THE INFLUENCE OF TORSION ON TRANSMISSION FUNCTION ASYMMETRIC TWIN CORE FIBRE

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Summary The transmission function of twin core fibre is determined by his fibre length and coupling length if only one of its cores is excited. For design of attenuation components or sensors it is useful known transmission dependence twin core fibres on coupling length variations, because the coupling length depends on difference of effective propagation phase constants appertaining to particular fibre cores. It is possible to change them by such deformation, which influences the difference of effective phase constants. For this purpose twin core fibres with one core in the centre of fibre are applicable. The simple deformation of fibre in torsion changes the length (and also effective propagation phase constant) of core located out of centre of fibre.

The measuring dependencies of the influence of torsion on transmission functions for different values of twist make possible ease interpretation. Their agreement (or disagreement) with description following from theory may be possible indication of eventual misalignment of cores what is important for design of attenuation components with control attenuation or sensors.

Abstrakt Prenosová funkcia dvojjadrového vlákna budeného do jedného z jeho jadier je určená jeho dĺžkou a väzobnou dĺžkou. Z toho dôvodu je pri konštrukcii útlmových článkov alebo senzorov potrebné poznať prenosové vlastnosti dvojjadrových vlákien pri zmene väzobnej dĺžky, pretože ich väzobná dĺžka závisí od rozdielu efektívnych fázových konštánt prislúchajúcich jednotlivým jadrám. Možno ich ovplyvniť takou deformáciou ktorá rozdiel fázových konštánt ovplyvňuje. Pre takéto štúdie sú vhodné nesymetrické vlákna s jedným jadrom v strede vlákna, pretože jednoduchá deformácia v torzii mení dĺžku (a tým aj efektívnu fázovú konštantu) iba jadra uloženého mimo stredu vlákna.

Namerané závislosti vplyvu torzie na prenosové funkcie pri rôzne veľkých skrutoch umožňujú jednoduchú interpretáciu a ich zhoda resp. nezhoda s popisom vyplývajúcim z teórie a umožňuje indikovať prípadné chybné uloženie jadier čo je dôležité i pre konštrukciu útlmových článkov s regulovateľným útlmom alebo senzorov.

1. INTRODUCTION

The potential of twin core fiber based components was recognized in the early report on this subject [1]. Recently, it is most used at spectral filters [2], for the equalisation of signal power in particular WDM channels or tunable directional coupler [3] because the parameters of twin core fibres depend on eventual mechanical fibre deformation quite sensitively, it is important to know how the deformation influences them. On the other hand their sensitivity could be used for sensors constructions. This is the reason why the presented paper is devoted to this topic.

2. ANALYSIS

The spectral properties of twin core fibres depend on the value of coupling coefficient C and also on the difference of effective propagation phase constants [4]. When only one of the cores is excited then the powers in the eventually cores are

$$P_1(z)=1-F^2\sin^2\left(\frac{z}{L_c}\right), \qquad (1)$$

$$P_2(z)=F^2\sin^2\left(\frac{z}{L_c}\right), \qquad (2)$$

where $P_1(z)$ is power in excited core and $P_2(z)$ is power in second core, F is coupling efficiency and depends on difference of phase constants appertaining to particular cores β_1-β_2

$$F=\left[1+\frac{(\beta_1-\beta_2)^2}{4C^2}\right]^{-\frac{1}{2}} \qquad (3)$$

and coupling length L_c is

$$L_c=\frac{\pi}{2C}\left(1+\frac{(\beta_1-\beta_2)^2}{4C^2}\right)^{-\frac{1}{2}}. \qquad (4)$$

The coupling coefficient C is given by overlapping integral

$$C_{ij}=k_0\int_0^{2\pi}\int_0^{\infty}\left(n(r,\varphi)-n_i(r,\varphi)\right)\psi_i(r,\varphi)\psi_j(r,\varphi)r\,dr\,d\varphi\ , \qquad (5)$$

where $n(r,\varphi)-n_1(r,\varphi)$ express the profile of investigated fibre toward surroundings (cladding) in cylindrical coordinate system, ψ_i, ψ_j are wave functions described transverse distribution of field of the cores in isolation.

The fibre deformation influences both of these parameters. The character of this influence strong depends not only on deformation geometry but on fibre geometry too. The signal dependence on deformation geometry is clearly seen from the bending of twin core fibre.

For example, let such bend of twin core fibre is performed that curvature centre lies on symetral of (parallel) cores. The length change of all cores is identical so the difference of phase propagation constants appertaining to particular cores is identical, too. The change of transmission properties can be caused only by variation of coupling coefficient. This variation can be activated by pattern change of mode functions involved bending. For small deformations (the diameter of cores is significantly smaller than radius of curvature), the fibre can be considered as straight from optical field computation aspect. This means that such change invoke irrelevant change of fibre field and coupling coefficient, too. However, for such bending that curvature centre is situated on plane that runs through fibre cores it causes different changes of lengths of cores [5]. In consequence of this the difference of effective phase propagation constants arise, because the phase difference of field (which is in the plane vertical to the fibre) arise. Strictly speaking, it causes the change of the difference of effective propagation constants, because their difference didn't have to be equal to value before deformation.

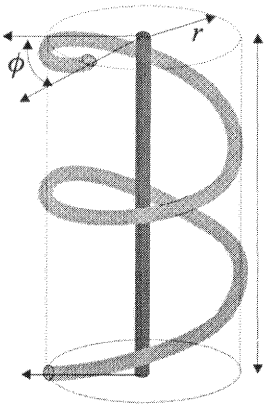

Fig.1. Schematic patern of asymetric twin core fibre deformed in twist (torsion).

It is similar for twin core fibre deformation in torsion. In torsion deformation of (cylindrical) twin core fibre with symmetrically located cores the torsion invokes the same lengths change of both cores, accordingly it make not change of difference of propagation constants. Though for twin core fibre where one core is located in the centre of the fibre and second one is located out of centre in distance r [6], the torsion deformation influences the difference of propagation constants, because the torsion invokes the change of length only of eccentric located core of the fibre.

The relative change of phase constant of eccentric located core is indirect proportion of relative change of fibre length, which can be express by relation

$$\delta l = l_0 \sqrt{1+\left(\frac{r}{l_0}(\phi+\phi_0)\right)^2} \quad , \qquad (6)$$

where l_0 is length of core in non-deformed fibre, ϕ is angle of slewing and ϕ_0 express eventual „twist“ of eccentric located core around centre core in state which it is taken for the state before deformation from macroscopic point of view (fig.1.).
It follows from relation (6) an interesting asymmetry of influence of torsion on variation of core length. It is because the difference of effective propagation constants depends on lengths of cores, zero deformation (ϕ_0) generates asymmetry of torsion influence on transmission properties of fibre.

In the fibre for which angle ϕ_0 is zero, the torsion influence is independent on direction of torsion. However, if in the „non-deformed“ state $\phi_0 \neq 0$, the effective phase constant of eccentric located core decreases if angles ϕ and ϕ_0 have identical signs and increases when their orientation is opposite. Consequence of this matter is more interesting if phase constants of particular cores of fibre β_1, β_2 are on unequal. In this case of If one of the phase constants increases or decreases it means the difference change $\Delta\beta$ and also the change of modulation amplitude of transmission signal which depends on difference of effective phase $\Delta\beta$ which is given by equations (1-4)

3. EXPERIMENTAL SET-UP AND RESULTS

We observed spectral dependencies of transmitted signals of particular cores in experimental set-up [7], which schema is shown in Fig.2.

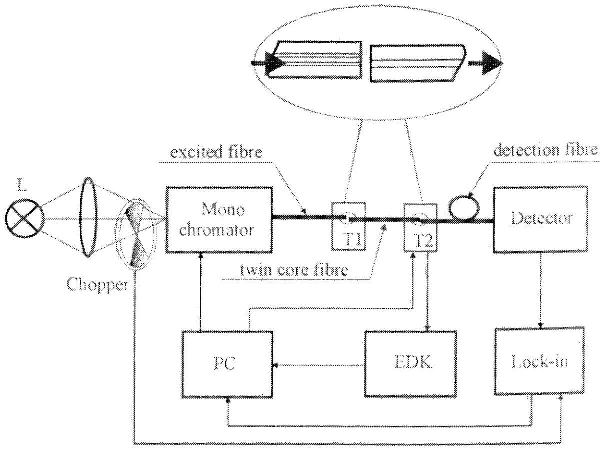

Fig.2. Experimental setup used for observation of spectral dependencies.

Light source is realised using an halogen lamp, which radiation was chopped and filtered by monochromator. The signal outgoing from the monochromator is coupled to the exciting fibre. The end face of this fibre together with end face of twin core fibre is located on 3D micro movement stage. It allows that only one of the cores of twin core fibre could be excited. The second end face of twin core fibre is located on the second 3D micro movement stage where using an detection fibre the signal is transported to the detector and recorded in PC.

At investigation of experimental twin core fibre we really observed asymmetric dependence of transmitted signal on torsion deformation direction (fig.3.).

From dependencies shown in Fig.3. it can be seen how the amplitude is changing in consequence of torsion of fibre.

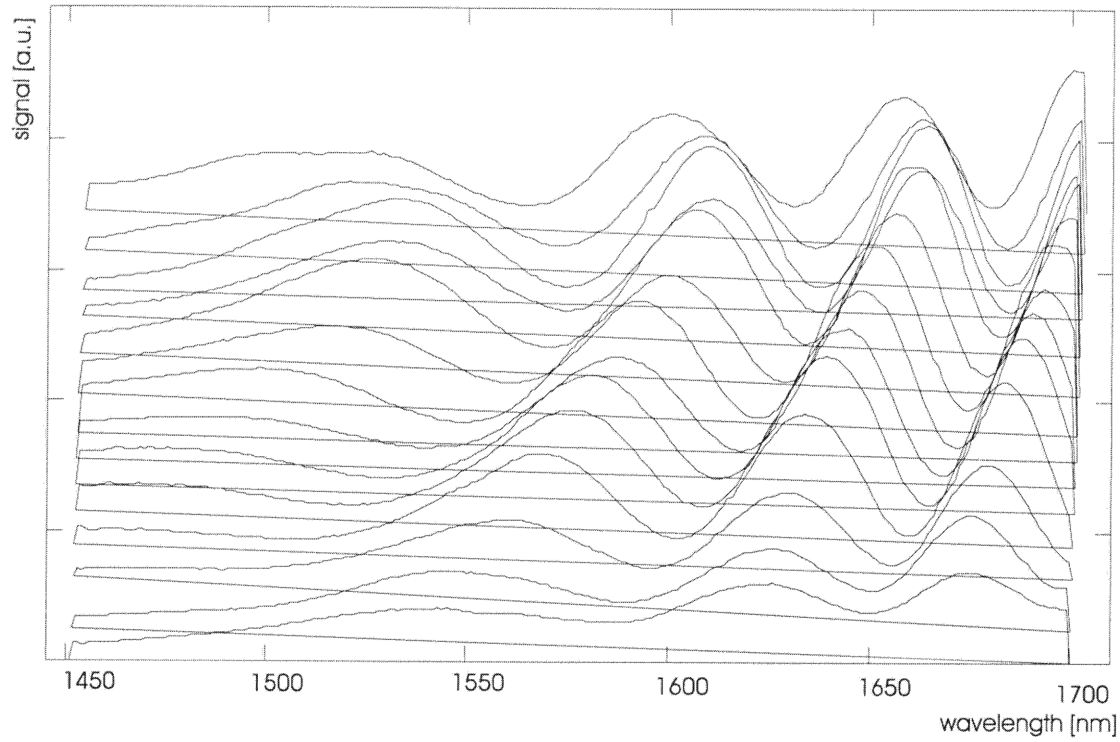

Fig. 3. Spectral dependencies of transmitted signal P_2 in torsion deformation twin core fibre with length 28 cm for angle ϕ form 0 to375 .

Also from the next figure it can be seen how the amplitude of transmitting signal depends on angle of twist for wavelengths 1550nm and 1680nm, respectively.

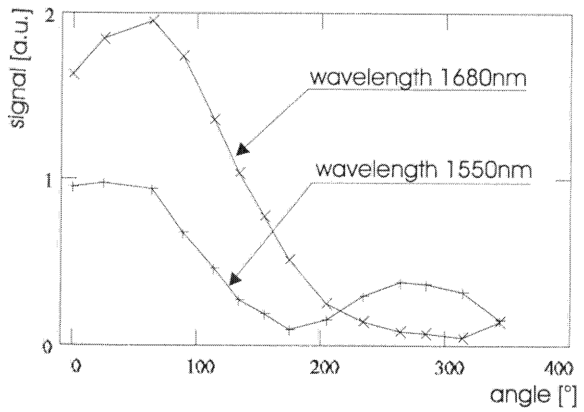

Fig.4. The angle dependencies of transmitted signal P_2 at two wavelengths.

The values given on fig 4 are relative values, which related to the local amplitude of dependencies between 1550 to 1600 nm. This allows eliminating the variation of signal caused by different fibre excitation at different angles of torsion (due to imperfection of equipment at rotation of the fibre, beginning slide movement of fibre centre occurred what required a new adjusting of the exciting fibre to the exact fibre core).

5. CONLUSION

The obtained results indicate that eccentrically located core is twisted around the central core in "non-deformated" fibre.

It shows that quite simple investigation of influence of torsion on transmission properties could inform about curious geometric of the fibre.

On the other hand the presented results also illustrate that such fibre can be used as a special spectral filter with parameter control by torsion deformation of the fibre.

Acknovledgement

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