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FIBRE-OPTIC COMMUNICATION SYSTEM

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ABSTRACT

In fibre-optic communication, a single-mode optical fibre (SMF) is an optical fibre designed to carry light only directly down the fibre - the transverse mode. Modes are the possible solutions of the Helmholtz equation for waves, which is obtained by combining Maxwell's equations and the boundary conditions. These modes define the way the wave travels through space, i.e. how the wave is distributed in space.

KEYWORDS :*fibre-optic communication, combining Maxwell's equations , boundary conditions.*

INTRODUCTION

Waves can have the same mode but have different frequencies. This is the case in single-mode fibres, where we can have waves with different frequencies, but of the same mode, which means that they are distributed in space in the same way, and that gives us a single ray of light. Although the ray travels parallel to the length of the fibre, it is often called transverse mode since its electromagnetic vibrations occur perpendicular (transverse) to the length of the fibre. The 2009 Nobel Prize in Physics was awarded to Charles K. Kao for his theoretical work on the single-mode optical fibre.[1-4]

Like multi-mode optical fibres, single mode fibres do exhibit modal dispersion resulting from multiple spatial modes but with narrower modal dispersion. Single mode fibres are therefore better at retaining the fidelity of each light pulse over longer distances than multi-mode fibres. For these reasons, single-mode fibres can have a higher bandwidth than multi-mode fibres. Equipment for single mode fibre is more expensive than equipment for multi-mode optical fibre, but the single mode fibre itself is usually cheaper in bulk.

SINGLE MODE OPTICAL FIBRE

A typical single mode optical fibre has a core diameter between 8 and 10.5 µm and a cladding diameter of 125 µm. There are a number of special types of single-mode optical fibre which have been chemically or physically altered to give special properties, such as dispersion-shifted fibre and nonzero dispersion-shifted fibre. Data rates are limited by polarization mode dispersion and chromatic dispersion. As of 2005, data rates of up to 10 gigabits per second were possible at distances of over 80 km (50 mi) with commercially available transceivers (Xenpak). By using optical amplifiers and dispersion-compensating devices, state-of-the-art DWDM optical systems can span thousands of kilometers at 10 Gbit/s, and several hundred kilometers at 40 Gbit/s.

The lowest-order bounds mode is ascertained for the wavelength of interest by solving Maxwell's equations for the boundary conditions imposed by the fibre, which are determined by the core diameter and the refractive indices of the core and cladding. The solution of Maxwell's equations for the lowest order bound mode will permit a pair of orthogonally polarized fields in the fibre, and this is the usual case in a communication fibre.

In step-index guides, single-mode operation occurs when the normalized frequency, V, is less than or equal to 2.405. Forpower-law profiles, single-mode operation occurs for a normalized frequency, V, less than approximately

$$2.405\sqrt{\frac{g+2}{g}},$$

where g is the profile parameter.

In practice, the orthogonal polarizations may not be associated with degenerate modes.
Os1 and OS2 are standard single-mode optical fibre used with wavelengths 1310 nm and 1550 nm (size 9/125 µm) with a maximum attenuation of 1 dB/km (OS1) and .4 dB/km (OS2). OS1 is defined in ISO/IEC 11801, and OS2 is defined in ISO/IEC 24702.

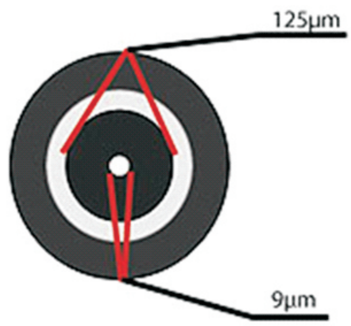

Fig.1.1 Single Mode Fibre Optic Cable

Single Mode fibre optic cable has a small diametral core that allows only one mode of light to propagate. Because of this, the number of light reflections created as the light passes through the core decreases, lowering attenuation and creating the ability for the signal to travel faster, further. This application is typically used in long distance, higher bandwidth runs by Telcos, CATV companies, and Colleges and Universities.

Left: Single Mode fibre is usually 9/125 in construction. This means that the core to cladding diameter ratio is 9 microns to 125 microns.

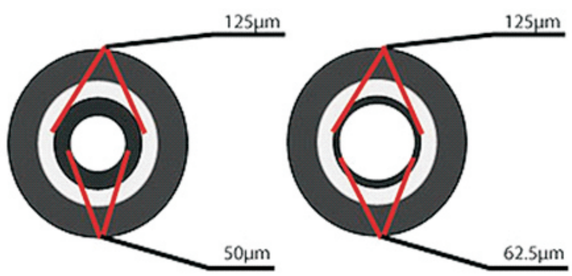

Fig.1.2 Multimode Fibre Optic Cable

Multimode fibre optic cable has a large diametral core that allows multiple modes of light to propagate. Because of this, the number of light reflections created as the light passes through the core increases, creating the ability for more data to pass through at a given time. Because of the high dispersion and attenuation rate with this type of fibre, the quality of the signal is reduced over long distances. This application is typically used for short distance, data and audio/video applications in LANs. RF broadband signals, such as what cable companies commonly use, cannot be transmitted over multimode fibre.

Above: Multimode fibre is usually 50/125 and 62.5/125 in construction. This means that the core to cladding diameter ratio is 50 microns to 125 microns and 62.5 microns to 125 microns.[3-6]

STEP-INDEX MULTIMODE FIBRE

Due to its large core, some of the light rays that make up the digital pulse may travel a direct route, whereas others zigzag as they bounce off the cladding. These alternate paths cause the different groups of light rays, referred to as modes, to arrive separately at the receiving point. The pulse, an aggregate of different modes, begins to spread out, losing its well-defined shape. The need to leave spacing between pulses to prevent overlapping limits the amount of information that can be sent. This type of fibre is best suited for transmission over short distances.

GRADED-INDEX MULTIMODE FIBRE

It Contains a core in which the refractive index diminishes gradually from the center axis out toward the cladding. The higher refractive index at the centre makes the light rays moving down the axis advance more slowly than those near the cladding. Due to the graded index, light in the core curves helically rather than zigzag off the cladding, reducing its travel distance. The shortened path and the higher speed allow light at the periphery to arrive at a receiver at about the same time as the slow but straight rays in the core axis. The result: digital pulse suffers less dispersion. This type of fibre is best suited for local-area networks.

The main difference between multi-mode and single-mode optical fibre is that the former has much larger core diameter, typically 50–100 micrometers; much larger than the wavelength of the light carried in it. Because of the large core and also the possibility of large numerical aperture, multi-mode fibre has higher "light-gathering" capacity than single-mode fibre. In practical terms, the larger core size simplifies connections and also allows the use of lower-cost electronics such as light-emitting diodes (LEDs) and vertical-cavity surface-emitting lasers (VCSELs) which operate at the 850 nm and 1300 nm wavelength (single-mode fibres used in telecommunications operate at 1310 or 1550 nm and require more expensive laser sources. Single mode fibres exist for nearly all visible wavelengths of light). However, compared to single-mode fibres, the multi-mode fibre bandwidth–distance product limit is lower. Because multi-mode fibre has a larger core-size than single-mode fibre, it supports more than one propagation mode; hence it is limited by modal dispersion, while single mode is not.

The LED light sources sometimes used with multi-mode fibre produce a range of wavelengths and these each propagate at different speeds. This chromatic dispersion is another limit to the useful length for multi-mode fibre optic cable. In contrast, the lasers used to drive single-mode fibres produce coherent light of a single wavelength. Due to the modal dispersion, multi-mode fibre has higher pulse spreading rates than single mode fibre, limiting multi-mode fibre's information transmission capacity.

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