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Speckle-Pattern Rotation of Light in Graphene-Coated Gyrotropic Optical Fiber.

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I. INTRODUCTION

It is well known, that when light is travelling into the gyrotropic medium, its polarization plane rotates due to Faraday effect. In [1] the possibility of observable speckle-pattern (radiation distribution at cross-section of the fiber) rotation of light passed through the gyrotropic optical fiber placed in longitudinal magnetic field has been predicted. It has been shown as well, that modes corresponding to the meridional rays are mainly responsible for the rotation of the speckle-pattern. This effect has been observed experimentally for linearly polarized light travelling through low-mode quartz fiber placed in longitudinal magnetic field [2]. Theoretical explanations of the effect based on peculiarity theory approach have been made in works [3, 4]. Method of detecting magnetic field variation based on rotation of the speckle-pattern has been proposed and implemented experimentally [5].

Nowadays, great attention of researchers is attracted by graphene. Graphene layer can support both TE- and TM- polarized highly localized surface plasmon polaritons. Multilayer graphene-based structures have a number of interesting properties, including waveguide ones. Structures based on graphene and gyrotropic materials have features as well.

Present work is devoted to investigation of fiber core coating by graphene layer influence on the speckle-pattern rotation. Investigation showed the possibility of inverse speckle-pattern rotation of linearly polarized light in such a fiber. This effect can be controlled be chemical potential of graphene layer. Investigated features may have both fundamental interest (interaction of light polarization with its trajectory) and various practical applications (determining the properties of graphene by the angle of the speckle-pattern rotation, for photonics and optoelectronics devices, etc.).

II. RESULTS AND DISCUSSION

Non-zero real part of conductivity becomes a reason of energy dissipation when electromagnetic wave is guided by the fiber (propagation constants are complex). Analytical calculations show that characteristic equation has a term with multiplier $m\sigma\varepsilon_a$ (m is a circular mode number, σ is a graphene conductivity, ε_a is non-symmetric part of the permittivity tensor). If sign of the conductivity is changed, relation between phase speeds for modes with different m signs is changed as well. Calculations show that at negative imaginary part of conductivity (like usually for metals and semiconductors), phase speed of modes with negative m is greater than speed of modes with $m > 0$. The same situation has a place for non-coated fiber. This is the reason of the clockwise speckle-pattern rotation (looking along wave guiding direction). Change in sign of imaginary part of conductivity leads to change of graphene contribution to mode's phase speeds (modes with $m < 0$ are slowing down, with $m > 0$ are speeding up). This decreases speckle-pattern rotation and at some conditions it may caused an inverse speckle-pattern rotation (counterclockwise speckle-pattern rotation). One can also note, that for single-mode fiber (only one mode with $m = 0$ may propagate in the fiber) speckle-patter rotation cannot be observed. Hence, few-mode regime is essential for the effect observation.

Chemical potential dependence of real and imaginary parts of graphene, speckle-pattern $I_x(x,y)$ for fiber length 5 cm, magnetic field value $H_0 = 30$ kOe, and different values of chemical potential of graphene layer are shown on fig. 2. Fig. 2 shows speckle-pattern for non-coated fiber as well. One can see, that graphene coating may compensate the rotation of the speckle-pattern typical for a gyrotropic fiber without graphene. When imaginary part of conductivity reaches a maximum ($\mu_{ch} \approx$ 1 eV, see fig. 2) speckle-pattern rotates counterclockwise (rotation angle is about 4.7° counterclockwise; for non-coated fiber rotation angle is about 12.5° clockwise). Total effect of graphene coating is a counterclockwise rotation on angle about 17° for fiber length 5 cm, magnetic field 30 kOe, and chemical potential of graphene layer 0.98 eV. The maximum of intensity is changed as well. This fact may be explained by superposition of Faraday and Cotton-Mouton effects.

Study showed the possibility of linearly polarized light speckle-pattern manipulation by both magnetic field and chemical potential of graphene changing (for example, by a gate voltage). This possibility may be used for light manipulation in various optoelectronics and photonics applications. By the other hand one can measure coating layer properties by speckle-pattern rotation angle, or suppress magnetic speckle-pattern rotation, when it is necessary.

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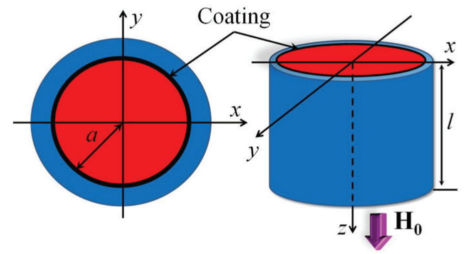
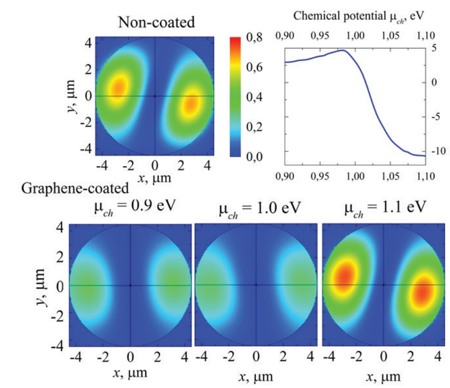


Scheme of the problem: fiber core coating by graphene layer.



Speckle-patterns for different μ_{ch}