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An Experimental Approach of Fibre Optics Refractometers

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Abstract--- *Refractometers are optical devices that measures the refractive index of the multiple transparent and semi-transparent resources either of solid or liquid state. Traditional refractometers operates on the principle of measuring "an optical critical angle", "Brewster's angle", "angular deviation of the light beam" etc. According to the last few decades, there is a speedy growth in the sensing technology of the fibre optics techniques led for developing the fibre optics refractometer. Within comparison sensors performs multiple recompenses to the traditional refractometers. In this literature, a brief assessment of few fibre optic refractometers are reported. These reviews entails detailed and accurate knowledge to the readers of the working principles, constructional methods and distinctive features of multiple fibres optic refractometers as reported till date.*

Index Terms— *SPR, FBG, OSA, Sensors, RI, Plasma.*

I INTRODUCTION

Refractometer is an optical instrument that measures the refractive index of the transparent and semi-transparent materials in either a solid state of the liquid state[1]. RI of an object can be calculated by calculating the proportion of the velocity of light in the medium and velocity of light in vacuum. RI of the medium analyses how fast the light can travel from medium. Calculation of the RI is mainly performed in the pharmaceuticals plants and beverage industries for determining concentration of preferred materials available in liquid samples. In optical industries, calculation of the RI is performed for determining optical properties of the optical devices such as thin films, lens, mirrors, glass, prisms and sheets of plastics etc[2]. Calculation of the outdated refractometers works on the basis of Brewster angle, critical angle, beam light angular deviations etc. according to the last few decades' fast advancement in "fibre optic sensing technology led" improvement in the fibre optic refractometers. Multiple benefits are attained by this sensor comparatively to the traditional sensors. According to this work, a brief analysis of the selected refractometers are performed recently. This work deals with the flawless and accurate ideas for the readers about the functional process and construction of the characteristic feature of the multiple fibre optic refractometers[3].

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II FUNDAMENTAL OF THE FIBER OPTICS SENSOR

Optical fibre is basically a waveguide based on optically dielectric, that allows transmission of light beams into it by the virtue of the reflection. Fig.1 illustrates the structure of the optical fibre and principle of the light of propagation, whereas Fig.2 illustrates basic schematic of the characteristic fibre optic sensor[4].

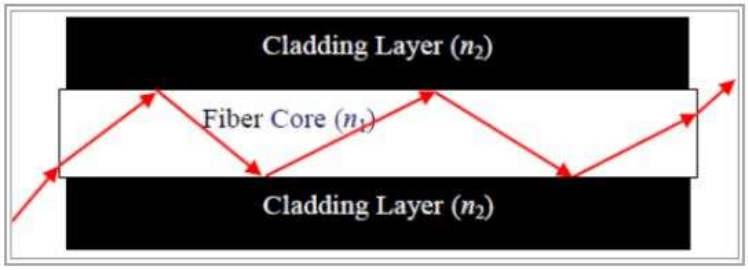

Fig. 1: Simplified diagram showing light propagation through optical fiber (cladding region has lesser RI as compared to core region, i.e. $n_2 < n_1$).

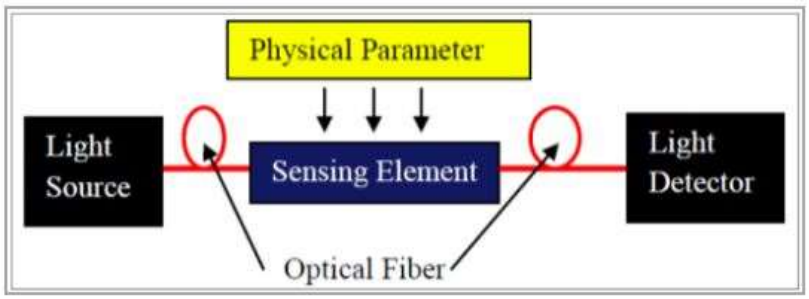

Fig. 2: Simplified schematic for a typical fiber optic sensor.

"Fibre optic sensors" are broadly clustered into two type of sensors i.e. of intrinsic and extrinsic. In intrinsic sensors, intonation of light occurs inside the fibre itself that proves that the sensing element is an optical fibre. In an extrinsic case the fibre optic sensor, the sensing component not an optical fibre, but few other materials that modulates the wave of lights. Fibre optics sensor works on the principle of intensity modulation, phase, wavelength and polarization of the wave of light. The design of fibre optics based on modulation of intensity is economical, however it provides least sensitivity in comparison with another modulation schemes[5].

III REFRACTOMETERS BASED ON FIBRE OPTICS

According to the researchers an extrinsic fibre optic refractometers works on the principle of longitudinal misalignment by the "multi-mode optic fibre". In particular sensor, dual "multi-mode fibres" being embedded into a hollow glass tube and a "longitudinal gap" had been sustained as illustrated in Fig.3[2].

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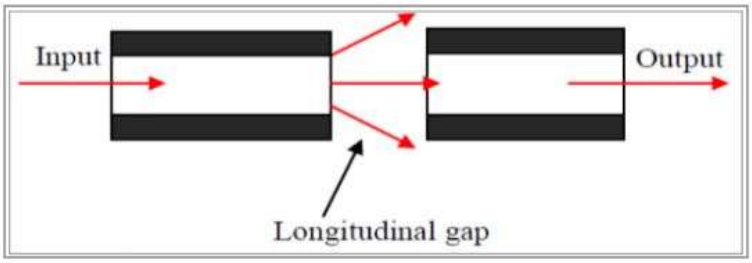

Fig. 3: Fiber optic refractometer based on longitudinal misalignment of fibers.

In this sensor, light power coupled to the receiving fiber varies with the RI of liquid sample introduced in the gap, and it is governed by (1), as in [7].

$$\eta = \left(1 - \frac{4(NA)z}{3\pi a n_L}\right) \quad (1)$$

Where, η is normalized light coupling efficiency; NA is numerical aperture of the fibers; z is longitudinal gap; a is radius of fiber core; n_L is RI of liquid.

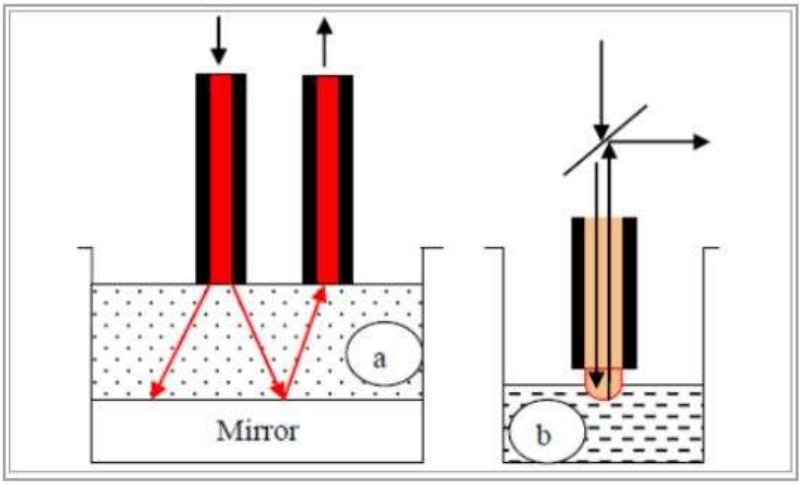

Fig. 4: Fiber optic refractometer based on detection of back reflected light.

FOR that calculates RI on the basis of Fresnel reflection of the light that is being reported. As per this sensor, single fibre leads beam of the light on the reflecting mirror on which the reflection by said mirror, as illustrated in figure 4(a). The collected light beam intensities fluctuates with in fluctuation of the RI of the medium and it is being directed by the proportional relation as stated below[4].

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$$\eta \propto R_m \cdot T_i(n_L) \cdot T_O(r, h, n_L) \quad (2)$$

Where, η is light coupling efficiency; R_m is mirror reflectivity; $T_i(n_L)$ is Fresnel transmittance of input fiber; $T_O(r,h,n_L)$ is Fresnel transmittance of output fiber; r is the distance

Calculated along receiver unit of fibre through transmitter fibre; distance h specifies the space between fibre tips and mirror. As per the research the unsatisfied TIR phenomenon for calculating change in RI of the medium by aid of hemispherical fibre tips, as illustrated in figure 4 (b). According to the TIR, a forward propagating mode parts is reflected back by the tip of the medium interface. According to the medium RI sample, the light reflected back vary with the intensities of the RI of said medium[5].

Optical brief of the wave is a static electromagnetic waves that exists at core-cladding fibre interface. Particular wave pierces into the cladding and it's amplitude deteriorates into the region of the cladding. Fibre optics refractometers based on the evanescent wave are also being reported from different researchers and they are more profound than reported sensing techniques. The optical behaviour lost in these sensors by evanescent wave interaction and the liquid at the interaface of medium is directed through reflection of Fresnel that provides coefficient of absorption of lights by the medium of liquid i.e[6]. smaller. RI is calculated by consenting liquid for the interaction through partially deluded area of optical fibre's evanescent wave. Extremely sensitive refractometers of fibre optics constructed through elongated optical fibre. The principle of the absorption of the evanescent wave was employed in these sensors. Figure. 5 illustrates a sample view of the elongated optical fibre. According to the elongated fibre optic sensors, sample of the liquid baing introduced into the elongated area for obtaining improved sensitivity[7].

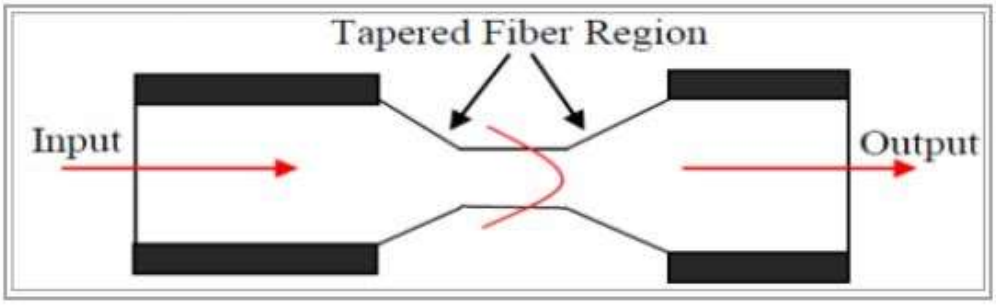

Fig. 5: Tapered fiber optic sensor for RI measurement.

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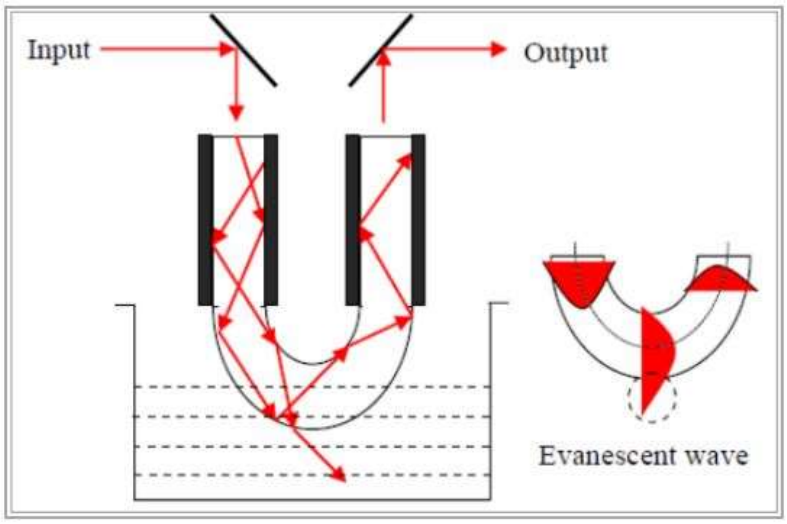

Fig. 6: Simplified schematic of U-shaped bent fiber refractometer.

The area of the fibre is particularly of the U-shaped bending of evanescent wave that pierces into the thickness of the cladding of the fibre. The evanescent wave depth of the piercing became more distinct from the outer part of U-shaped bent fibre that depends on the lights radius and wavelength. As of the dipping of the bent region into the liquid medium, evanescent wave interacts toughly by the liquid medium[8]. Therefore, improved sensitivity is being attained

"Fibre Bragg Grating (FBG)" is attained from periodic variation of the RI into the optical fibre by the aid of exposure of the intense beam of light. FBG sensors feats "Bragg's reflection phenomenon. The harsh behaves as a wavelength discerning filter that satisfies Bragg's resonance wavelength λ_B as stated below.

$\lambda_B = 2\Lambda n_{eff}$.

n_{eff} is operational RI of the grating area; Λ is a period of strident. When layer is scraped from the strident area, evanescent wave cooperates from the medium that is connected through grating region. The outcome from the shifting of the λB with respect to the medium RI. Figure. 7 illustrates the basic diagram of the grating area. The reflected wavelength of the light within shifting of the RI that undergoes into FBG refractometers. In "Optical Spectrum Analyser (OSA)" the spectra of the transmitting wave is being attained[9].

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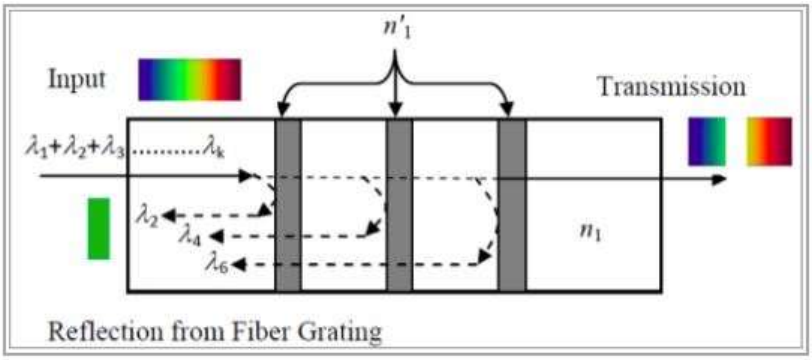

Fig. 7: Simplified schematic of fiber Bragg refractometer sensor.

"Surface Plasmon" is a quantum of the plasmic oscillations occurring on the interface of the metallic dielectric. Plasma surface excitation by the involvement of the energy transfer through the plasma photons[10]. At the resonating situation, extreme energy is transmitted to the plasmon and reflected lights energy reduces up to a lowest level. The incidence angle of the light under particular condition is called as resonating angle. This resonating angle with in RI variation of dielectric materials that comes in contact with the layer of the metal. SPR refractometers that is constructed with in deposition and the ultra-coating of the layer of gold and silver on the exposed area of the optical fibre. The crystals of the photons have the periodicity in the change of RI along the dimensions, and they also exhibits the band of the photons effects of the gap for the propagation of the light by them[2]. Construction of the photonic crystals fibre from such fibre that are reported by theses of the sensors that can be founded[6].

IV CONCLUSIONS

This work represents the qualitative review of the refractometers based on the fibre optics. Even though the researches had been already exists in this field, the conventional work is expected as the profitable source of the information to the young researchers and students into the field of the sensors for the fibre optic. Amongst fibre optics refractometers as testified till date, FBG, Photonic crystals and SPR based refractometers had the finest measurement resolution that ranges from (10^{-4}-10^{-5}). Nevertheless, the novelty of the intensity moderated sensors that are of cheaper and simple construction. There is a long felt need for performing research on the development of the signal processing electronics for SPR and FBG sensors. For the clustering and the test the OSA is implemented into this sensors. FBG and SPR sensors makes the OSA unsuitable for the commercial use, as the OSA is very complicated and costlier equipment. This is an unaddressed problem of this work in SPR and FBG sensors. The fabrication of these sensors also makes it complicated and costlier.

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