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The influence of the TFBG tilt angle on the spectral response

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ABSTRACT

Periodic fiber structures generally referred to as fiber Bragg gratings are of increasing interest to sensor designers. In recent years, structures in which the phase planes are not perpendicular to the fiber axis have appeared. The paper is devoted to modeling the dependence of the TFBG spectral response on the phase plane tilt angle. The article also contains measurement results of gratings produced on the basis of the model.

Keywords: fiber Bragg gratings, TFBG, optical fiber sensors

1. INTRODUCTION

Interest in periodic optical fiber structures has been booming since the early 20th century. A huge number of applications of these structures, which are generally called Bragg gratings, include monitoring systems, e.g. of the state of mechanical structures, including residential buildings located in seismic zones, bridges, dams, pipelines, etc., as well as measuring systems, e.g. of temperature, mechanical stress, deflection, pressure, etc. A special feature of Bragg gratings is their immunity to the influence of electromagnetic fields [1-6].

In practice, both uniform gratings, in which the period of change of the refractive index in the core of a single-mode optical fiber is constant, and non-uniform ones, with a variable period, so-called chirp gratings, are used. Among uniform gratings, a special place is occupied by Bragg gratings with inclined diffraction plane, which are called tilted gratings. In such structures, there is a resonance associated with the coupling with part of the input signal to the core mode and a number of resonances caused by the coupling of the input signal with the so-called cladding modes of a single-mode fiber. In spite of the fact that a fiber with a Bragg grating created in it is single-mode, it also propagates a number of cladding modes, which are the so-called leaky modes. This means that some light is radiated through the cladding into the surrounding medium. This makes such gratings interesting from the application point of view. Changing the tilt angle gives the possibility to shape spectral transmission characteristics in a relatively large spectral range. A great potential of application of tilted fiber Bragg gratings (TFBG) as sensors of many physical and chemical quantities results also from their small size and electromagnetic interference immunity.

2. PROPERTIES OF TILTED FIBER BRAGG GRATINGS

The tilted fiber Bragg grating is a structure in which the planes of refractive index changes form a non-zero angle with the normal to the longitudinal axis of the fiber [7], Fig. 1

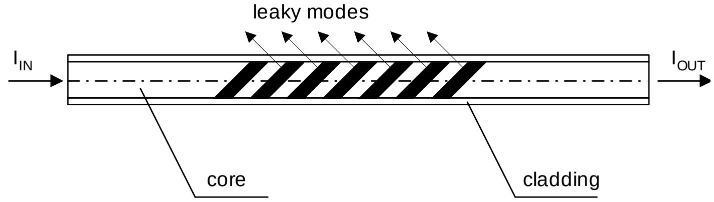

Fig. 1 Scheme of a tilted fiber Bragg grating (TFBG)

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The result of this structure is that the light is poorly guided in the core, and some of the input light radiates out as cladding modes. The tilt of the grating diffraction planes and the amplitude of refractive index changes, determine the light leakage intensity and bandwidth.

The coupled-mode theory (CMT) approach proposed by Erdogan and Sipe [8] can be used for the theoretical analysis of oblique Bragg TFBG gratings. Numerical calculations using the adaptation of coupled-mode theory to the Analysis of oblique Bragg meshes have been carried out for meshes of 10mm length and inclination angles of 3°, 5° and 7°, the results of which are shown in Fig.2,3 and 4. The measurement results presented in these figures have been normalised.

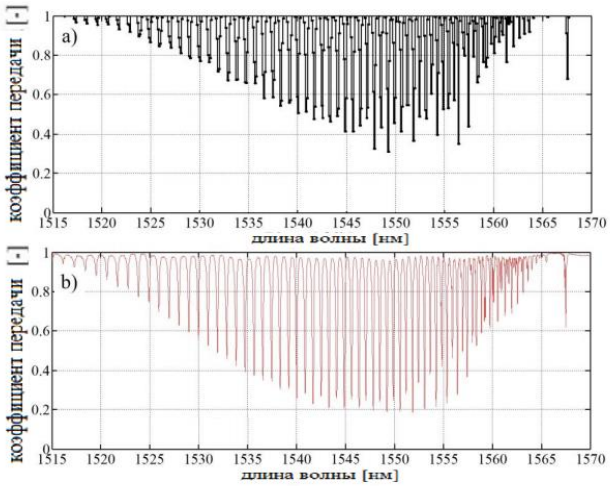

Fig. 2. Transmission characteristics of TFBG grids with inclination angle = 3°; from numerical calculations (above) and measured (below).

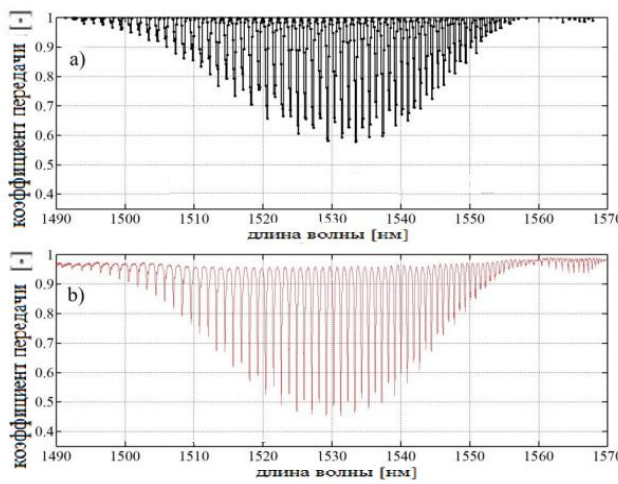

Fig. 3. Transmission characteristics of TFBG grids with inclination angle = 5°; from numerical calculations (above) and measured (below).

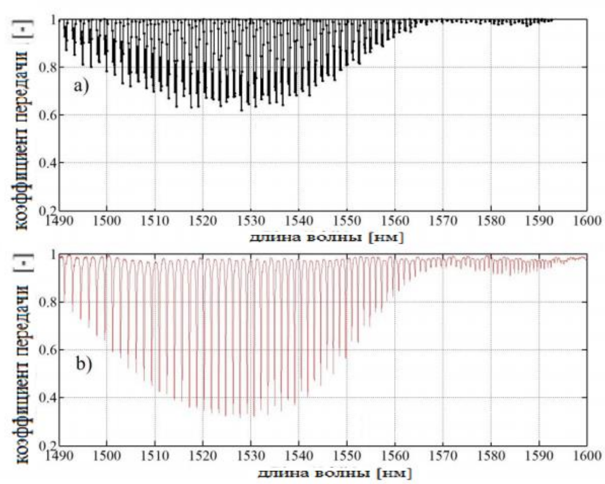

Fig. 4. Transmission characteristics of TFBG grids with inclination angle = 7°; from numerical calculations (above) and measured (below).

Fig.5. Laboratory measurements of transmission spectral characteristics of TFBG structures

Measurements of characteristics of TFBG produced in the laboratory were carried out in the system presented in fig. 5. The measuring system consists of broadband source SLD (1) presented in fig. 5a and optical spectrum analyser (2). Fig. 5b shows a photograph of the spectrum analyser with the recorded spectrum of a tilted grating. Measurements were performed at a constant temperature, for the sake of that the grating was placed in the climatic chamber (3). Example non-normalised measurement results are presented in Fig. 7, and the light source characteristics in Fig. 6.

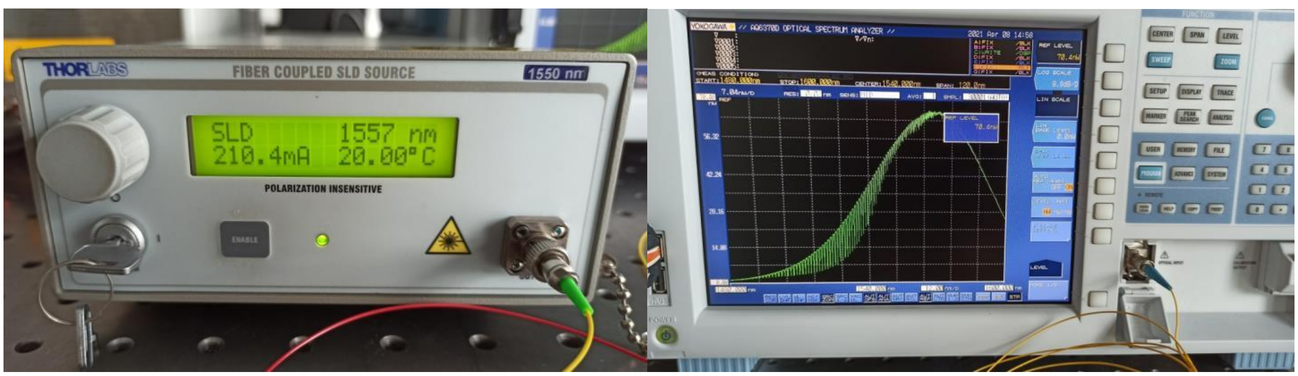

Fig. 6. Measured spectral characteristics of the SLD light source.

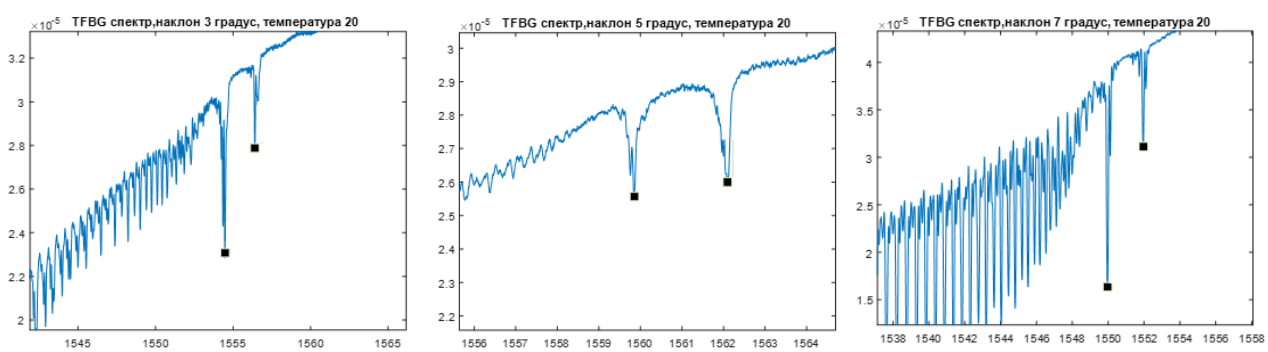

Fig. 7. Measured spectral characteristics of TFBG gratings with angle: a) $\Theta = 3°$, b) $\Theta = 5°$, c) $\Theta = 7°$

It should be noted that in addition to the Bragg modulus, the so-called ghost mode has appeared on the spectral characteristics of TFBG. This mode gives an additional degree of freedom that can be used in practice.

3. CONCLUSIONS

The spectral properties of TFBG grids can be analysed both on the basis of numerical calculations and physical measurements. From the comparisons made, a high convergence between theoretical results and practical measurements is apparent. In both approaches, a significant influence of the inclination angle of diffraction planes on the shape of spectral characteristics is observed. The course of the characteristics measured in the laboratory is influenced by the spectral characteristics of the light source. In order to become independent of its shape, normalisation should be performed. As mentioned earlier, the so-called ghost mode, appears on the spectrum, giving an additional degree of freedom. TFBG grids can be used for mode separation and conversion, or to separate waves of different wavelengths.

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