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ЗАСТОСУВАННЯ ФОТОННО-КРИСТАЛІЧНИХ ВОЛОКОН У НАВІГАЦІЇ

Волоконно-оптичний гіроскоп — це одна зі сфер застосування оптичних волокон, що залежить головним чином від ефекту Саньяка. Область космічної навігації є важливою сферою застосування волоконно-оптичного гіроскопа. У цій статті автор запропонував використовувати фотонно-кристалічні волокна з порожнистим осердям 1550 nm λ, ∅ 10 мкм в оптичному гіроскопі. Фотонно-кристалічні волокна демонструють специфічні властивості та можливості, які призводять до величезного потенціалу для використання в області вимірювань.

Ключові слова: *фотонно-кристалічне волокно, ефект Саньяка, волоконно-оптичний гіроскоп, звичайні волокна.*

1. Introduction

Optical fiber sensors have become more favored due to their electromagnetic immunity, network compatibility, miniaturization, the aptitude for remote and the field of navigation. The emergence of photonic crystal fibers (PCFs) is a significant evolution in fiber optic technology, leading to a new properties that overcome many problems. Photonic crystal fibers are special types of optical fiber where air holes are arranged in a periodic nature in the cladding. Photonic crystal fibers guide the electromagnetic field by an arrangement of air holes that run down the entire fiber length. With the modulation of the location and size of the cladding air holes, the characteristics of photonic crystal fibers, such as transmission, birefringence, mode shape spectrum, dispersion and nonlinearity, could be tunable to manage the anticipated values. The existence of air holes provides the possibility to insert functional materials, the refractive index of which is dependent on external physical fields. This enables further dynamic modification of the waveguide properties and provides perspectives for various all-in-fiber tunable or sensing devices [1]. One of modern fiber optic applications in the field of navigation is an optical gyroscope. Optical gyroscope is based on the Sagnac effect, the time for light to travel in a coil is dependent of the rotation of the coil.

2. Analysis of published data and problem statement

Hollow core fiber photonics is based on microstructured fiber design using a photonic band gap (PBG) cladding composed of silica and air holes surrounding a hollow core for guiding. The photonic band gap guiding mechanism is fundamentally different from the traditional total internal reflection guiding principle in conventional fibers. Thanks to the flexibility for the cross section design, photonic crystal fibers (PCFs) [2] have achieved excellent properties in nonlinearity, birefringence, dispersion, single polarization single mode and effective mode area, and also excellent performances in the applications of fiber sensors [3], fiber lasers and nonlinear optics [4] over the past several years. Large numbers of research papers are highlighted some optical properties of the PCFs such as ultrahigh birefringence and unique chromatic dispersion, which are almost impossible for the conventional optical fibers. During the last decade, photonic crystal fibers (PCFs) have been extensively studied for various applications utilizing their unique capabilities such as tailored dispersion, endless single mode operation, suppressed optical nonlinearity and high birefringence [5, 6]. These unique features come from the fact that optical properties of the guided modes in the core can be easily manipulated by changing the air-hole structure in the cladding.

3 Purpose and objectives of the study

In this paper we proposed to use of a photonic crystal fiber in navigational guidance as optical gyroscope. There are many reasons made us think about this project. The following tasks were solved to reach the work purpose:

- The low nonlinearities. As more than 98 % of the mode is confined in air, not silica, the fibers are less sensitive to nonlinearities such as the Kerr effect.
- Pure silica material, with no co-dopants that can add to fiber environmental sensitivities.
- No Fresnel reflections at open fiber end when free-space coupling in air.
- The polarization maintaining design using form birefringence for low temperature sensitivity.
- Bending sensitivity is low compared with the conventional fibers. Fibers may be bent to very small diameters of less than 1 inch without added losses, thereby enabling smaller form factor designs.

4. Basic principles of fiber optical gyroscope

Fiber optical gyroscope is based on the Sagnac effect. Sagnac effect generates an optical phase difference ($\Delta\varphi$) between two counter propagating waves in a rotating fiber coil [7]. Fig. 1 shows that fiber optic gyroscope is the simplest rotation sensors. They are widely used in commercial applications where their dynamic range and linearity limitations are not constraining.

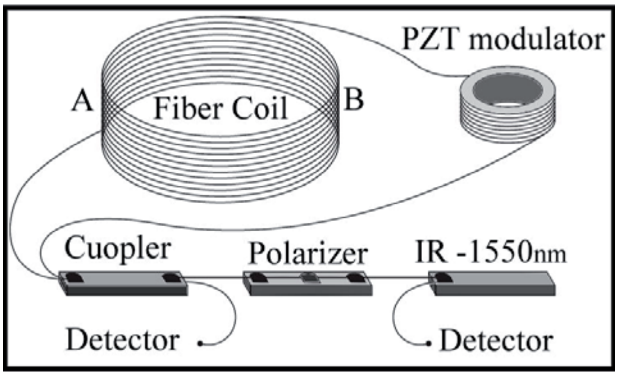

Fig. 1. Scheme of fiber optic gyroscope

During the rotation of angular velocity contour an apparent distance between points B and A for the oppositely traveling beams changes. For a wave traveling from point A to point B, i. e., in a direction similar to the direction of rotation of the contour, the distance is extended, as in a time dt point B moves to the angle ($d\varphi = \Omega dt$). Lengthening the path of the light beam is equal to dt, since at each instant the beam is directed at a tangent to the contour at that same tangential linear velocity directed projection ($\bar{\upsilon} = \bar{\upsilon}\cdot\cos\alpha = \Omega\cdot r\cdot\cos\alpha$). Thus, the length of the path traversed by the beam is equal to $Dl + \acute{\upsilon}dt$. Arguing similarly, for opposing traveling light beam will be a reduction in the apparent path segment $Dl - \acute{\upsilon}dt$. Considering the speed of light invariant quantity, apparent elongation and reduction paths for opposing beams can be considered equivalent to extensions and contractions of time intervals, i. e.:

$$\Delta t_1 = \frac{1}{c}(\Delta l + \nu dt), \tag{1}$$

$$\Delta t_1 = \frac{1}{c}(\Delta l - \nu dt). \tag{2}$$

If the relative time delays of counter propagating waves occurring during the rotation, expressed in terms of the phase difference of counter propagating waves, it will be:

$$\Delta\varphi = \omega\Delta\tau = \frac{4\omega S}{c^2}\cdot\Omega = \frac{8\pi\nu S}{c^2}\cdot\Omega = \frac{8\pi S}{\lambda c}, \tag{3}$$

where $\omega = 2\pi\nu$, $\lambda = \frac{C}{\nu}$.

An optical fiber is used in the fiber optic gyroscope as the medium of propagation for the IR 1550 nm λ. A long fiber cable is winded into loops in order to increase the effective area of the system. Two beams are again propagating through the fiber in opposite directions. Due to the Sagnac effect, the beam traveling against the rotation experiences a slightly shorter path delay than the other beam. Adversely affect the angle of rotation loop fiber optic gyroscopes and registered phase of the optical signal. These effects associated with the process of optical radiation propagation in the material of the optical medium, leading to a phase shift of counter propagating waves, which is not associated with the rotation of the closed loop. The negative effects are also associated with the processes of scattering and reflection of light in optical path, the polarization non-reciprocity effect associated with the asymmetric arrangement of anisotropic elements, relative to the centre of the fiber loop. This problem was solved by the use of frequency and phase modulation of the optical radiation is used, which allows to shift the zero point on the slope with the maximum slope of the interference signal. The resulting differential phase shift is measured through interferometry, thus moving one component of the angular velocity into a shift of the interference pattern which is measured photometrically.

5. Hollow-core photonic crystal fibers (HC-PCFs)

Hollow-core photonic crystal fibers are optical fibers with claddings made of glass incorporating arrays of air holes. The core is formed by omitting several unit cells of material from the cladding. The «holey» cladding has a two dimensional photonic band gap that can confine light to the core for wavelengths around a minimum-loss wavelength λ_c, even when the core is hollow and filled with air [8]. In contrast, a conventional fiber guides light by total internal reflection so its core must have a higher refractive index than the cladding. Usually, this preform is then first drawn to a cane with a diameter of e. g. 1 mm, and thereafter into a fiber with the final diameter of e. g. 125 μm. Particularly soft glasses and polymers (plastics) also allow the fabrication of preforms for photonic crystal fibers by extrusion [9]. There is a great variety of hole arrangements, leading to photonic crystal fibers with very different properties. All these photonic crystal fibers can be considered as specialty fibers. In this paper used the fibers of the type Hollow Core photonic crystal fiber, 1550 nm, ∅ 10 μm, hollow core Photonic Bandgap Fibers guide light in a hollow core, surrounded by a microstructured cladding of air holes and silica. If the transverse scale of hollow-core photonic crystal fibres changes without otherwise changing the fibre's structure, the wavelength λ_c of minimum attenuation must scale in proportion [10]. Without recourse to the approximations of the previous section, the mean square amplitude of the roughness component that couples light into modes with effective indices between n and $n + \delta n$ is:

$$u^2 = \frac{k_B T}{4\pi\gamma(n - n_0)}\coth\left(\frac{(n - n_0)kW}{2}\right)\delta n, \tag{4}$$

where γ — the surface tension; k_B — Boltzmann constant; T — the temperature.

The attenuation to these modes is proportional to u^2 [11] but the only other independent length scale it can vary with is λ_c. As attenuation has units of inverse length, it must therefore by dimensional analysis be inversely proportional to the cube of λ_c. If this is true for every set of destination modes, it must be true for the net attenuation α to all destination modes, so:

$$\alpha(\lambda_c) \approx \frac{1}{\lambda_c^3}. \tag{5}$$

This equation (described phenomenologically in [10] but without theoretical support) predicts the attenuation of a given fiber drawn to operate at different wavelengths. The result differs from the familiar $1/\lambda^4$ dependence of Rayleigh scattering in bulk media [12], and importantly applies to inhomogeneities at all length scales not just those small compared to λ. We measured attenuation spectra by the cut-back technique. A cut-back length of at least 50 mallowed transients' leaky modes is decay away. So, only the fundamental mode is measured. For a set of similar Hollow-core photonic crystal fibers we determined the minimum attenuation as a function of the wavelength λ_c of the minimum. The fibers had 7-cell cores but were drawn to different scales, giving them different λ_c but otherwise comparable properties [10]. The minimum attenuation is plotted in Fig. 2 against λ_c on a log-log scale. A straight-line fit is shown and has a slope of 3.07, supporting the predicted inverse cubic dependence in Equation (5).

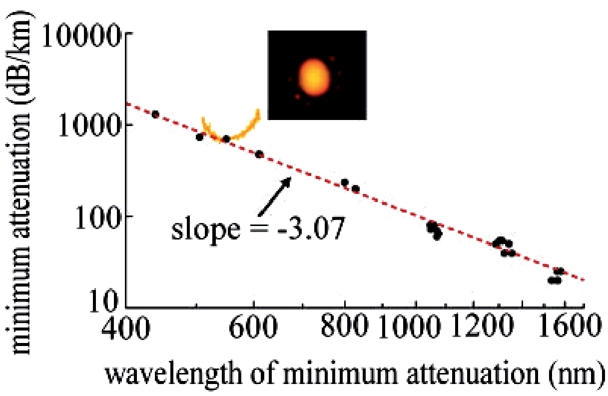

Fig. 2. (Solid orange curve) the low-loss part of the measured attenuation spectrum of a 7-cell hollow-core photonic crystal fiber, with a minimum of 700 dB/km at λ_c = 550 nm. (Left inset) measured near field pattern at the output of this fiber at 550 nm (points). The minimum attenuation of similar hollow-core photonic crystal fibres with various transverse scales, versus the wavelength λ_c of minimum attenuation (broken red line). A straight-line fit to the points, having a slope of 3.07. (Right inset) SEM of representative of these hollow-core photonic crystal fibers, with $\lambda_c \approx$ 1550 nm

The minimum optical attenuation of ~ 0.15 dB/km in conventional fibers is determined by fundamental scattering and absorption processes in the high-purity glass [12], leaving little prospect of much improvement. However, over 99 % of the light in hollow-core — photonic crystal fibers can propagate in air [10] and avoid these loss mechanisms, making hollow-core photonic crystal fibers promising candidates as future ultra-low loss telecommunication fibers. The lowest loss reported in hollow-core photonic crystal fibers is 1.7 dB/km [10], though we have since reduced this to 1.2 dB/km. An understanding of the fundamental limitations to this loss is therefore of great importance. Since only a small fraction of the light propagates in silica, the effect of material nonlinearities is insignificant and the fibers do not suffer from the same limitations on loss as conventional fibers made from solid material alone.

6. Interferometer on photonic crystal fibers

The main argument in favor of a replacement of optical fiber to another medium is that the first Sagnac experiments conducted in the hollow pipe and the low pressure air is not observed effects are manifested in the optical fiber. In this regard, it is evident that the use of such optical media, which on the one hand, would allow optical radiation to channel, and on the other hand did not change to its frequency and phase characteristics. Such environments include photonic crystals with defects. The defect in such environments is a hollow waveguide. Manufactured photonic crystal fiber has a refractive index of 1.82 at wavelength 500 nm for this fiber type Kagome effective single-mode propagation occurs in a wavelength range (750–1050 nm) in diameter mainly 30 micro and loss of about 0.7 dB/m [13] see Fig. 3.

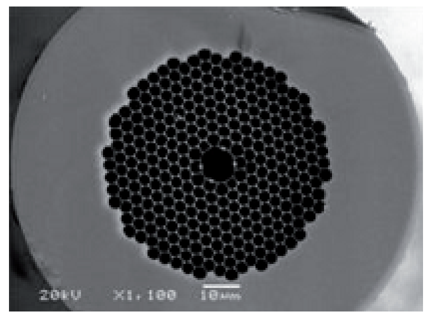

Fig. 3. Example of photonic crystal fiber with a hollow core diameter of about 30 microns

The collapsed zones in the PCF cause a broadening of the beam when it propagates from the SMF to the PCF [14]. The broadening of the beam combined with the axial symmetry and the modal properties of the PCF are what allow the excitation (and recombination) of modes that have similar azimuthal symmetry [15]. The modes excited in the PCF have different effective indices (or different propagation constants), thus, they move at different speeds. As a result, the modes accumulate a phase difference as they propagate along the PCF. Due to the excitation and recombination of modes in the device, the reflection spectrum is expected to exhibit a series of maxima and minima (interference pattern). When two modes participate in the interference the transmitted or reflected intensity (I) can be expressed as:

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos(\Delta\phi). \quad (6)$$

In Equation (6) $I1$ and $I2$ are, respectively, the intensity of the core mode and the cladding mode and $\Delta\Phi = 2\pi\Delta nL/\lambda$ is the total phase shift. $\Delta n = n_f - n_c$, nf and nc being, respectively, the effective refractive index of the core mode and the cladding mode. L is the physical length of the PCF and λ the wavelength of the optical source. The fringe spacing or period (P) of the interference pattern is given by $P = \lambda 2/(\Delta nL)$. The maxima of the interference pattern appear at wavelengths that satisfy the condition:

$$\Delta\Phi = 2m\pi, \text{ with } m = 1, 2, 3\ldots .$$

This means at wavelengths given by:

$$\lambda_m = \Delta n \frac{L}{m}. \quad (7)$$

The fringe contrast or visibility (V) of a modal interferometer is an important parameter, particularly when the interferometer is used for sensing applications. Typically, higher visibility is desirable since it leads to larger signal-to-noise ratio and more accurate measurement. The visibility of a two-mode interferometer can be calculated by the well-known expression: $V = (I_{max} - I_{min})/(I_{max} + I_{min})$, where I_{max} and I_{min} are, respectively, the maximum and minimum values of I given in Equation (6). According to the definition and Equation (6) V can be expressed as [16]:

$$V = \frac{2\sqrt{k}}{(1+k)}, \tag{9}$$

where $k = (I_1/I_2)$.

Many research groups prefer fringe contrast (expressed in dB) instead of visibility. The fringe contrast is defined here as $FC = -10\log(1 - V)$. It can be noted that the fringe contrast increases as (k) approaches to 6, i. e., when the two modes that participate in the interference have equal intensities. Fig. 4 shows the fringe contrast in a mode of interferometer as a function of (k) or the intensity of the cladding mode to that of the core mode ratio. The inset shows the theoretical reflection spectrum in the case of $k = 0.4$ (dotted line) and $k = 0.96$ (solid line).

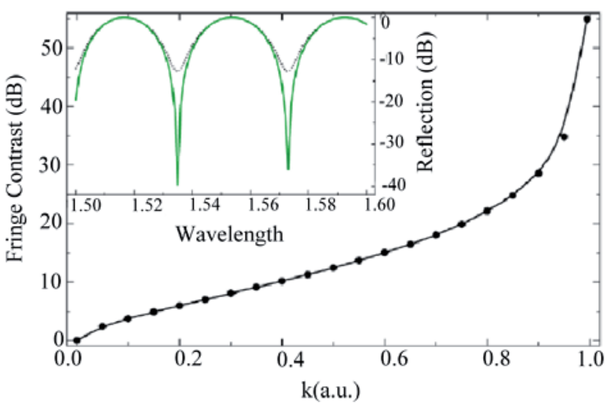

Fig. 4. Fringe contrast in a mode of interferometer

The physical mechanism for the waveguide propagation of radiation in photonic fibers is not associated with the phenomenon of total internal and with the presence of the photonic band gap in the transmission spectrum of the fiber cladding. Waveguides of this type are promising for the creation of gas sensors, spectral elements, as well as laser-cooled atom management. Experimental studies have shown that in some cases [17]. Relatively high loss optical fibers with core air owing to scattering of light by irregularities of the glass surface due to the capillary waves Frozen. Solution to reduce optical loss photonic fibers requires further fundamental research, however, we can already use small pieces of photonic fibers in special measuring instruments, which include the fiber optic gyroscopes. Photonic crystal fiber is a two-dimensional photonic crystal structure based on the song «quartz glass-to-air» formed in the shell.

7. Propagation of radiation in hollow core Photonic crystal defect

In [18] were considered in detail the conditions of formation of photonic crystal fibers and spread them in the optical radiation. Experimental studies of PCF were conducted in a number of studies, for example, [19]. Photonic band gaps arising in the transmission spectrum of 2D periodic cladding, provides a high reflection coefficient for radiation propagating along the hollow core photonic crystal fibers, realizing mode waveguide propagation. In [19] the results of an experimental determination of the optical emission intensity distribution in the cross-sectional center of the defect and the results of numerical calculation of the distribution of power density in cross-section are given. These results are shown in Fig. 5.

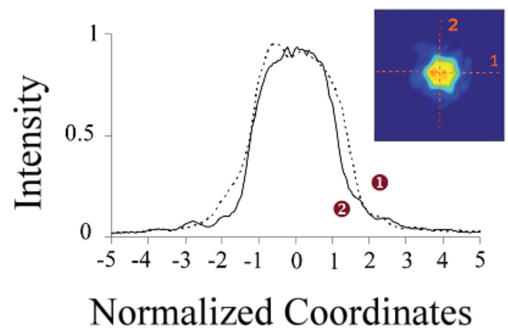

Fig. 5. Distribution of the output power with a hollow core PCF

To date, conditions of use of photonic crystal fiber for transmitting optical information signals in telecommunication systems were researched, however, the use of photonic crystal fiber in optical interferometers have only begun to explore, for precision measurements of some physical quantities. In [20] the results of measurement of voltage using cylindrical photonic crystal fibers, which is formed by the interferometer, are given. To describe the operation of a fiber gyroscope based on photonic crystal fibers must use the description of the optical waves propagating along the two-dimensional photonic crystal defect [21]. To implement the necessary photonic crystal fibers gyroscope with a minimum loss of less than 1 dB/km, which extends single-mode radiation. The low level of absorption in these fibers allows you to create on their basis multiturn ring interferometer, which implements the Sagnac effect. The main technical challenge in applying photonic crystal fiber is the junction of the individual elements of the photonic crystal fiber with some distinctive features of the assembly fiber interferometer.

8. Discussion of the results

The hollow core fiber offers a low reflectance interface, offering improved stability. Where designs require an alternative interface, such as a splice, mechanical coupling, or other type, reflections and mechanical integrity of the interface will need to be managed for hollow core fibers to realize their potential and advantages over conventional fibers in fiber optic gyroscopes. Long fiber lengths in a photonic crystal fibers gyroscope generally offer improved measurement sensitivity. The current loss levels of hollow core fibers designed for single mode transmission limit the fiber length. Although most of the light propagates in air, the portion that interacts with the silica hollow core wall experiences scattering and other loss mechanisms due to imperfections at this boundary. Fiber optic gyroscopes are gaining in addressing many of the markets traditionally dominated by mechanical and ring laser gyroscopes, in particular those used in navigation and guidance of aircraft and spacecraft where performance requirements are demanding. Within the area of fiber optic gyroscopes, the choice of fiber type can play a key role in determining the gyroscope capabilities. Advancements in photonic crystal fiber 1550 nm λ, ∅ 10 µm offer an attractive alternative to conventional silica core fibers.

9. Conclusion

Photonic crystal is one of the most promising platforms for optical information processing as it can enable compact and efficient photonic devices and also their large scale integration on-chip. In this paper we discusses of using hollow-core photonic crystal fibers, 1550 nm λ, ∅ 10 µm as part of the optical gyroscope. Hollow core photonic crystal fibers (HC-PCFs) are a type of fiber optics that present a diversity of new and improved features. Due to their unique geometric structure, HC-PCFs present special properties that lead to an outstanding potential for navigational guidance. The use of hollow core photonic crystal fibers instead of fiber in the conventional fiber optics will overcome many of the problems that are present in the conventional fibers.

References

1. Kirkendall, C. K. Overview of high performance fibre-optic sensing [Text] / C. K. Kirkendall, A. Dandridge // Journal of Physics D: Applied Physics. — 2004. — Vol. 37, № 18. — P. 197–216. doi:10.1088/0022-3727/37/18/r01
2. Chau, Y.-F. A comparative study of high birefringence and low confinement loss photonic crystal fiber employing elliptical air holes in fiber cladding with tetragonal lattice [Text] / Y.-F. Chau, C.-Y. Liu, H.-H. Yeh, D. P. Tsai // Progress In Electromagnetics Research B. — 2010. — Vol. 22. — P. 39–52. doi:10.2528/pierb10042405
3. Dong, X. Temperature-insensitive strain sensor with polarization-maintaining photonic crystal fiber based on Sagnac interferometer [Text] / X. Dong, H. Y. Tam, P. Shum // Applied Physics Letters. — 2007. — Vol. 90, № 15. — P. 151113. doi:10.1063/1.2722058
4. Dudley, J. M. Ten years of nonlinear optics in photonic crystal fibre [Text] / J. M. Dudley, J. R. Taylor // Nature Photonics. — 2009. — Vol. 3, № 2. — P. 85–90. doi:10.1038/nphoton.2008.285
5. Yablonovitch, E. Photonic Band Structure: The Face-Centered-Cubic Case Employing Nonspherical Atoms [Text] / E. Yablonovitch, T. J. Gmitter, K. M. Leung // Physical Review Letters. — 1991. — Vol. 67, № 17. — P. 2295–2298. doi:10.1103/physrevlett.67.2295
6. Birks, T. A. Endlessly single-mode photonic crystal fiber [Text] / T. A. Birks, J. C. Knight, P. St. J. Russell // Optics Letters. — 1997. — Vol. 22, № 13. — P. 961–963. doi:10.1364/ol.22.000961
7. Shinde, Y. S. Dynamic Pressure Sensing Study Using Photonic Crystal Fiber: Application to Tsunami Sensing [Text] / Y. S. Shinde, H. K. Gahir // IEEE Photonics Technology Letters. — 2008. — Vol. 20, № 4. — P. 279–281. doi:10.1109/lpt.2007.913741
8. Mangan, B. J. Low loss (1.7 dB/km) hollow core photonic bandgap fiber [Electronic resource] / B. J. Mangan, L. Farr, A. Langford, P. J. Roberts, D. P. Williams, F. Couny, M. Lawman, M. Mason, S. Coupland, R. Flea, H. Sabert, T. A. Birks, J. C. Knight, P. S. J. Russell // In: Optical Fiber Communication Conference. — 2004. — Available at: \www/URL: http://opus.bath.ac.uk/8940/
9. Ravi Kanth Kumar, V. V. Extruded soft glass photonic crystal fiber for ultrabroad supercontinuum generation [Text] / V. V. Ravi Kanth Kumar, A. George, W. Reeves, J. Knight, P. Russell, F. Omenetto, A. Taylor // Optics Express. — 2002. — Vol. 10, № 25. — P. 1520–1525. doi:10.1364/oe.10.001520
10. Cregan, R. F. Single-Mode Photonic Band Gap Guidance of Light in Air [Text] / R. F. Cregan // Science. — 1999. — Vol. 285, № 5433. — P. 1537–1539. doi:10.1126/science.285.5433.1537
11. Payne, F. P. A theoretical analysis of scattering loss from planar optical waveguides [Text] / F. P. Payne, J. P. R. Lacey // Optical and Quantum Electronics. — 1994. — Vol. 26, № 10. — P. 977–986. doi:10.1007/bf00708339
12. Miya, T. Ultimate low-loss single-mode fibre at 1.55 µm [Text] / T. Miya, Y. Terunuma, T. Hosaka, T. Miyashita // Electronics Letters. — 1979. — Vol. 15, № 4. — P. 106–108. doi:10.1049/el:19790077
13. Jiang, X. Single-mode hollow-core photonic crystal fiber made from soft glass [Text] / X. Jiang, T. G. Euser, A. Abdolvand, F. Babic, F. Tani, N. Y. Joly, J. C. Travers, P. St. J. Russell // Optics Express. — 2011. — Vol. 19, № 16. — P. 15438–15444. doi:10.1364/oe.19.015438
14. Jha, R. Ultrastable in reflection photonic crystal fiber modal interferometer for accurate refractive index sensing [Text] / R. Jha, J. Villatoro, G. Badenes // Applied Physics Letters. — 2008. — Vol. 93, № 19. — P. 191106:1–191106:3. doi:10.1063/1.3025576
15. Cárdenas-Sevilla, G. A. Photonic crystal fiber sensor array based on modes overlapping [Text] / G. A. Cárdenas-Sevilla, V. Finazzi, J. Villatoro, V. Pruneri // Optics Express. — 2011. — Vol. 19, № 8. — P. 7596–7602. doi:10.1364/oe.19.007596
16. Zhang, Y. Fringe Visibility Enhanced Extrinsic Fabry-Perot Interferometer Using a Graded Index Fiber Collimator [Text] / Y. Zhang, Y. Li, T. Wei, X. Lan, Y. Huang, G. Chen, H. Xiao // IEEE Photonics Journal. — 2010. — Vol. 2, № 3. — P. 469–481. doi:10.1109/jphot.2010.2049833
17. Tuchin, V. V. Sensornye svojstva fotonno-kristallicheskogo volnovoda s poloj serdcevinoj [Text] / V. V. Tuchin, Ju. S. Skibina, V. I. Beloglazov et. al. // Pis'ma v ZhTF. — 2008. — Vol. 34, № 15. — P. 63–69.
18. Russell, P. J. Photonic-Cristal Fibers [Text] / P. J. Russell // Journal of Lightwave technology. — 2006. — Vol. 24, № 12. — P. 4729–4749.
19. Fedotov, A. B. Volnovodnye svojstva i spektr sobstvennyh mod polyh fotonno-kristallicheskih volokon [Text] / A. B. Fedotov, S. O. Kononov, O. A. Koletovatova et. al. // Kvantovaja jelektronika. — 2003. — Vol. 33, № 3. — P. 271–274.
20. Chen, W. Ring-core photonic crystal fiber interferometer for strain measurement [Text] / W. Chen, S. Lou, L. Wang, S. Jian // Optical Engineering. —2010. — Vol. 49, № 9. — P. 094402. doi:10.1117/1.3488045
21. Mogilevtsev, D. Localized Function Method for Modelling Defect Modes in2-d Photonic Cristals [Text] / D. Mogilevtsev, T. A. Birks, P. J. Russell // Journal of lightwave technology. — 1999. — Vol. 17, № 11. — P. 2078–2081. doi:10.1109/50.802997

ПРИМЕНЕНИЕ ФОТОННО-КРИСТАЛЛИЧЕСКИХ ВОЛОКОН В НАВИГАЦИИ

Волоконно-оптический гироскоп — это одна из сфер применения оптических волокон, зависящая главным образом от эффекта Саньяка. Область космической навигации является важной сферой применения волоконно-оптического гироскопа. В этой статье автор предложил использовать фотонно-кристаллическое волокно с полым сердечником 1550 nm λ, ∅ 10 мкм в оптическом гироскопе. Фотонно-кристаллические волокна демонстрируют специфические свойства и возможности, которые приводят к огромному потенциалу для использования в области измерений.

Ключевые слова: фотонно-кристаллическое волокно, эффект Саньяка, волоконно-оптический гироскоп, обычные волокна.

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