The analysis of creation perspectives of photonic crystal fiber components

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Abstract - The creation perspectives of components on fibers of new type - photonic crystal fibers, possible areas of their application are considered. Comparative analysis PCF and standard quartz fibers are carried out. Advantages and limitations of PCF use in electronic techniques are selected. The further direction of researches is determined.
Keywords: Photonic crystal fibers, photonic band gap, losses of radiation, dispersion.

Recently alongside with usual quartz optical fibers in electronic techniques are more widely used the new type of fibers - photonics crystal (PCF) or microstructured (MS) fibers. Due to unusual structure of a cladding core PCF can be hollow. And it means, that attenuation, nonlinearity, chromatic and polarizing mode dispersion in them can be reduced by the order in comparison with a modern quartz fiber.

On the mechanism of light holding in a core such fibers can be divided into two classes [1]. The first class form PCF in which light holding in a core occurs thanking its mirror reflection from a cladding to periodically changing refraction index. Feature of the given class of fibers is that they are capable to transfer with small attenuation optical radiation only with the wavelengths lying in some area, which named photon band gap (BG). The photon BG exist in optical fibers with two types of periodic structures: one-dimensional (1D) as coaxial cylindrical layers and two-dimensional (2D) as hollow a tube. 1D fibers with the photon band gap called to Bragg fibers, and 2D – photonic band gap fibers.

The mechanism of light holding in the second class PCF is quite traditional for an optical fiber - full internal reflection. However in them is used the new management principle of the cladding refraction index, based on its dependence on cladding structure. The effective refraction index of the microstructured cladding can be defined [2]

$$n_{clad} = \frac{\beta_{clad}}{k}, \qquad (1)$$

where β_{clad} - propagation constant of the main mode of the structure conterminous to structure of cladding, but not containing defect as a fiber core; $k = \frac{2\pi}{\lambda}$ - wave value; λ - radiation wavelength.

Presence hollow a tube in cladding PCF results in reduction of an effective refraction index of a cladding, as provides performance of full internal reflection conditions for the light beams extending in PCF core. For comparison the structures of standard and photonic crystal fibers, and also a course of light beams in them are shown on fig. 1.

In spite of the fact that the mechanism of light holding is traditional, the possibility to change of a cladding refraction index value opens earlier inaccessible capabilities of management of spatial, dispersive and nonlinear properties of a fiber due to what have extended boundary of use PCF in components of electronic techniques. High contrast of a core and air tube refraction indexes allows using for a lot of applications PCF with the simplified structure, representing fibers which core is surrounded with only one layer of air tube. Versions of PCF structures are shown on fig. 2.

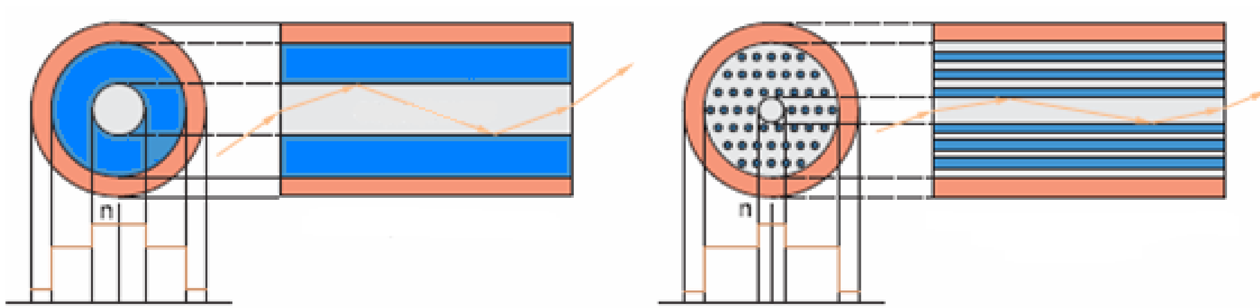

Fig.1

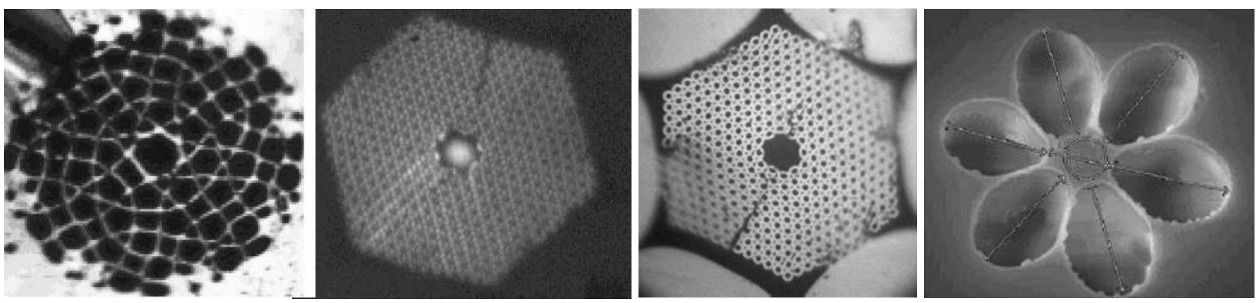

Fig.2

Photonic crystal fibers for functional electronic elements usually are produced of a glass, quartz or transparent plastic by extraction from press form, are created of densely packed a tubes and cores, and collected according to a fiber cross-section. Depending on structure of cross-section, these fibers have various properties, such as a single mode condition of propagation in a wide spectral band, big or, on the contrary, the small area a mode field for increase or reduction of nonlinear effects, low or high losses on curving, high nonlinearity for generation of harmonics and a supercontinuum, precisely controlled polarization, group speed dispersion, spectrum capacities and two-refraction. If the structure of a fiber cladding is not quite periodic, and the period of modulation of its refraction index changes monotonously (occurs chirp) then turns out a diffraction grating with linearly changing period. Such gratings can be used for compensation of a chromatic dispersion in the fiber communication link or for correction of a chirped signal of laser source. The Bragg fiber grating can be used as the optical filter in devices of multiplexing and demultiplexing, as the compensator of a chromatic dispersion, or in a combination with circulators in channels input/output multiplexers.

Photonic crystal fibers have of advantages before usual quartz fibers:

– the single mode condition for all radiation wavelengths;
– wide diapason of change of the main mode field area (up to hundreds square micrometers);
– constant value of a dispersion factor (the dispersive inclination is equal 0.002 $ps \cdot nm^{-1} \cdot km^{-1}$ for 1.3-1.5 μm wavelengths);
– high values of a dispersion factor (2000 $ps \cdot nm^{-1} \cdot km^{-1}$ for specially developed structures);

- the abnormal and zero dispersion for wavelengths is less 1.3 μm (a seen spectrum);
- controllable localization of a field in air apertures.

Not looking on obvious PCF advantages, they lose to usual fibers on attenuation. At present an attenuation in PCF managed to be lowered up to 1.7 dB/km whereas losses of standard quartz fiber are equal 0.2 dB/km. Reduction of losses in PCF is reached due to increase in diameter of a core that results to multimode condition of radiation propagation. In PCF three mechanisms of attenuation of light waves are known: absorption light in a core and a cladding; partial penetration (tunneling) of light for limits of a periodic reflecting cladding; dispersion on structural defects [3]. The total factor of light attenuation in PCF is equal to the sum

$$\alpha_{\Sigma} = \alpha_{\mathrm{T}} + \alpha_{\mathrm{A}} + \alpha_{\mathrm{S}}, \qquad (2)$$

where α_{T}, α_{A}, α_{S} - the partial attenuation factors caused by tunneling, absorption and dispersion accordingly.

The analysis of losses mechanisms in PCF shows, that there are no obstacles principle for reduction in attenuation to a level of less than 0.1 dB/km that makes perspective use of such fibers for telecommunications systems and signal transfer on a long distance.

Due to the unusual properties possible ranges of photonic crystal fibers applications are great enough:

- WDM devices and dispersive compensation;
- telecommunication systems;
- fiber lasers;
- near field microscopy;
- generation of femtosecond a continuum;
- the optical generators;
- sensors of the spectral chemical analysis in a real time condition;
- temperature measurement sensors of a contactless method;
- opportunity of realization of multicore fibers [4].

In these cases connection of photonic crystal fibers among themselves or with other elements of functional electronics is necessary. Owing to complex structure of an cladding of such fibers, and also their dispersive and polarizing features process of connection PCF and the subsequent analysis of brought attenuation of a signal is rather difficult and besides insufficiently studied. In the existing special literature on the given problem the information practically is absent. The further researches in this area are directed on studying of influence of PCF optic geometrical parameters, and also their connections on signal transfer. Work above a choice of methods of definitions of geometrical mismatches between fibers and the control of construction technological parameters of PCF connections is spent.

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