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Optical Wave in Optical Fibber Communication System

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Abstract: Optical fibers act for optical frequencies (10^{15}Hz) as waveguides act for microwaves (10^{10}Hz) but they have many advantages over waveguides. Optical frequencies, being of the order of 10^{15}Hz, are much greater than microwaves (10^{10}Hz), so a optical beam, when used as a carrier wave for sending information, is capable of carrying far more information than radio or microwaes. I.e. information carrying capacity of an optical fiber is much greater than microwaves systems at optical frequency.
Keyword: Wave guide, frequency (H_z), Optical wave, optical frequency, microwaves,

I. INTRODUCTION

The ray-based model of light has developed first followed by the wave model of light. Progress in electromagnetic theory in 19th century led to discovery that light waves (optical waves) were in fact electromagnetic radiation. Some phenomena depend on the fact that light has both wave-like and particle like properties. Optical science is relevant to and studied in many related disciplines including astronomy various engineering fields, photography and medicine. Practical applications of optics are found in a variety of technologies and everyday objects including mirrors, lenses, telescope, microscope, lasers and now-a-days a great demand, the use of optical in fiber technology. Optics treats the light (or electromagnetic radiations in general) with explicit recognition of its wave nature. The counterpart of wave optics is ray optics or geometrical optics, assuming the propagation of optical wave as a straight – line phenomenon except for reflection or refraction. The word optics comes from the ancient Greek Word (Optika), meaning - "appearance, look”. It is the branch of physics which involves the behaviour and properties of light wave (optical wave) including its interactions with matter. Optics usually describes the eaviour of visible, ultraviolet and infrared optical wave Because light is an electromagnetic wave, other forms of electromagnetic radiation such as X-rays, microwaves and radio waves exhibit similar properties. In this paper we have discussed quantum nature of optical wave and optical spectral band used in optical fiber communication system.

A. Body text Quantum nature of optical wave

The wave theory of light adequately accounts for all phenomena involving the transmission of light. However, in dealing with the interaction of light and matter, such as occurs is dispersion and in the emission and absorption of light, neither the particle theory nor the wave theory of light is appropriate. Instead, we must turn to quantum theory, which indicates that optical radiation has particle as well as wave properties. The particle nature arises from the observation that light energy is always emitted or absorbed in discrete units called quanta or photons. In all experiment used to show the existence of photons, the photon energy is found to depend only on the frequency ν. This frequency, in turn, must be measured by observing a wave property of light.The relationship between the energy E and the frequency v of a photon is given by

$$E = hv \qquad ....(1)$$

where$h = 6.625\times10^{-34}$ J.s is Planck’s constant. When light is incident on an atom, a photon can transfer its energy to an electron within atom, thereby exciting it to a higher energy level. In this process either all or none of the photon energy is imparted to the electron. The energy absorbed by the electron must be exactly equal to that required to excite the electron to a higher energy level. Conversely, an electron in an excited state can drop to a lower state separated from it by an energy hv by emitting a photon of exactly this energy.

B. Optical Spectral band

All telecommunication systems use some form of electromagnetic energy to transmit signals. The spectrum of electromagnetic (EM) radiation is shown in Fig. '1’& '2'. Electromagnetic energy is a combination of electrical and magnetic fields and includes power, radio waves, microwaves, infrared light, visible light, ultraviolet light, x-rays, and gamma rays. Each discipline takes up a portion (or band) of the electromagnetic spectrum. The fundamental nature of all radiation within this spectrum is that it can be viewed as

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electromagnetic waves that travel at the speed of light, which is about c = 3×10^8 m/s in a vacuum. Furthermore the speed of light s in a material is smaller by the refractive-index factor n than the speed c in a vacuum. For example, $n\approx 1.45$ for silica glass, so that the speed of light in this material is about $s = 2\times10^8$ m/s. The physical properties of the waves in different parts of the spectrum can be measured in several interrelated ways. These are the length of one period of the wave, the energy contained in the wave, or the oscillating frequency of the wave. Whereas electrical signal transmission tends to use frequency to designate the signal operating bands, optical communication generally uses wavelength to designate the spectral operating region and photon energy or optical power. The Fig. '1' & '2' depicting electromagnetic spectrum, there are three different ways to measure the physical properties of a wave in various regions in the EM spectrum. These measurement units are related by some simple equations. First of all, in a vacuum the speed of light c is equal to the wavelength λ times the frequency v, so that

$$c = \lambda v \qquad \text{.................................. (2)}$$

Where the frequency v is measured in cycles per second or hertz (Hz).

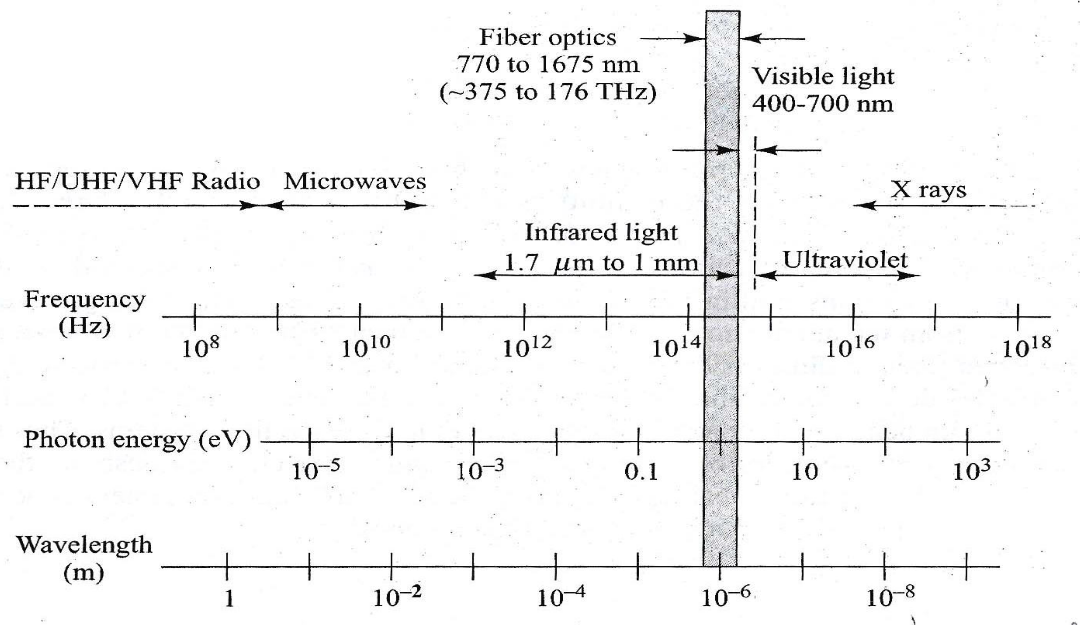

Fig -(1)

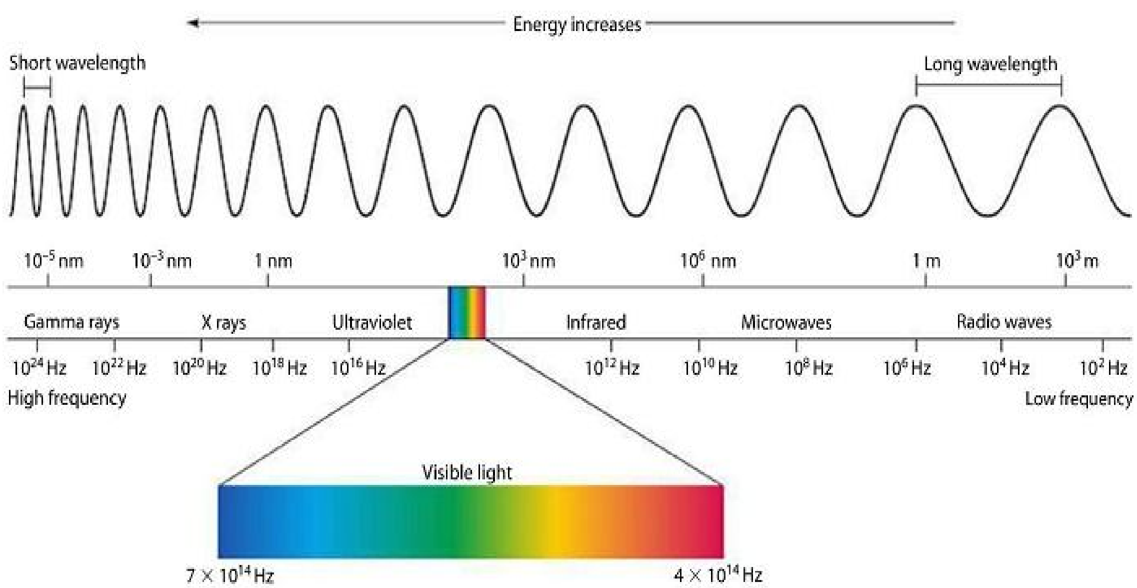

Fig-(2)

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Fig.'1' &'2': Electromagnetic radiation spectrum. The figure shows higher will be the frequency, higher will be the quantum energy of optical wave and lower will be the wave length of the wave and vise-versa.

The relationship between the energy of a photon and its frequency (or wavelength) is determined by the equation known as Planck's law

$$E = h\nu \qquad \text{..................... (3)}$$

Where the parameter $h = 6.63\times10^{-34}$Js = 4.14 eV-s is Planck's constant. The unit J means joules and the unit eV stands for electron volts. In terms of wavelength (measured in units of μm), the energy in electron volts is given by

$$E(eV) = \frac{1.2406}{\lambda(\mu m)} \qquad \text{..................... (4)}$$

Fig.'1' shows, the optical spectrum ranges from about 5 nm in the ultraviolet region to 1 mm for far-infrared radiation. In between these limits is the 400-to-700 nm visible band. Optical fiber communications use the near–infrared spectral band ranging from nominally 770 to 1675 nm.

The International Telecommunications Union (ITU) has designated six spectral bands for use in optical fiber communications within the 1260–to–1675-nm region. These long-wavelength band designations arose from the attenuation and dispersion characteristics of optical fibers and the performance behavior of an erbium-doped fiber amplifier (EDFA) respectively. Figure '3' shows and table '1' defines the regions which are known by the letters O, E, S, C, L and U. The 770–to–910 nm bands is used for shorter–wavelength multimode fiber systems. Thus this region is designated as the short-wavelength or multimode fiber band.

Table '1' : Spectral band used in optical fiber communication

Name	Designation	Spectrum (nm)	Origin of Name
Original band	O-band	1260-1360	Original (first) region used for single-mode fiber links
Extended band	E-band	1360-1460	Link use can extend into this region fort fibers with low water content
Short band	S-band	1460-1530	Wavelength are shorter than the C-band but higher than the E-band
Conventional band	C-band	1530-1565	Wavelength region used by a conventional EDFA
Long band	L-band	1565-1625	Gain decreases steadily to 1 at 1625 nm in this longer wavelength band
Ultra-long band	U-band	1625-1675	Region beyond the response capability of an EDFA

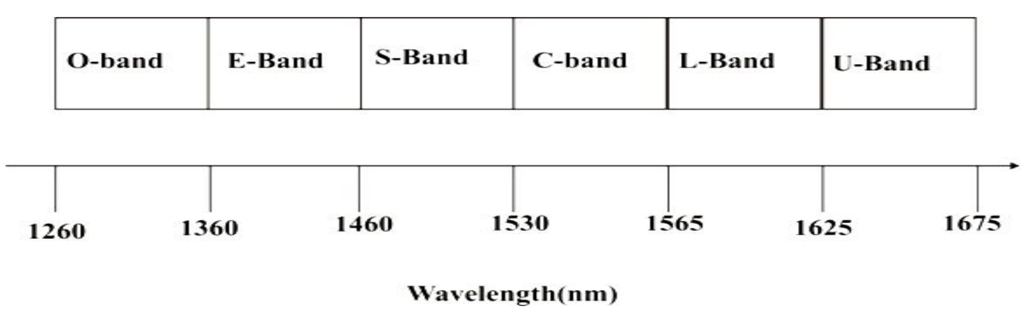

Fig.'3' : Designations of spectral bands used for optical fiber communications.

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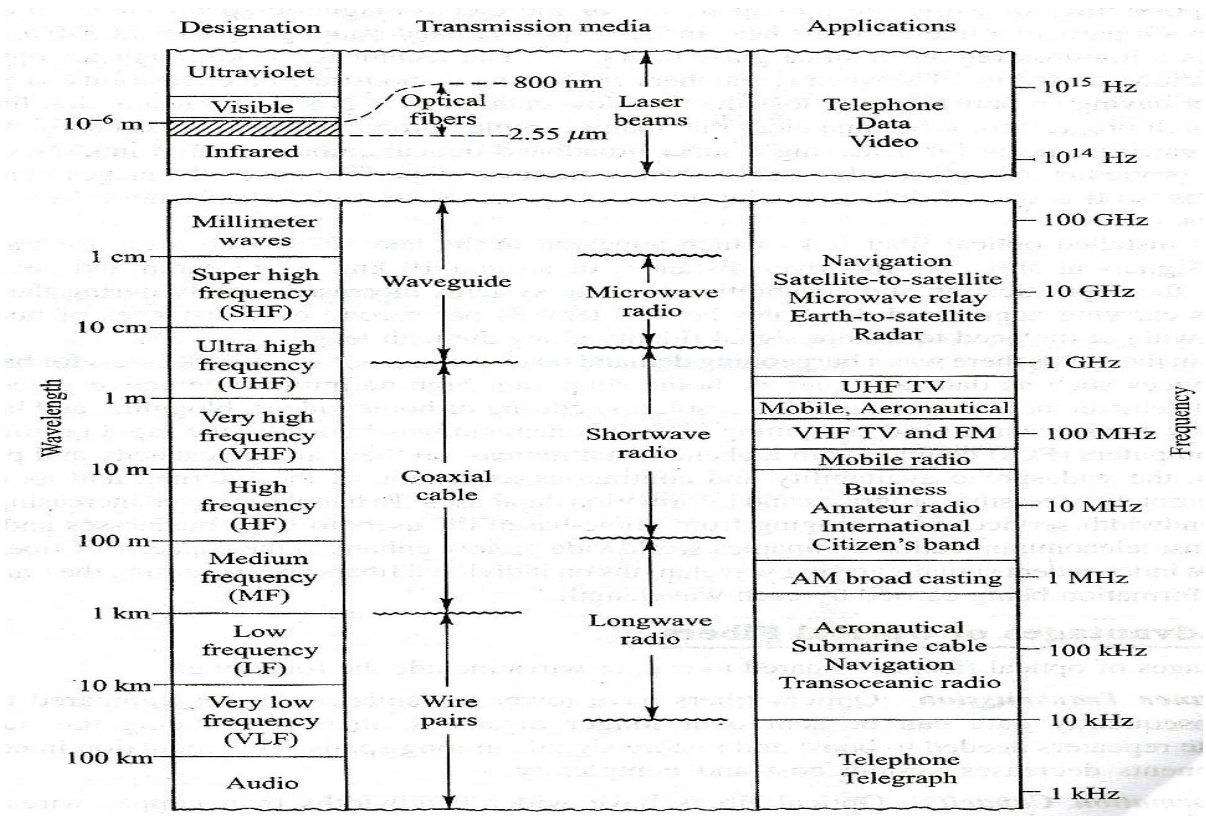

Fig. '4': The regions of electromagnetic spectrum used for radio and optical fiber communications.

II. RESULT & DISCUSSION

The amount of information that can be transmitted is directly related to the frequency range over which the carrier operates, increasing the carrier frequency theoretically increases the available transmission bandwidth and consequently, provides a larger information capacity of the optical fiber communication link. Figure '4' shows the electromagnetic spectral bands used for transmission. As the diverse radio technologies move from high frequency (HF) to very high frequency (VHF) to ultra high frequency (UHF) bands with nominal carrier frequencies of 10^7 ,10^8 and 10^9 H_z respectively ,increasingly higher information transmission speeds can be employed to provide a higher link capacity. Thus the trend in electrical communication system developments was to use progressively higher frequencies, which offer corresponding increases in bandwidth or information capacity.The figure '1' discuses three different ways to measure the physical properties of a wave in various regions in the EM spectrum which related by the equation '2'. This figure also shows, the optical spectrum ranges from about 5nm in the ultraviolet region to 1 mm for far infrared radiation. In between these limits is the 400-to 700-nm visible band. Optical fiber communication use the near –infrared spectral band ranging from nominally 770 to 1675 nm.

III. CONCLUSION

Electromagnetic energy is a combination of electrical and magnetic fields and includes power, radio waves, microwaves, infraredlight, visible light, ultraviolet light, x-rays, and gamma rays. Each discipline takes a portion called band of the em spectrum. Optical frequencies, being of the order of 1015 Hz are much greater than micro (1010 Hz) and other waves. So higher the frequency, higher will be the quantum energy of the optical wave and lower will be the wave length of the wave. Hence, optical beam when used as a carrier wave for sending information is capable of carrying far more information than micro or other waves. Thus information carrying capacity of optical fiber communication will be higher at optical frequencies.

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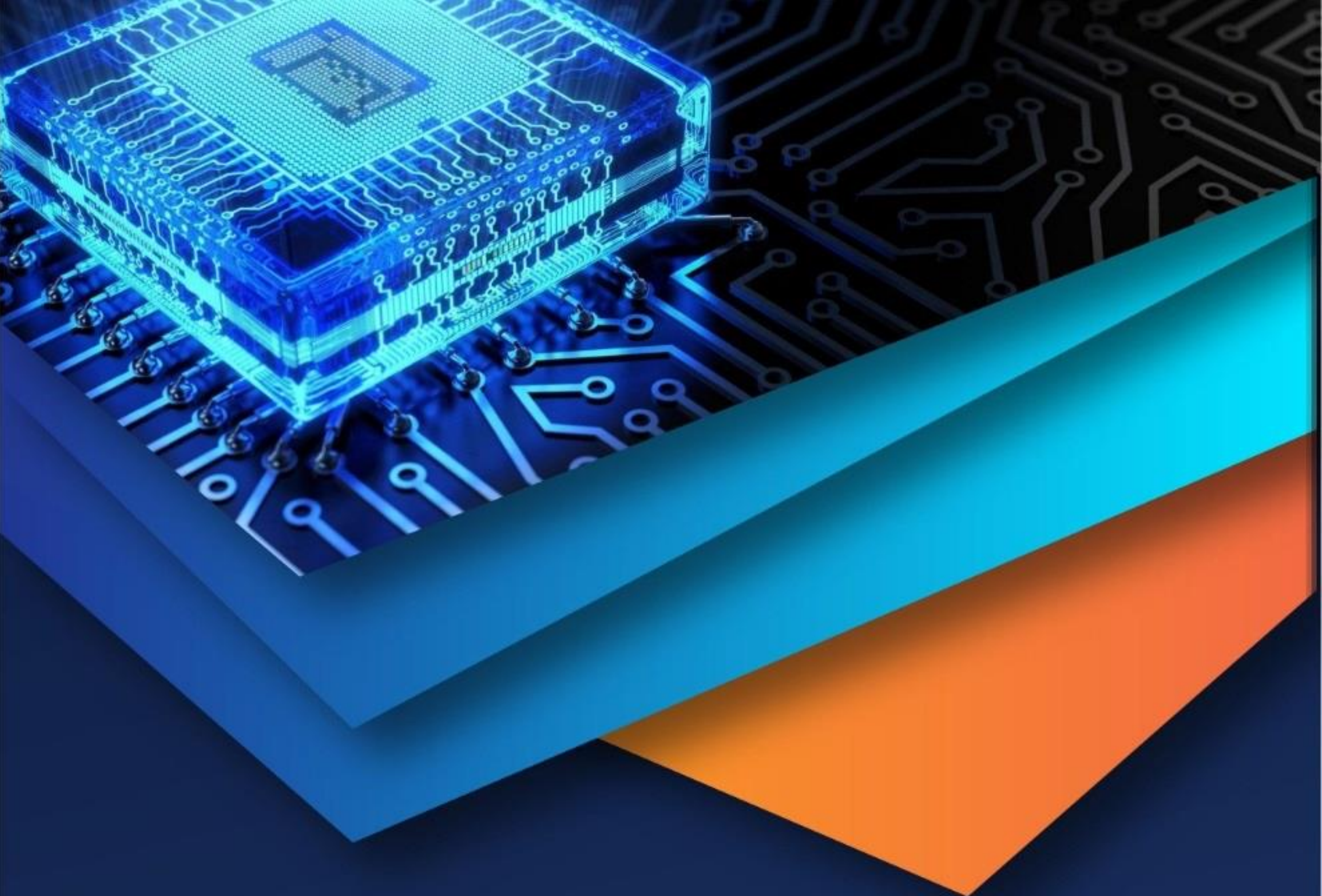

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