APPLICATION OF NANOTECHNOLOGY IN OPTICAL FIBRE COMMUNICATION

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Abstract: Nanophotonics or Nano-optics is the study of the behavior of light on the nanometer scale. It is considered as a branch of optical engineering which deals with optics, or the interaction of light with particles or substances, at deeply subwavelength length scales. Technologies in the realm of nano-optics include near-field scanning optical microscopy (NSOM), photoassisted scanning tunnelling microscopy, and surface plasmon optics. Traditional microscopy makes use of diffractive elements to focus light tightly in order to increase resolution. But because of the diffraction limit (also known as the Rayleigh Criterion), propagating light may be focused to a spot with a minimum diameter of roughly half the wavelength of the light. Thus, even with diffraction-limited confocal microscopy, the maximum resolution obtainable is on the order of a couple of hundred nanometers. The scientific and industrial communities are becoming more interested in the characterization of materials and phenomena on the scale of a few nanometers, so alternative techniques must be utilized. Scanning Probe Microscopy (SPM) makes use of a "probe", which either locally excites a sample or transmits local information from a sample to be collected and analyzed. The ability to fabricate devices in nanoscale that has been developed recently provided the catalyst for this area of study. This paper highlights the novel properties of light at the nanometer scale and its applications enabling highly power efficient devices for engineering uses.

Keywords: nanometer, nano-optics, subwavelength, photoassisted, microscopy, diffraction, confocal, efficient.

I. INTRODUCTION

Optical communication, also known as optical telecommunication, is communication at a distance using light to carry information. It can be performed visually or by using electronic devices. An optical communication system uses a transmitter, which encodes a message into an optical signal, a channel, which carries the signal to its destination, and a receiver, which reproduces the message from the received optical signal as shown in figure 1. When electronic equipment is not employed the 'receiver' is a person visually observing and interpreting a signal, which may be either simple (such as the presence of a beacon fire) or complex (such as lights using color codes or flashed in a Morse code sequence). Optical fiber is the most common type of channel for optical communications. The transmitters in optical fiber links are generally light-emitting diodes (LEDs) or laser diodes. Infraredlight, rather than visible light is used more commonly, because optical fibers transmit infrared wavelengths with less attenuation and dispersion.

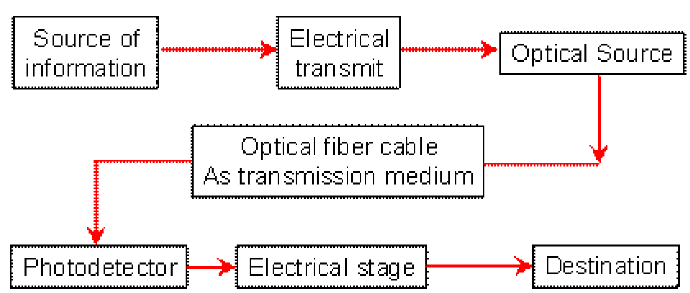

Figure 1. Elements of OFC

II. LITERATURE REVIEW

Malik Sulaiman, Norhana Arsad et. al [1] said that the implementation of three channels wavelength division multiplexing (WDM) network using a low cost and all POF components are developed. A low cost and high performance of 1x3 POF fused coupler/splitter using POF polymethyl methacrylate (PMMA) is fabricated as the multiplexer/de-multiplexer. Three visible LED light source transmitters; 470 nm, 520 nm and 650 nm are utilized in sending three data inputs; the CCTV and DVD video and audio signal. The optical lights are multiplexed into a single POF link and de-multiplexed back at the receiver end. The unwanted wavelengths are performed using thin color film filter before the receivers. With link margin 5 dB, the maximum POF link length is 25 meters which is suitable for informatics, infotainments, triple play in the field of last miles communications.

Xing Lü, Hong-Wu Zhu et.al [2] investigated a generalized nonlinear Schrödinger model with variable dispersion, nonlinearity and gain/loss, which could describe the propagation of optical pulse in inhomogeneous fiber systems. By employing the Hirota method, one- and two-soliton solutions are obtained with the aid of symbolic computation. Furthermore, a general formula which denotes multi-soliton solutions is given. Some main properties of the solutions are discussed simultaneously. As one important property of nonlinear evolution equation, the Bäcklund transformation in bilinear form is also constructed, which is helpful on future research and as far as we know is firstly proposed in this paper.

Luai E. Hasnawi and Richard A. Thompson[3] said that Time Division Multiplexing has been employed for decades in backbone networks. However, time channels have yet to be switched in the optical domain. The conventional time-switching method is to convert a signal from the optical to electrical domains before the switching operation is performed using electronic timeslot interchangers (TSI). Many proposed photonic timeslot interchangers (PTSI) have been published, but they are yet to be commercialized. One proposed model1 claims to perform PTSI without blocking under a given component-count, but the claim was not verified or proven. This paper describes a simulation of that proposed model and verifies their claim. However, this paper proves that the originally-assumed componentcount was over-estimated.

H. H. R. Sherazi, I. Raza et.al [4] postulated Vehicular Ad-hoc Networks (VANET) are employing heterogeneous technologies now a days to meet the increasing demands of Intelligent Transportation System (ITS) applications such as enriched multimedia, video conferencing, gaming and online collaboration. Deployment and maintenance cost for infrastructures are also a major concern. This work proposes a framework, capable of catering multiple technologies simultaneously (such as local area network, wide area networks and cellular networks), that deploys wired and wireless integrated technologies to exploit the advantages of both. Therefore, it offers the architecture based on radio over fiber technology to meet the future requirements of high data rate for Road Vehicle Communication (RVC) in VANETs and it comes up with the most important and perhaps desperately needed feature of 'Future Technology Support' yielding very high data rates support. Several traditionally deployed architectures are striving to come up with the future needs but due to their various limitations they were unable to attain their expected outcomes. The proposed RoF based architecture justifies its need inducing a true value and powerful features to dramatically enhance the overall performance of the entire system. Several evaluation parameters have been chosen that clearly present the strength of proposed RoF framework and prove that RoF framework is the better option for the service providers in the area of ITS applications.

Mohd Nizam Abdullaha, Sahbudin Shaari et.al [5] explained that Four wave mixing (FWM) is one of the non linear optical phenomena in optical fibre, in the presence of high optical field. Even though FWM has negative impact towards dense wavelength division multiplexing(DWDM) system, nevertheless, this phenomenon is also one of the alternative resources in deriving new signals to be adapted in the current and future telecommunication network. The main objective of this research is to study the generation FWM through photonic crystal fibre (PCF) at telecommunication operating wavelength. It covers the structure and manipulation of instrument's configuration to generate FWM through PCF, by applying Fibre Ring Laser (FRL) approach. However, the PCF has zero dispersion at 1040 nm, while the range of signals is around 1550 nm. A system which combines FRL locked with few units of fibre Bragg grating (FBG) and a PCF are used to facilitate the generation of the harmonic signals. Suitable FBGs specifications were identified to match with the output spectrum. Experiments were performed to further analyse the dynamics in generating FWM, including the generated wavelength formations. The results obtained, shows that the agreement between theory and experiments results on positions of multi wavelengths signal due to FWM is 0.3 % on average with expanded uncertainty of 4.9 % at k=2.

S. Pipatsart, A. Afroozeh et.al [6] designed a new modal of THz frequency carrier generation for radio frequency identification (RFID) application is proposed. The dense wavelength division multiplexing can be generated and obtained by using a Gaussian or soliton pulses propagating within a modified add-drop filter known as a PANDA ring resonator. The broad bandwidth of THz signals can be obtained and available for useful applications, in which the use of the generated THz pulses for RFID application, for instance, Ad-Hoc network using RFID. Results obtained have shown that the increasing in channel capacity can be obtained and useful for the large demand of RFID applications.

III. PROBLEM FORMULATION

Fibre-optic communication systems are finding increasing interest, mainly due to the promising properties of glass fibres. The transmitters and receivers of such systems operate with semiconductor devices (laser diodes, light-emitting diodes, photodiodes) whose properties have to be matched to those of fibres and to the signals to be transmitted. For this purpose numerous physical, technological and transmission requirements have to be coordinated, e.g. an optical wavelength has to be chosen that allows for low fibre loss, appropriate materials for light sources and detectors have to be found and processed, the size and the angular radiation characteristic of the source have to be adapted to the fibre, the operating conditions of the source have to be optimized, and the receiver, consisting of detector, amplifier and filter, has to be designed for optimum signal recovery.

a) Objectives of the work

(i) To highlights the novel properties of light at the nanometer scale and

(ii) its applications enabling highly power efficient devices for engineering uses.

IV. PRESENT WORK

Visible light communication (VLC) is a data communications medium using visible light between 400 and 800 THz (780–375 nm) as shown in figure 2. Using visible light is less dangerous for high-power applications because humans can perceive it and act to protect their eyes from damage. VLC is a subset at the optical wireless communications technologies. The technology uses fluorescent lamps (ordinary lamps, not special communications devices) to transmit signals at 10 kbit/s, or LEDs for up to 500 Mbit/s. Low rate data transmissions at 1 and 2 kilometres (0.6 and 1.2 mi) were demonstrated. RONJA achieves full Ethernet speed (10 Mbit/s) over the same distance thanks to larger optics and more powerful LEDs. Specially designed electronic devices generally containing a photodiode receive signals from light sources,[1]although in some cases a cell phone camera or a digital camera will be sufficient. The image sensor used in these devices is in fact an array of photodiodes (pixels) and in some applications its use may be preferred over a single photodiode. Such a sensor may provide either multi-channel communication (down to 1 pixel = 1 channel) or a spatial awareness of multiple light sources. VLC can be used as a communications medium for ubiquitous computing, because light-producing devices (such as indoor/outdoor lamps, TVs, traffic signs, commercial displays, car headlights/taillights, etc.) are used everywhere.

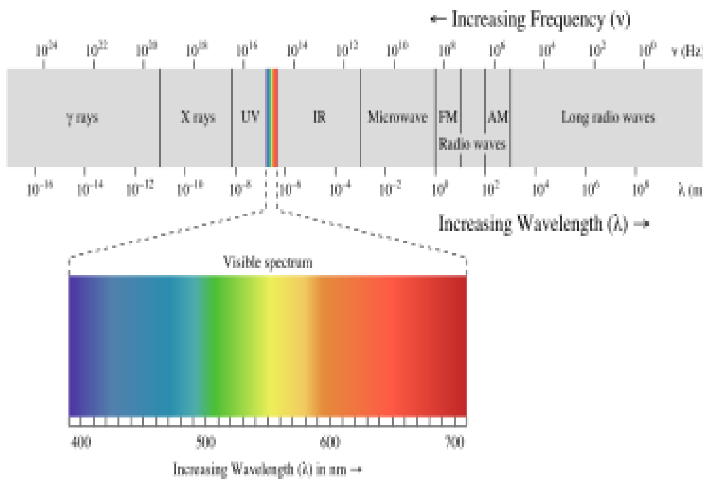

Fig 2. Light Spectrum

A. Principle of ray propagation :

This is the most interesting thing about optical fiber cables. Such an indispensable part of modern day communication system works on an extremely simple property of light ray i.e. Total Internal Reflection. As we all know that when light ray is passing from denser (refractive index is higher) dielectric medium to a rarer (refractive index is lower) dielectric medium then from the point of incidence at the interface it bends away from the normal. When the incidence angle is sufficiently high such that the angle of refraction is 90º then it is called critical angle. Now if light ray falls at the interface of the two mediums at an angle greater than the critical angle then the light ray gets reflected back to the originating medium with high efficiency (around 99.9%) i.e. total internal reflection occurs. With the help of innumerable total internal reflections light waves are propagated along the fiber with low loss as shown in figure2. In this context, two parameters are very crucial namely Acceptance Angle and Numerical Aperture.

Figure 3

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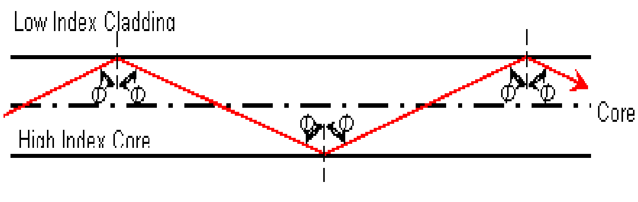

Fig 3. Propagation of light

Acceptance angle is the maximum angle at which light may enter the fiber in order to be propagated and is denoted by θa in figure4. The relationship between the acceptance angle and the refractive indices of the three media involved-core, cladding and air, leads to the definition of Numerical Aperture which is given by –

$$NA = (n_1^2 - n_2^2)^{½} = n_0 \sin\theta a$$ where n_0 is the refractive index of air.

The light ray shown in figure3 is known as a meridional ray as it passes through the axis of the fiber. However, another category of ray exists which is transmitted without passing through the fiber axis and follows a helical path through the fiber.

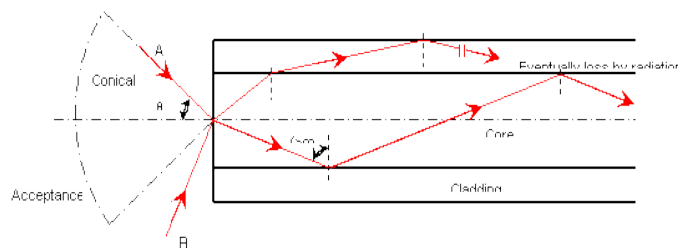

Fig. 4 Acceptance Angle and Numerical Aperture

B. Nanotechnology and Nano photonics or Nanooptics

Nanotechnology ("nanotech") is the manipulation of matter on an atomic, molecular, and supramolecular scale. Photonics is part of the modern science of light primarily concerned with the control, generation, and manipulation of optical signals. The wave lengths of this light are usually on the order of 1 µm = 1000 nm, so at first sight the relevance of nanoscale physics might appear strained. Nonetheless, it plays an essential role. This is because the goals of photonics require the light to be coupled to matter, and with this second component we must work on the nanoscale. We generate light from things like sodium atoms in a streetlamp, or an electron-hole plasma in a diode laser; steer and trap it with metallic or dielectric mirrors and waveguides – and then send it around the world with combinations of the two. Nanophotonics is about the optical properties of these engineered structures, which include quantum dots, wells, and metallic nanocrystals. Because they derive from both the wave-like properties of light and the strong interactions within matter these optical properties are a significant challenge for theoretical physics.

The term typically refers to phenomena of ultraviolet, visible and near IR light, with a wavelength of approximately 300 to 1200 nanometers.The interaction of light with these nanoscale features leads to confinement of the electromagnetic field to the surface or tip of the nanostructure resulting in a region referred to as the optical near field. This effect is to some extent analogous to a lightning rod, where the field concentrates at the tip. In this region, the field may need to adjust to the topography of the nanostructure (see boundary conditions of Maxwell's equations). This means that the electromagnetic field will be dependent on the size and shape of the nanostructure that the light is interacting with.

This optical near field can also be described as a surface bound optical oscillation which can vary on length scale of tens or hundreds of nanometers – a length scale smaller than the wavelength of the incoming light. This can provide higher spatial resolution beyond the limitations imposed by the law of diffraction in conventional far-field microscopy. The technique derived from this effect is known as near-field microscopy, and opens up many new possibilities for imaging and spectroscopy on the nanoscale. A novel embodiment which has picometer resolution in the vertical plane above the waveguide surface is dual polarisation interferometry.

Novel optical properties of materials can result from their extremely small size. A typical example of this type of effect is the color change associated with colloidal gold. In contrast to bulk gold, known for its yellow color, gold particles of 10 to 100 nm in size exhibit a rich red color. The critical size where these and related effects take place are correlated with the mean free path of the conduction electrons of the metal.

In addition to these extrinsic size effects that determine a material's optical response to incoming light, the intrinsic properties of the material can change. These size effects occur as particles become even smaller. At this stage some of the intrinsic electronic properties of the medium itself change. One example of this phenomenon is in semiconductor nanostructures where the extremely small particle size confines the quantum mechanical wavefunction, leading to discrete optical transitions, e.g., fluorescence colors that depend on the size of the particle. The changing bandgap of the semiconductor is the reason for this color change. This effect, however, since not directly correlated with optical wavelength, is not unanimously included when referring to nano-optics.

With the increasing demand for smaller, faster, and more highly integrated optical and electronic devices; as well as extremely sensitive detectors for biomedical and environmental applications; a field called nano-optics or nano-photonics is emerging - studying the many promising optical properties of nanostructures.Like nanotechnology itself, it is a rapidly evolving and changing field – but because of strong research activity in optical communication and related devices, combined with the intensive work on nanotechnology, nano-optics appears to be a field with a promising future.

Nanophotonics is seen as a crucial technology for extending Moore's Law into the next few decades. In the past few years nanophotonics researchers worldwide have developed, On Chip Silicon Lasers, Gigahertz Silicon Electro Optic Switches, and Low Loss Highly Integratable Compact Nanowires (With waveguides of 100’s of nanometers' width). Nanophotonics is mainly expected to play a complementary role to micro/nano electronics on chip and extend the capacity of telecommunication networks into the Terabit/s regime. One of the major emphasis’s in the last few years has been developing on-chip interconnects to break the bottle neck for higher data rates within integrated chips. In conjugation with Nanofluidics, Nanophotonics is also finding applications in biomedical sensors, Medical diagnosis, etc.

Nanophotonic components such as Microcavities with ultra high life time of trapped photons are expected to find applications in fundamental experimental physics such as gravitational wave detection. Intel, IBM, Lucent, and Luxtera have highly functional and well funded nanophotonic research groups. A number of universities in: US, UK, Japan, Italy, China, Belgium, etc. have been actively pursuing nanophotonics. Apart from a growing number of hits on the word in publication databases like "Web of Science", which shows it is already getting increased attention, it is also increasingly mentioned in the aims of the funding agencies, which will surely add to the activity in the field as increased economical support becomes available.

C. Enabling photonic components for commu nications

- Optical fibers
- Optical amplifiers
- Wavelength-Division Multiplexing (WDM) components
- Laser diodes
- Modulators
- Photodetectors

D. Various types of Optical Networks

Network Type	Long-Haul	Metro	Access	Interconnect
Distance (scale)	>100 km	10 km	Limited to 20 km by International Telecommunications Union (ITU) standard; often <10 km	<100 m
Laser type	Primarily DFB	DFB, VCSEL	Downstream: DFB Upstream: DFB or Fabry-Pérot	VCSEL
Wavelength	1,550 nm (C-band); 1,565 to 1,625 nm (L-band)	1,310 nm; 1,550 nm	Downstream: 1,490 nm and/or 1,550 nm Upstream: 1,310 nm	850 nm; 1,310 nm
Modulation scheme	Direct or external	Direct	Direct	Direct
Speed	10 Gbps	10 Gbps	Downstream: ≤2.5 Gbps Upstream: ≤1.24 Gbps	10GigE; 40GigE and 100GigE standards expected mid-2010
Multiplexing scheme	WDM, DWDM or coarse WDM	Coarse WDM or DWDM	WDM	Governed by Fiber Channel and Ethernet protocols

E. Advantages of Optical Fibres

- *Long Distance Transmission*: The lower transmission losses in fibers compared to copper wires allow data to be sent over longer distances.
- *Large Information Capacity*: Fibers have wider bandwidths than copper wires, so that more information can be sent over a single physical line.
- *Small Size and Low Weight*: The low weight and the small dimensions of fibers offer a distinct advantage over heavy, bulky wire cables in crowded underground city ducts or in ceiling-mounted cable trays.
- *Immunity to Electrical Interference*: The dielectric nature of optical fibers makes them immune to the electromagnetic interference effects.
- *Enhanced Safety*: Optical fibers do not have the problems of ground loops, sparks, and potentially high voltages inherent in copper lines.
- *Increased Signal Security*: An signal is well-confined within the fiber and an opaque coating around the fiber absorbs any signal emissions.

V. CONCLUSIONS

In today's world, the use of wireless communication is rapidly increasing. The main drivers for the use of nanotechnology in wireless devices are high performance, lower power consumption and compact size and novel features. Present RF technologies for high data rate communication systems will be capable of meeting the needs of the industry for the next 10 to 15 years, but after that the basic physical limits of radio electronics will begin hindering development. Nanotechnology-enabled devices will form the core of the next generation of wireless communication technologies, allowing wireless networks to keep up with the performance demands of mobile electronic devices.

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