Two-beam interferometer based on a quartz beam-splitting unit with a fixed photodetector and simulated rotational tuning

S.L. Mikerin and V.D. Ugozhaev*

Institute of Automation & Electometry, SB RAS

**E-mail:vdu@iae.nsk.su*

Two-beam interferometers with the possibility of varying the period of the recorded diffraction gratings are in wide demand in various fields of holography and photonics. They are in demand, for example, for studying the properties of photopolymer materials and holograms recorded in them [1], for recording arrays of distributed Bragg gratings (FBGs) in optical fibers as sensors of the physical state of the fiber [2] and for other applications. In [3], an interferometer based on a beam-splitting cube (BSC) with two mirrors and a photodetector (PD), fixed relative to the BSC is described. In the interferometer, the stabilization of the position of the interference pattern (IP) while the angle of convergence of partial light beams (PB) is varied is provided by mutually coordinated linear and angular displacements of the movable mirror (MM) directing the light beam to the BSC. Such interferometers can be combined into systems for recording two-dimensional gratings with an independent setting of the period in each dimension [4]. However, for recording extended FBGs (10–15 mm), an interferometer based on a beam-splitting unit (BSU) seems to be more suitable [5], since in it the path length of light beams in BSU material is more than 3 times shorter than in BSC of the corresponding dimensions. The purpose of this report is to analyze the period tuning in a quartz glass BSU-based interferometer with stabilization of the IP position, provided by matching the linear and angular displacements of the initial light beam (IB) at the entrance to the BSU by means of a rotation simulation mechanism [3].

Fig. 1 shows the optical scheme of the interferometer under study, and the path of light beams is displayed by their axes. The interferometer, which includes BSU *1* and two mirrors *3.1* and *3.2*, is optically coupled with PD *4*, which is at a distance L_{ph} from the end of C_2C_3. BSU consists of two identical plates of quartz glass with a length M and a thickness of $A \approx 0.15M$, tightly joined by their working surfaces, with a dividing mirror (DM) *2* between them. The mirrors are installed symmetrically to the DM plane at a distance H from each other at an angle ξ (in Fig. 1 $\xi > 0$). IB *7* with diameter D is directed to the entrance surface C_1C_2 at a distance Q from the C_1 edge at an angle of incidence θ by MM *5* and then splits by DM into two PB *8.1* and *8.2*. After reflection from mirrors the axes of these beams intersect at the point O at the angle of convergence 2α at a distance $L \approx L_{ph}$ from the end C_2C_3: $\alpha = 90° + 2\xi - \theta$.

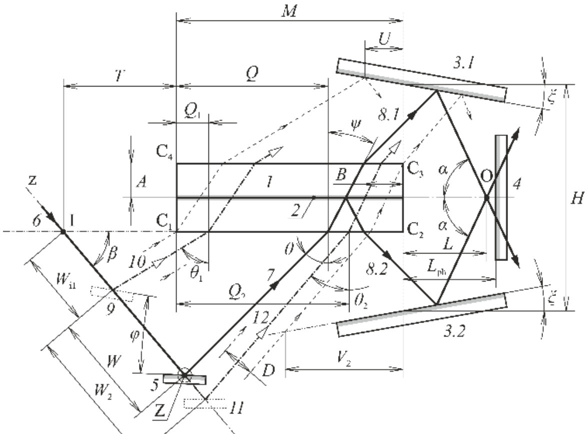

Fig. 1. Optical scheme of the interferometer

The current MM position is given by coordinates W and φ. MM is moved along the input beam *6* from the initial position *9* ($W_1 = 0$, $\varphi_1 = 0$) to the final position *11* (W_2,

φ_2), corresponding to the lower *10* (Q_1, θ_1) and upper *12* (Q_2, θ_2) boundary positions of IB. The latter are caused by touching IB edge C_1 and touching PB edges C_2, C_3. In turn, the pairs of IB coordinates (Q_1, θ_1) and (Q_2, θ_2) satisfy the condition $L \approx L_{\mathrm{fix}} = \mathrm{const}$, supported in the entire interval between them. Such movement of IB is determined by the formula:

$$Q = M - 2A\,\mathrm{tg}\,\psi - \left[H\sin(\theta-\xi)\cos\xi - A\sin\theta - L_{\mathrm{fix}}\cos(\theta-2\xi)\right]\big/\cos\theta\,, \qquad (1)$$

where $\mathrm{tg}\,\psi = \sin\theta\big/\sqrt{n^2-\sin^2\theta}$, n — refractive index of the BSU material. The boundary positions can be found numerically according to the above-mentioned touching conditions: $Q_1 = \mathrm{D}/(\cos\theta_1)$, $Q_2 = M - 2A\,\mathrm{tg}\,\psi_2 - D/(\cos\theta_2)$ and set the corresponding boundary values of the angle α: α_1 and α_2, as well as the width of the tuning range of this angle: $\Delta\alpha = \alpha_2 - \alpha_1$. The dependence $Q(\theta)$,obtained from (1), is close to linear for a wide set of combinations of the parameters H and L_{fix}, which opens up the possibility of using the lever mechanism in [3] as a mechanism for coordinating linear and angular displacements of MM. The $Q(\theta)$ dependence was analyzed taking into account vignetting by the BSU working surfaces (parameter G) and/or by the mirror on the input surface side (parameters U, V, and V_2). The parameters G and V for the current IB position are determined similarly to the parameters U and V_2 (see Fig. 1). This restriction is possible in the case of $H \approx M$ and $L_{\mathrm{fix}} < M$ at least for $\xi < 0$.

Fig. 2 shows the delimitation of the range of parameters $h = H/M$ and $l_{\mathrm{fix}} = L_{\mathrm{fix}}/M$ by the criterion of the presence or absence of vignetting in the studied interferometer at $\xi = -15°$. Above curve *1* there is an area free of vignetting; below curve *2*, the light beams overlap partially or completely in the entire tuning range limited by the touching conditions. Between curves *1* and *2*, the tuning ranges are partially limited by vignetting. Curves *3* and *4* are extrapolations of the corresponding curves *1* and *2* to the edges of the studied area; *5* — $h = 1.175$; *6* — $l_{\mathrm{fix}} = 0.24$. For example, for recording FBGs with $\lambda_{\mathrm{Б}} = 1\ldots2$ microns in a quartz fiber with $n = 1.5$, it is possible to implement an interferometer characterized by pairs of parameters (h; l_{fix}): (1.0; 1.25), (1.0; 1.75), (1.25; 2.5). The rotation imitation mechanism is analyzed similarly to [3].

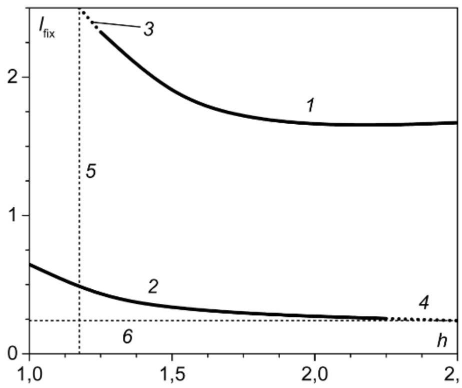

Fig. 2. Regions of vignetting

References

[1] V.V. Shelkovnikov, E.V. Vasil’ev etc., *Optics and Spectroscopy* **99**, Iss. 5 806–815 (2005) - DOI: 10.1134/1.2135860

[2] J. Habel, T. Boilard, Y. Messadeq, F. Trépanier, M. Bernier, *Advanced Photonics Congress* (BGPP, IPR, NP, Networks, NOMA, Sensors, SOF, SPPCom) OSA, BM3A.4 (2010)

[3] S.L. Mikerin, V.D. Ugozhaev, *Applied photonics* **5**, Iss. 3, 218-237 (2018) - DOI: 10.15593/2411-4367/2018.3.07

[4] S.L. Mikerin, V.D. Ugozhaev, *Intern. Conf. “SibOptica-2018”*: Proc. in 2 v. – Novosibirsk : SSUGT, V. **1**, 101–107 (2018)

[5] V.D. Ugozhaev, *Optoelectronics, Instrumentation and Data Processing* **54**, Iss. 4, 375-384. (2018) - DOI: 10.3103/S875669901804009X