CHAPTER 1
OPTICAL FIBRE TECHNOLOGY IN COMMUNICATION DEVICES AND SENSING

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1.1 OVERVIEW OF OPTICAL FIBRES

In the early 1840s, Daniel Collodon and Jacques Babinet made the initial discovery of the light phenomenon while it was being efficiently guided down a stream of water. Subsequently, John Tyndall revealed the light propagation phenomenon along a curved water stream, suggesting the signal transmission potential in 1854. In 1880, Abraham Bell introduced the photophone, which was described as an optical telecommunication system. Meanwhile, William Wheeler developed a system involving light pipes equipped with highly reflective materials during the same period. The design provided illumination to households by utilising electric arc lamps positioned in basements, with the light being directed throughout the house via these pipes.

The fibre optic advancements persisted when Henry Saint-Rene devised a mechanism involving bent glass rods to facilitate light image transmissions. In 1954, Van Heel reported a cladded fibre system that effectively reduced signal interference and crosstalk among fibres. Considering that the laser was introduced in 1958, telephone companies widely implemented fibres to modernise their communication infrastructure during the late 1970s and early 1980s. The Erbium

Doped Fibre Amplifier (EDFA) was also designed in 1986 by David Payne from the University of Southampton and Emmanuel Desurvire from Bell Laboratories. Therefore, significant progress has been made in the development of photonic crystal fibre since 1991, leading to its widespread use in several areas. These areas include sensing, telecommunication, networking, medical, and the oil and gas sector.

Optical fibres have been employed in non-communication applications, such as fibre lasers, amplifiers, and sensors. These components comprise diverse materials, including metals, plastic, and semiconductors. A fibre laser denotes a device utilising a considerable optical fibre length to generate a laser beam. The functioning mechanism involves an optical cavity to facilitate the light reflection, enabling the stored atom stimulation by a stream of photons at various wavelengths. Nevertheless, optical fibre sensors have employed optical fibres as a sensing or transporting medium, transmitting the transduced light to the electronic systems responsible for optical signal processing. Hence, physical, chemical, and biochemical sensors have been extensively studied and proven effective in measuring Refractive Index (RI), temperature, and pressure.

Fibre optic or optical fibre is a technological method for delivering information using light propagation in thin fibres. Given that fibre optic technology is widely regarded as the backbone of the global communication system, all data-transmitting applications are observed to be interconnected using fibre optics. Fibre optic cables consist primarily of glass (silica) or plastic materials, serving as the medium for light wave transmission. These cables do not conduct electricity, and the diameter of a single fibre optic strand measures approximately 125 μm (equivalent to a human hair's diameter). Fibre optic technology also transmits voice data and video information through high-speed light rays, rendering fibre optics more desirable than traditional copper cables.

A fibre optic consists of three layers: Core, cladding, and the outer coating. Figure 1.1 illustrates the cross-section area of a fibre optic cable composition, whereby the core is positioned in the innermost layer, followed by the cladding and the exterior coating.

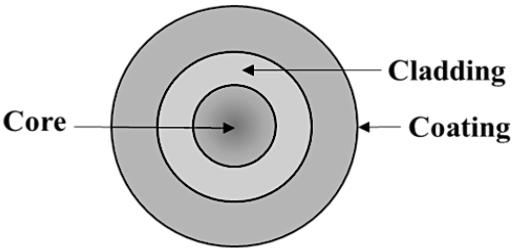

Figure 1.1 The cross-section structure of an optical fibre

The core density in a fibre optic cable is typically higher than the cladding, resulting in a core with a higher RI than the cladding. Light reflection occurs when light transitions from a higher to a lower RI medium. This light undergoes deviation from the normal line perpendicular to the RI interference (see Figure 1.2). The incident light rays are then reflected into the medium with a higher RI at a particular angle referred to as the critical angle (θ_c). Consequently, no light rays penetrate the lower RI medium, which is commonly referred to as the total internal reflection in fibre optics for light transmission.

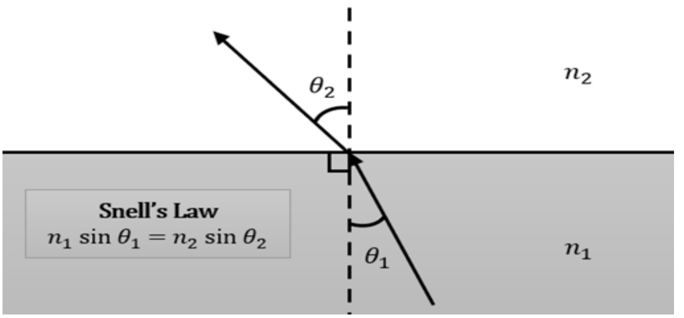

Figure 1.2 The law of refraction following Snell's Law

When an incident ray encounters the interface between two dielectrics with distinct RIs, it undergoes reflection and refraction following Snell's Law. Eq. (1.1) presents the law of refraction based on Snell's law as follows:

$$n_1 \sin\ \theta_1 = n_2 \sin\ \theta_2 \tag{1.1}$$