


Figure 1.5: Phase-LCD array based adaptive attenuator

6. EXPERIMENTAL RESULTS

To prove the design principle, a prototype 6-stage FOSA device working at approximately λ= 1.55 μm telecom band is experimentally demonstrated. Quartz crystals of 5mm

Thickness is used as birefringent materials. The FSR for a single quartz crystal is calculated to be 7.1 THz in the nearinfrared band. Although only one crystal is used for the first FOSA stage, the device dimension is determined by the sixth stage with 6 quartz crystals. An 8-um-thick LC cell was used for the experiments. The inner surfaces of the substrates are coated with thin polyimide layers in ant parallel rubbing directions, which introduce a homogeneous alignment of LC molecules. Then the cell was filled with a Merck E44 LC mixture through a capillary effect. To determine the operating voltages of this LC cell, voltage-dependent transmittance was measured between the two crossed polarizers. Figure 1.6 shows the results. As the applied voltage increases, the transmitted light intensity oscillates. From Fig. 1.6

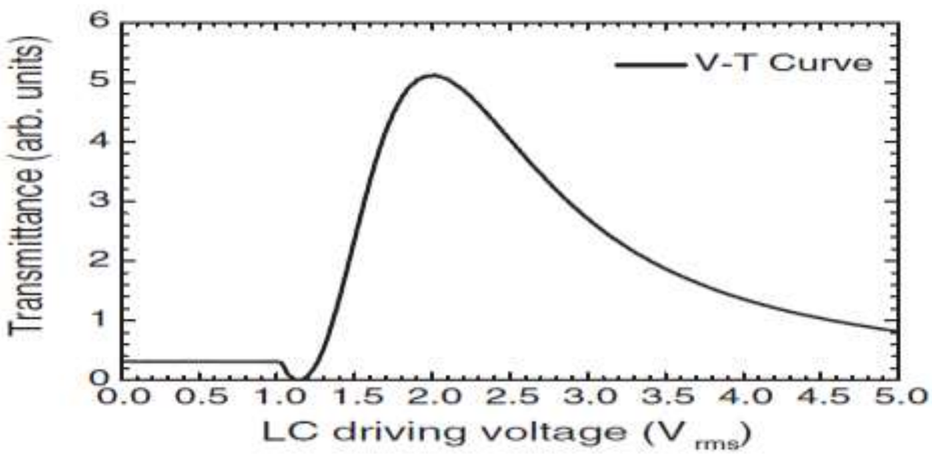


Figure 1.6:. Voltage-dependent transmittance of homogeneous E44 LC cell between two crossed polarizers. Cell gap d= 8μm, λ = 1.55 μm and T=220 C

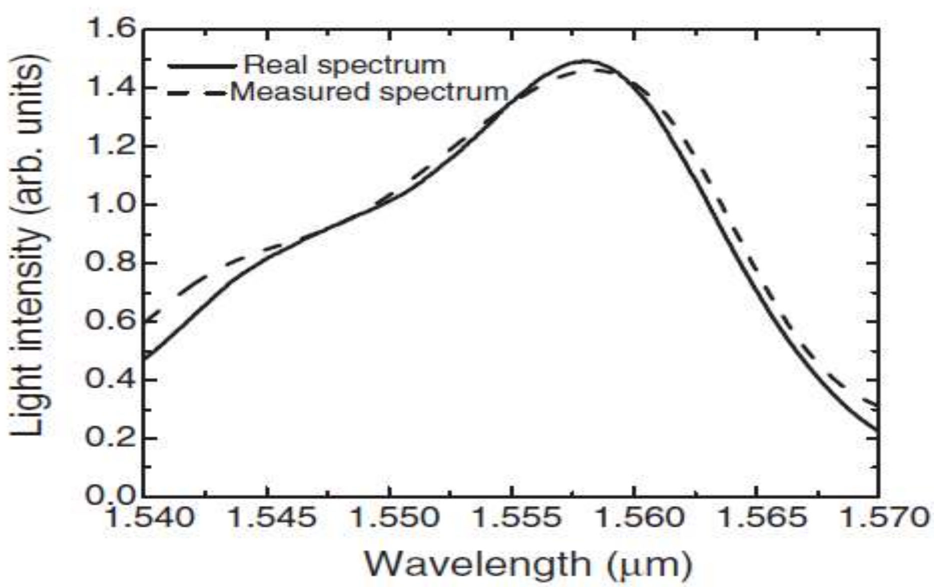


Figure 1.7: Spectrum of broadband infrared source centered at λ =1.56 um. The solid line is measured with a grating-based spectrometer, while the dashed curve is the spectrum reconstructed using the 6-stage FOSA.

voltage-dependent phase retardation can be calculated. We found that the operating voltages corresponding to π/2, 3π/2 and 2 π, phase retardations are 3.1, 1.5 and 1.1Vrms, respectively. After installing the LC cell in the experimental setup, a computer-controlled Lab VIEW system was used to drive the LC cell in the designed voltages sequentially and record the transmitted light intensity for each state. The input light spectrum is thus mathematically rebuilt from the calculated Fourier coefficients. Figure 1.7 shows the spectrum of a broadband infrared amplified spontaneous-emission light source centered at

λ =1.56 um The dashed line is reconstructed from Fourier modules measured using a 6-step fossa, while the solid line is a spectrum measured using a spectrometer based on high resolution grading. The spectral curve measured with our fossa corresponds to the actual spectrum. The fossa successfully determines the shape of the base curve, peak position and spectral width. Many factors not considered in the calculation can lead to test errors being examined. For example, in our prototype fossa, the phase retardation of each byrfrint filter is very large. Due to incorrect alignment and thickness variation of the crystal the phase retardation of each filter may not be more accurate than the first step, which affects the final results. Our LC-controlled fossa and Wolston-Prism-based FTS have no moving parts. However, the LCF fossa is based on the Fourier series, the latter being based on the Fourier transformation. LC Fosa is more suitable for digital control as it does not require complex image processing. Their achievable resolution is comparable. The main difference is the maximum spectral range that can be measured. It only works in the spectral range created by LCFOS, although FTS has no such restrictions. The measurable spectral range of the fossa can be expanded by increasing the number of steps to maintain a single resolution by reducing the phase retardation difference between adjacent steps. The fossa is therefore similar to the FLTS based on the Wolston prism with a gradually embedded LC cell. In this case, the "Wollaston prism" and LC cells cause the variable phase difference. This hybrid FTS may have some unique and interesting features. On the other hand, the LC used in the experiment was only a uniformly arranged cell. The transition time between different driving voltages is more than 100 milliseconds, which is not very fast. To reduce response time, several approaches can be considered, for example, the use of high-quality merit LCs, improvements to the driving scheme and the introduction of polymer networks to LCs.

7. CONCLUSION & FUTURE WORK

Its disadvantages may be: performance is related to the accuracy of the lens system; The position of the core of the collected fiber is related to accuracy, numerical aperture and diameter; The performance of the device is smooth with segment mirror phase control accuracy and beam distribution power distribution. Future action will include further simulation of the effect presented by the lens deflection, the effect introduced by the fiber position and aperture, and the effect introduced by the segment mirror face control tolerance. The Gaussian beam works on the compensation problem such as the weight in front of the mirror to eliminate performance deterioration. Fourier analysis of multi-beam interaction is suggested first and then applied to multi-beam interaction design. Several novel adaptive attenuators based on Fourier analysis have been demonstrated. The adaptive attenuator based on the segment deformable mirror is studied in detail and its performance simulation results. Fourier analysis is a very powerful tool in the analysis and design of multi-beam interaction devices. High efficiency devices can be designed based on this understanding. Segment Deformable Mirror Based Adaptive is one of the best identifiers of concept on adapter. It is a powerful tool for spectrum formation. It has great advantages over traditional multi-beam interaction devices: direct unrestricted spectrum structure; Low inclusion loss; High speed; Computer controlled; Polarization sensitive; Simple device construction; High flexibility. We experimented with a 6-step fossa without moving parts. Unlike traditional spectrometers, the LC phase modulator recovers the Fourier spectrum of the fossa spectrum instead of controlling the phase retardation and measuring the direct spectrum. The measured spectrum of the infrared source shows good coordination with the actual spectrum. It also discusses some possible approaches to improve fossa performance.

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