Color multiplexing using directional holographic gratings and linear polarization

L I Lugo, A Rodríguez, G Ramírez, S Guel, OF Núñez
Instituto de Investigación en Comunicación Óptica (IICO)
Universidad Autonoma de San Luis Potosi, S.L.P. (UASLP), México
E-mail: roca@cactus.iico.uaslp.mx

Abstract. We propose a system of multiplexing and de-multiplexing, which uses a holographic diffraction grating to compel modulated light of different colors to be sent through an optical fiber. Diffraction gratings were fabricated specifically to pick the desired direction in which we wanted the light of different wavelengths to impinge the optic fiber, and also to be separated at the output. It was been found that the system preserves the polarization of light, which give us a one more freedom degree, allowing us to process twice the original information amount.

1. Introduction
Radio electromagnetic waves have been utilized for a long time as a mean of sending large amount of information by multiplexing several waves that use the same carrier.

For the time being, there exist several techniques of multiplexing electronically, several radio waves such as: the one known as Multiplexing Code Division, (MCD), which allows several signals from different sources to be transmitted simultaneously using only one carrier. The Frequency Division Multiplexing (FDM) method which allows the transmission of several messages using the same frequency band; this method uses subsystems to modulate the messages to be sent. Finally we have the Time Division Multiplexing, (TDM) where information from different sources is intercalated, and so each message is transmitted one after other using a single channel. All these techniques have the characteristic that in order of multiplexing different signals, either the frequency or the amplitude of the carrier has to be modified, however all these methods have proven their effectiveness and are widely used in information processing systems [1].

Lately, several alternative methods of multiplexing have been proposed which use light beams as carrier of different stacks of information and that utilize an optic fiber as the channel through which modulated light is sent. In both sides of the fiber, photo-voltaic transducers transform electrical signals into light pulses and vice versa. In this way, the carrier of information is a light wave modulated only in intensity [2].

In this work we propose a multiplexing system which utilizes light of different wavelength and holographic gratings made ex-profeso, whose spatial frequency is determined depending of what color is to be obtained in some also pre-determined direction. Each wavelength can be modulated with a digital or analogical different signal; in such a way that multiple information can be sent simultaneously, using only one channel which can be an optical fiber. De-multiplexing is carried out using a similar grating, working backwards, allowing throughout an electronic system to recuperate the modulating information. It was been found that the system preserves the polarization of light, which give us a one more freedom degree, allowing us to process twice the original information amount [3].
2. Method and Experimental Results

As it is well known a grating is an optical tool which can diffract a beam of light by changing its direction depending on the spatial frequency of the grating itself. In the simplest experiment, figure 1 shows a beam of green light impinging on a grating that is deviated at some $\theta$ angle given by the relation:

$$\sin \theta = \frac{\lambda}{\sigma}$$

(1)

Where $\lambda$ is the wavelength of incident light and $\sigma$ is the grating spatial frequency. Then we see that for different wavelengths, angles can be easily calculated.

![Figure 1. Diffraction pattern for a green beam ($\lambda = 514 \text{ nm}$), both schematic and real picture. a) Central lobe, b) and c) Diffracted lobes at $\theta = 25^\circ$.](image)

On the other hand, gratings can be fabricated for any desired value of $\sigma$ using a holographic system as the one shown in figure 2; by recording on a holographic plate, the interference pattern of two plane wave fronts prevailing at some angle $\theta$.

![Figure 2. Experimental scheme to fabricate holographic gratings. a) Laser, b) Spatial filter, c) Beam splitter, d) Reference wave, e) Object beam, f) g) y h) Mirrors, i) Interference angle $\theta$, j) Holographic plate.](image)

Once the different wavelengths are chosen, the holographic gratings are fabricated for the desired $\sigma$ values. Then with an array as the one shown in figure 3, beams of different colors each modulated by different signals, are enforced in an unidirectional way through a
polarization preserver optical fiber with the aid of one of the holographic gratings, as shown in figure 3; thus completing the multiplexing.

![Figure 3. Scheme of the multiplexing system](image)

**Figure 3.** Scheme of the multiplexing system a) Tunable argon laser, b) Beamsplitter, c) and d) Short band filters e) f) g) and h) Mirrors, i) Holographic grating, j) Microscope objective k) Optical fiber, l) Focusing lens, m) Spectrometer, n) HeNe laser, ñ) Computer.

De-multiplexing can be carried out with one of the holographic gratings working backwards, this is: light coming out from the output of the optical fiber is made to enter in direction normal to a grating which spatially separates the different wavelengths in different angles according to what has been explained previously; thus allowing their analysis with an spectrometer, as shown in figure 4. Results can be completed setting up polarizers in front of each laser, inasmuch as polarized light also plays an important role in the experiment; since as can be seen from figures 5 and 6, it is still possible to remove one or more of the multiplexed wavelengths, depending of their original polarization states, by using an analyzer at the fiber output.

![Figure 4.](image)

**Figure 4.** Polarization Preserver Fiber (PPF) spectrum of multiplexed signals. Polarizers with axis in vertical and horizontal directions are fixed up in front of the Ar (488 nm, 514 nm) and He-Ne (633 nm) lasers, respectively.
Figure 5. Fiber Output spectrum when the analyzer axis is fixed up in vertical direction eliminating the wavelength: \(\lambda = 633\ nm\).

Figure 6. Fiber output spectrum when the analyzer axis is fixed up in vertical direction eliminating the wavelengths: \(\lambda = 458\ nm\) and \(\lambda = 514\ nm\).

3. Conclusions
In now days communications systems become more and more complexes. Wave light technology allows somehow a simplified point of view to the perspective offered by such a methods. The aim of this work was simply to present how a basic characteristic of light properties can be used in favor of a simplified methodology in the field of the communications and the world of information processing and transmitting data.
4. Bibliography

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