Syarahan Perdana

LIGHT, LIGHTWAVE AND SYSTEM
- a Malaysian Perspective

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Light

The concept of photonics and lightwaves has been around since the early days, especially with the beginning of Greek civilization. It was described in books written by Socrates and Aristotle. The Greeks envisaged that vision was accomplished by lights rays being emitted from the eyes. It is now known, that vision is realized by lightwaves from sources like the sun bouncing off objects and entering our eyes.

During the era of Sir Isaac Newton, a well known British scientist, light was postulated to be particles but was proven to be other wise by Huygens with a clearer explanation indicating that light is a form of wave, in an attempt to explain various phenomena in optics. The idea of light, as waves and particles, have been in constant argument until finally, it has been decided that light can have a dual behaviour, that is, it can be a particle or a wave, depending on the type of interaction.

The beginning of modern lightwave communication could be traced back to the time of Alexander Graham Bell's 1880 photophone where he demonstrated that light could be utilized as a form of communication. The photophone uses mirrors that vibrated from the pressure of the speaker's sound waves. The vibrating light signals from the mirrors, were then transmitted through the atmosphere to a photocell in a phone receiver,which in turn was connected to an electric current source that powered a loudspeaker.

Since the photophone days, photonics has come a long way to provide conveniences and advances in civilization of the human race. The television is a photonics device, the display in our cars, computers, optical storage media and many more are direct examples of contribution from photonics R&D.

The definition of photonics and optoelectronics are given below whereby optoelectronics devices are part of photonics products.

Photonics

Photonics is an area of technology associated with generation and harnerssing of light and other forms of radiant energy whose quantum unit is the photon. A key capability is the transmission of information using light as the carrier frequency. The science of photonics information systems includes light emission, transmission, deflection, amplification and detection by optical components and associated instruments.

Lasers and other light sources, fiber optics, electro-optical instrumentation, related hardware and electronics, and associated sophisticated systems are commonly referred to as photonic devices. The range of applications of photonics extends from energy generation, detection, communications and information processing and storing of data.

Lightwave Systems

Lightwave systems are essentially telecommunication systems with optical fibres as the information carrying medium or as is usually termed, fibre backbone. These optical fibres have almost covered the entire planet, in the endeavour to network the globe.

Ligthwave systems have replaced the conventional copper networks, except at the last point to the users but this will change too. The reason for this revolution is due to the advantages of optical fibres such as immunity to electromagnetic pulses/disturbances, low losse, high bit rates, high security, and able to carry multiple communication channels. The last advantage is popularly known as Wavelength Division Multiplexing (WDM) where multiple channels of different colour or wavelengths are transmitted down a single strand of optical fibre, instead of one fibre per channel.

WDM is the answer to ever increasing bandwidth requirements. Fig. 1 shows the advantages of WDM, where different types of services are realised by transmitting different information contents onto different coloured carriers. WDM technology, however, is only possible due to all optical fibre amplifiers. Optical fibre amplifiers, specifically Erbium-doped Fibre Amplifiers (EDFAs) were discovered in the late '80s and is one of the most important components of a lightwave network.

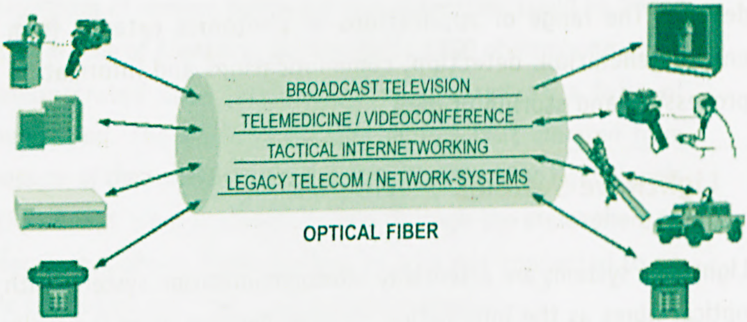


Fig. 1 : *Concept of WDM where multiple channels or services can be realised with a single strand of optical fibre.*

EDFAs are speciality optical fibres which have the rare earth element Erbium (Er) doped into the fibre core. These speciality fibres enable the amplification of optical signals seamlessly in-fibre, without conversion to electronic forms, as had been done previously. In addition to providing all-optical amplification, independence from bit-rates, transparency to protocols, and ability to amplify multiple channels simultaneously are some of the most important characteristics of the EDFAs.

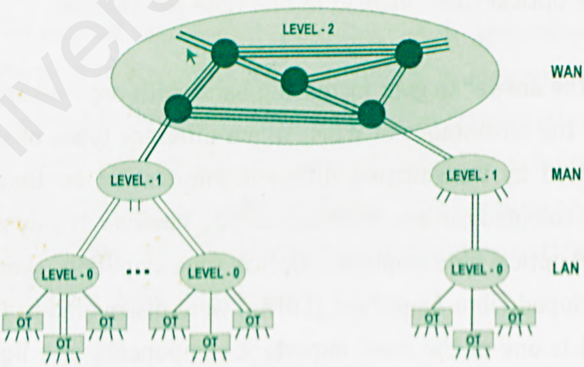


Fig. 2 : *WDM all-optical networks showing the progress to an ever widening circle of connectivity with various optical components performing their tasks. OT= Optical Transport, LAN=Local Area Network, MAN=Metropolitan Area Network and WAN=Wide Area Network.*

Lightwave networks were only possible with the advent of EDFAs and presently more advanced optical networks are being designed, as is seen from Fig. 2. These advanced lightwave networks require a multitude of new components such as new generation of EDFAs, optical switches, wavelength converters, optical add/drop multiplexers and so forth. In order to be able to manufacture these components to the exacting standards of the telecommunications industry, thorough research must be planned and carried out. To this end the Photonics Laboratory of UM has been engaged in the research of optical amplifiers and its various forms and functions.

Photonics Lab, University of Malaya (PL UM)

The Photonics Laboratory in UM has been in active research for the past 20-25 years, where the recent 10 years has been actively devoted to the specific field of optical fibres. During this time various issues of a specific aspect of optical telecommunications technology, optical fibre amplifiers, has been investigated.

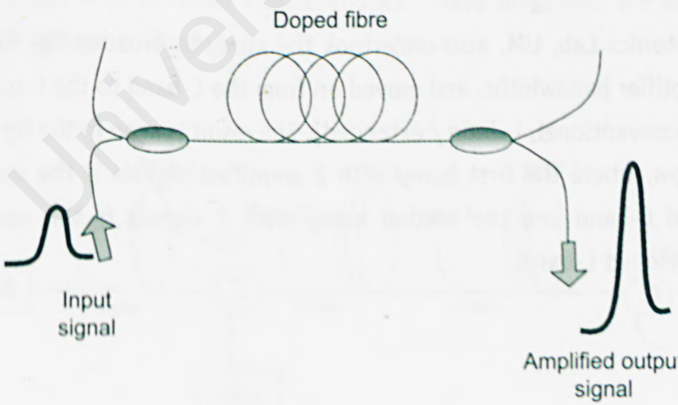


Fig. 3 : *Basic configuration of an optical fibre amplifier, where the input optical signal is amplified optically without conversion to electronics.*

Optical amplifiers allow amplification of optical signals, figure above, without conversion to electronic formats, as had been done previously. This is made possible by the amplifier itself being of a fibre form and able to operate or amplify signals in the optical domain. Furthermore, the bit- and protocol-transparent nature of these amplifiers allow upgrading of the transmitting and receiving end without incurring costs to upgrade the fibres and the amplifiers.

This most desired feature of the optical fibre amplifier has led to the birth of a new optical communications technology – wavelength division multiplexing (WDM). Traditionally, optical signals were sent down by per signal or channel per fibre, which necessitated the need for armoured fibre cables with many fibres inside. The advent of WDM, however, has made possible the sending of many signals or channels per fibre, from as low as 1 channel to as high as 128 channels. This fundamental increase in information carrying capacity was the much awaited boon that the internet community needed. Soon the capacity limit of the amplifier were being approached which led to research on expanding the available amplifier bandwidths.

Photonics Lab, UM, also undertook the study to broaden the fibre amplifier bandwidths, and moved on from the C-band to the L-band [C=conventional, L=long / extended]. The result is seen in the figure below, where the first hump with 2 amplified signals is the much used C-band and the second hump with 2 signals is the newly developed L-band.

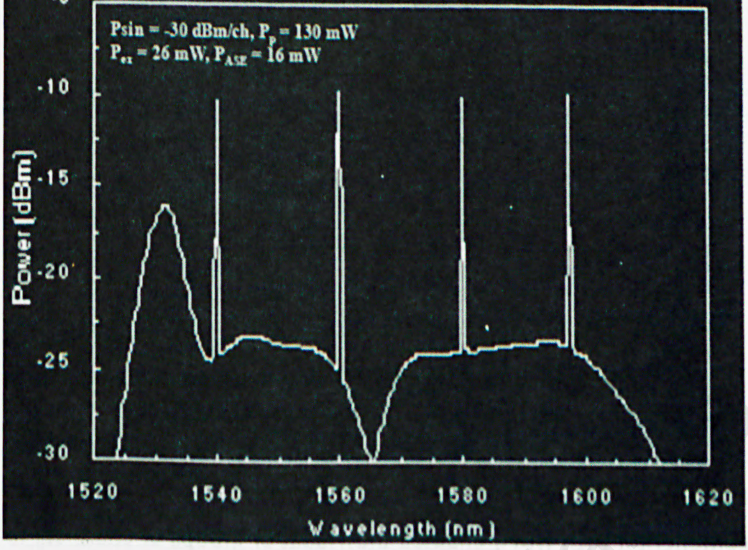
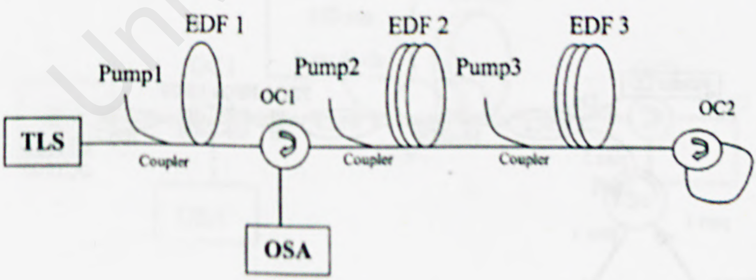
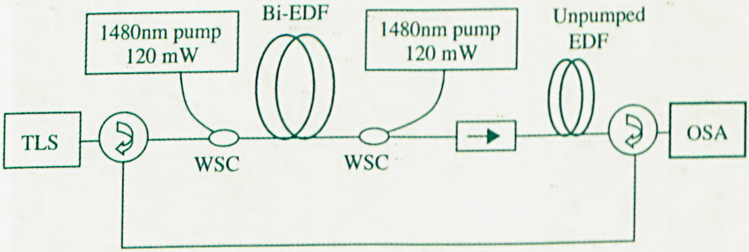


Fig. 4 : *Spectum showing the dual bands , C- and L-band, with the spectral hump on the left being the C-band and the one on the right is the L-band. A newer S-band lies to the left of the C-band.*

Various working methods and theories of the L-band were researched in this laboratory, which has resulted a number of different types of amplifiers with different characteristics. These amplifiers are also shown below in Fig. 5.



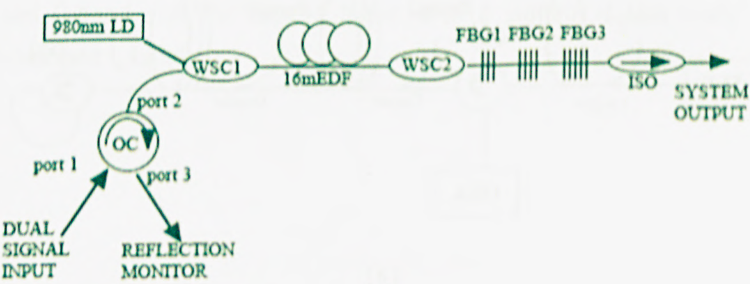
(a)



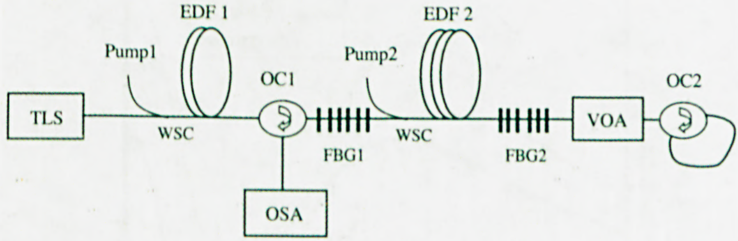
(b)

Fig. 5 : *Different optical layouts of L-band amplifiers that produce different levels of gain and noise in the L-band region.*

Further developments in optical communications technology, in conjunction with WDM, enabled individual or groups of channels to be added to or removed from the present traffic. This new add/drop operation, as it is known, caused a host of new problems to presently installed amplifiers. Research into a new group of amplifiers known as "gain-clamped" amplifiers were then begun. These fibre amplifiers enable equal level amplification of multiple optical signals regardless of the number of channels. Again, various techniques were explored and has culminated as gain-clamped amplifiers, both in the C- and L-band regions. The figures below depict the fibre amplifier designs that have been produced from the laboratory.



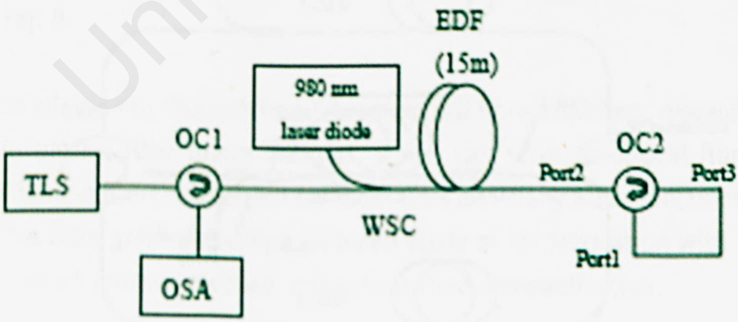
(a)



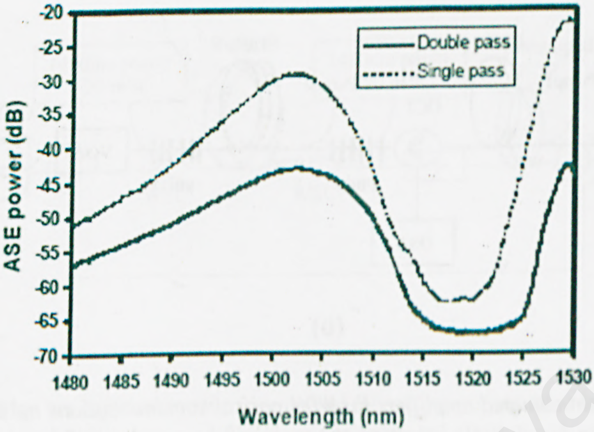
(b)

Fig. 6 : *Gain-clamped amplifiers for WDM optical communications network, where gain for multiple incoming channels will be equal, (a) C-band and (b) L-band*

Presently, to cater for the insatiable demand for bandwidth or information carrying capacity, research has been started on the S-band [S=short]. This new band, together with the earlier C- and L-bands, utilise the extremely wide bandwidth of the optical fibres used. All three bands occupy a range of wavelengths known as the third telecommunications window, which exhibits the lowest loss of about 0.2dB.



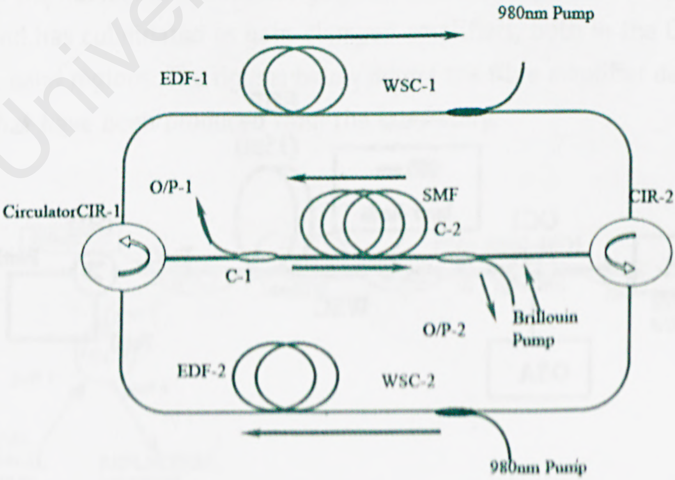
(a)



(b)

Fig. 7 : *The newly explored S-band amplifier (a)circuit and its (b) spectra.*

In addition to optical amplifiers, research on Brillouin fibre lasers was also carried out. These special lasers utilise the special Brillouin scattering process that occurs in the optical fibres and amplifies them to laser intensities. Re-use of the laser allows creation of additional wavelengths. This manner of cascading lasers in a single



(a)

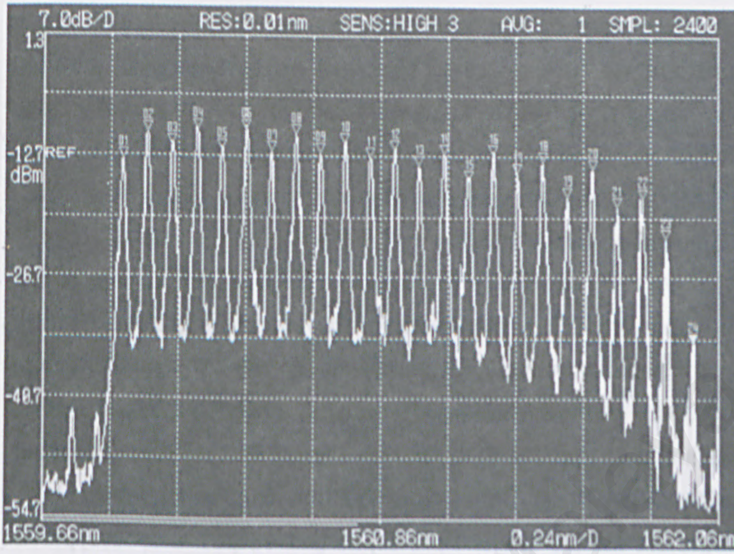


Fig. 8 : *Brillouin Erbium fibre laser light source, (a) optical circuit and (b) output spectra, showing multiple laser output from a single source.*

laser oscillator enables extraction of multiple laser output which can replace conventional laser diodes in communications networks. A major reduction of overhead cost, electronics cost and real-estate cost is immediately apparent. A typical Brillouin fibre laser optical circuit and its output, as researched from this laboratory is seen in Fig. 8.

In addition to research into Erbium optical fibre amplifiers, research in optical fibre Bragg gratings, which can serve as optical fibre filters, mirrors, dispersion compensators and many other functions. The fibre grating research included study of its fabrication with a contact printing method, characterisation and application.

The total aim of the research output from Photonics Laboratory, UM, is to be able to integrate all the optical communications devices for a complete optical WDM network. The fibre Brillouin sources function as transmitters, that are able to launch multiple wavelengths, of fixed spacing between wavelengths, into a single fibre. Modulation of the fibre Brillouin laser output before launching in the network fibre enables information to be "loaded" onto the individual wavelengths.

The fibre amplifiers then function to amplify these wavelengths optically and seamlessly, without format conversion. The wavelength choice for the WDM transmitter can be arbitrarily chosen, within the amplifier bands, that range from 1480nm-1520nm (S-band), 1520nm-1570nm(C-band) and 1570nm-1620nm(L-band). These amplifiers have a single fibre input and output and have proven ability to amplify multiple signals simultaneously.

Amplification of the multiple signals or mutiple wavelength channels simultaneously enables the longer distance transmission of these signals. All optical amplification also eliminates costly use of electronic amplifiers that only operate for a single channel and are dependent on protocol as well as bit rates.

Fibre Bragg gratings or FBG's, also researched at the Photonics Lab, can be used for a variety of functions for an optical telecommunications network. The detection end utilises fibre gratings to separate wavelengths for the appropriate receivers, thereby separating the wavelengths or channels. The FBGs can also function as add/drop multiplexers, at midway stations, where selected channels can be removed and/or added back to the network. This is a very important optical function that has simplified the process compared to doing it electronically. Finally, specially fabricated FBGs are used as dispersion compensators, which counter the negative aspects of transmitting optical signals through an optical fibre.

Achievements of Photonics Lab, UM

This laboratory, has produced more than 100 articles in peer reviewed, international journals such as the acclaimed IEEE, and other prestigious journals. These articles have also been cited by other authors as seen in the citation index.

Besides producing papers and working prototypes, this laboratory has also given birth to other photonics laboratories and centres as will be found in Universiti Putra Malaysia (UPM), Universiti Teknologi MARA (UiTM), Telekom Malaysia Photonics Research Centre.