PROCEEDINGS OF SPIE

SPIEDigitalLibrary.org/conference-proceedings-of-spie

Fiber optic gyroscope based on the registration of the spatial interference pattern

Tuzhanskyi, Stanislav Ye., Sakhno, Andrii, Komada, Paweł, Kashaganova, Gulzhan

Stanislav Ye. Tuzhanskyi, Andrii M. Sakhno, Paweł Komada, Gulzhan Kashaganova, "Fiber optic gyroscope based on the registration of the spatial interference pattern," Proc. SPIE 9816, Optical Fibers and Their Applications 2015, 98160Z (17 December 2015); doi: 10.1117/12.2229340

Event: 16th Conference on Optical Fibers and Their Applications, 2015, Lublin and Naleczow, Poland

Fiber optic gyroscope based on the registration of the spatial interference pattern

Stanislav Ye. Tuzhanskyi*[a], Andrii M. Sakhno[a], Paweł Komada[b], Gulzhan Kashaganova[c]
[a]Vinnytsia National Technical University, 95 Khmelnytske Shosse, 21021 Vinnytsya, Ukraine;
[b]Lublin University of Technology, 38A Nadbystrzycka Str., 20-530 Lublin, Poland;
[c]Kazakh National Research Technical University after K. I. Satpaev,
22 Satpaev Str., 050013 Almaty, Kazakhstan

ABSTRACT

Design of a fiber optic gyroscope FOG using a photosensitive line to scan interferograms is proposed. Shift periods depends mainly on the change of the phase of counter light waves propagating along the closed loop in opposite directions while rotating loop around an axis that is normal to its plane. Phase shift is proportional to the angular velocity Ω and the area of the circuit S which is bypassed by the counter-propagating waves. Proposed FOG design significantly reduces the impact of the following optical noise factors: zero drift, Rayleigh scattering, the Kerr effect, etc.

Keywords: fiber optic gyroscope, interferometer gyroscope, polarization, interference, angular velocity and phase shift, linear photodetector, Faraday effect, optical Kerr effect.

1. INTRODUCTION

The demand of accurate and rapid orientation of objects in space predetermines the need to improve the existing inertial navigation tools that are able to operate consistently in a wide speed range. The applications of fiber-optic gyroscope (FOG) control and navigation systems of mobile objects (ground transportation, ships, aircraft, etc.) is undeniably promising. Thus, FOG with a wide range of characteristics of precision ω – from 10.0 deg/h to 0.001 deg/h [1], is required (Fig. 1).

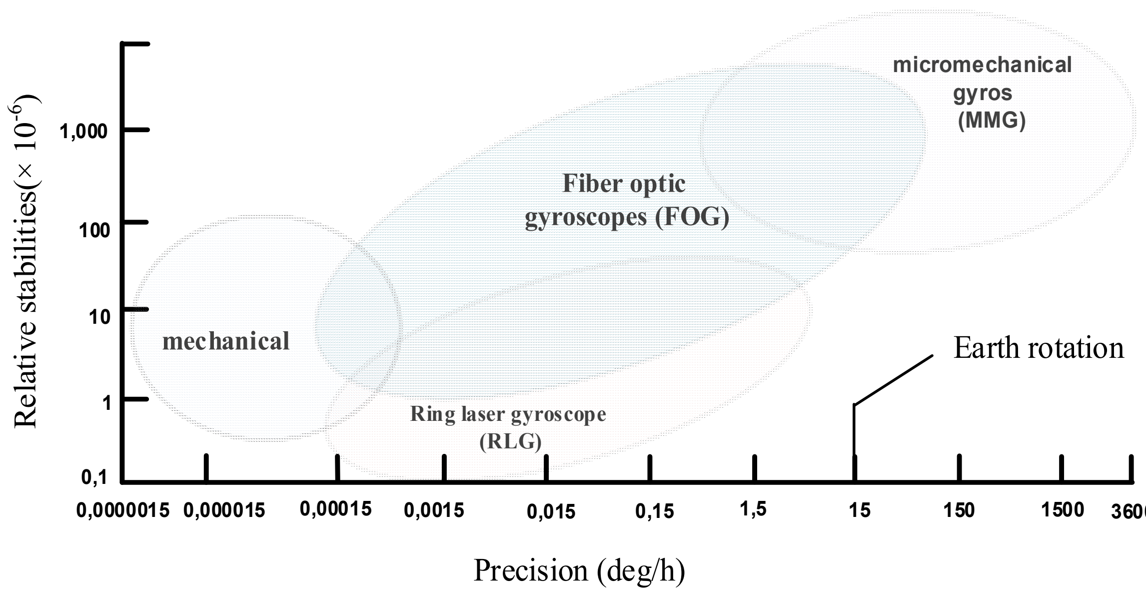

Figure 1. Stability and accuracy of the main type's gyroscopes.

2. AIM OF THE WORK

Modern FOG uses a photo sensor, which responds to changes in the brightness depending on the direction and speed of rotation. Such design is vulnerable to many noise factors [2,3]. To eliminate or at least decrease the influence of noise

Optical Fibers and Their Applications 2015, edited by Ryszard S. Romaniuk,
Waldemar Wojcik, Proc. of SPIE Vol. 9816, 98160Z · © 2015 SPIE
CCC code: 0277-786X/15/$18 · doi: 10.1117/12.2229340

various sophisticated methods are used. This leads to the complication of the device's design as well as of the signal processing algorithms, resulting in a significant deterioration of weight and size, and increased power consumption and costs.

We propose FOG (Fig. 2) based on the registration of radiation intensity spatial changes in the process of interference of counterpropagating light beams.

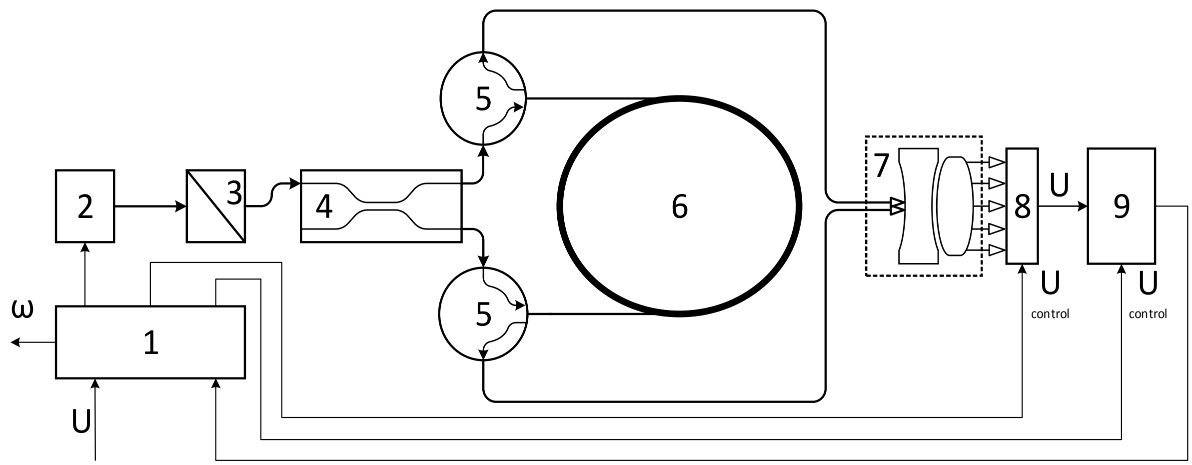

Figure 2. FOG schematic diagram.

The main components of the device are a single-frequency laser, an optical splitter, fiber optic circulators, the coil of optical fiber, an optical system for radiation focusing, a linear coordinate photodetector based on CCD, and a signal registration and processing block. Proposed FOG design significantly reduces the impact of the following noise factors:

- oscillation of polarization in optical fibers;
- difference of optical path length of colliding light waves;
- dynamic instability of the spectrum of the light source;
- change of the output signal phase due to the Faraday effect in the fiber;
- intensity fluctuation of forward and backward beams in beam splitters due to an optical Kerr effect;
- interference of forward and backward beams in the process of Rayleigh scattering.

The proposed FOG consists of the power and control unit UP (1), stabilized single-frequency laser as a source of radiation L (2), the polarizer P (3), the optical directional coupler ODC (4), two optical circulators OC (5), the fiber loop FL (6), the bonding node and the focusing lens (7). To optimize the FOG operation we propose to use line of photodetectors CCD (8), which function as an alternative photosensor. The lens projects interferogram from closely located ends of the fiber to the CCD photodetectors. The CCD registers a slight change in the spatial position of the interference fringes (Fig. 3). The processing unit (9) computes the changes in acceleration.

The device operates as follows. The single-frequency laser generates the polarized light that passes an optical coupler 50/50, forming a two-reference beam. Each of the beams incidents on the corresponding circulator, and they transmit into the fiber coil toward one another. Forward and reverse waves acquire shifts in phase difference, due to the propagation along a closed loop in opposite directions. Upon rotation of the loop around the axis, occurs the phase shift, proportional to the angular velocity *Ω*, and the area *S*, which is bypassed by the counterpropagating waves, as shown in Eq. 1:

$$\Phi_s = \frac{8\pi \mathrm{Ns}}{\lambda \mathrm{c}}\Omega = \frac{4\pi \mathrm{R}L}{\lambda \mathrm{c}}\Omega = \frac{8\pi^2 \mathrm{R}^2 N}{\lambda \mathrm{c}}\Omega = \frac{2\mathrm{L}^2}{\lambda \mathrm{cN}}\Omega, \tag{1}$$

where $s = \pi R^2$ – area of one loop, N – number of turns, R – radius turns, $L = 2\pi RN$ – total length multiturn coil, λ – wavelength of light, c – speed of light.

After exiting the fiber contour rays fall on the opposite circulators and are broadcasted to the gluing of fibers in front of the lens with the minimal losses. The lens forms several peaks of brightness of the interference image on the CCD matrix. The computing device reads the image on CCD with the period T.

If necessary, the sensitivity of the proposed gyroscope can be accustomed, depending on the work conditions, by adjusting the scanning period (including the adaptive methods) and applying different techniques of digital signal processing [4,5].

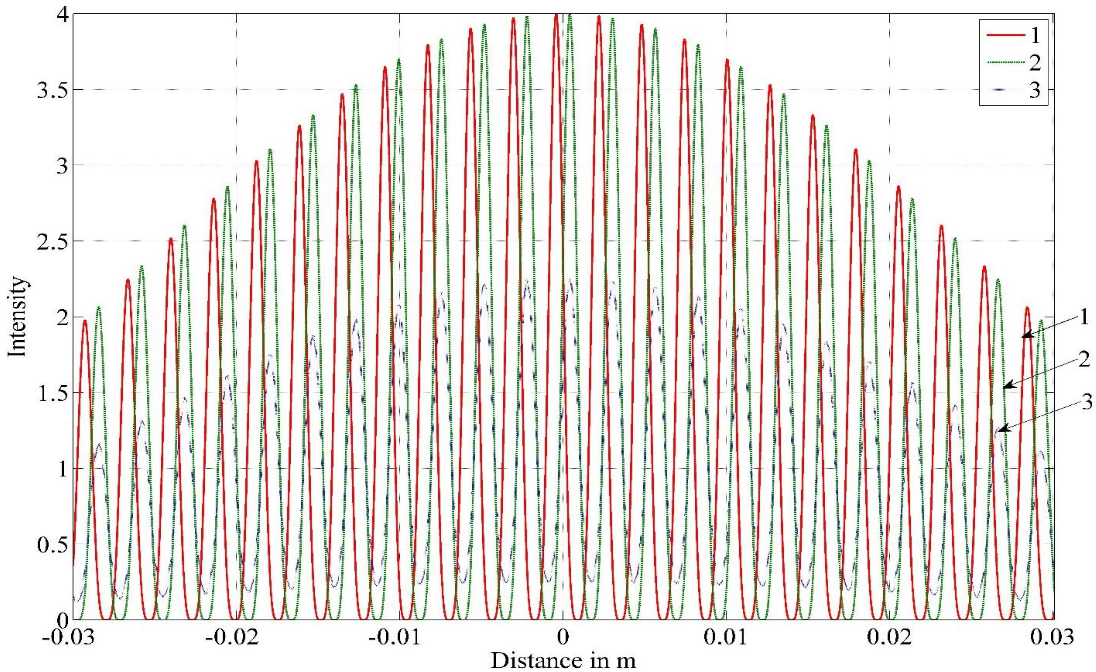

Figure 3. Modeled intensity on CCD: 1 – reference interference pattern (ω=0); 2 – shifted interference pattern (ω≠0); 3 – shifted interference pattern (ω≠0, decreased power of one laser).

3. CONCLUSIONS

In this paper, the key advantage is potential device insensitivity to the majority of FOG accuracy restriction factors. The destabilizing effects leads to the change in brightness, while the spatial position of the peaks remains unchanged. This effect can be accounted in relevant algorithms of digital signal processing, in contrast to the current schemes of fiber-optic gyroscopes, where do not allow for this.

REFERENCES

[1] Udd, E., and Spillman Jr., W. B., [Fiber Optic Sensors: An Introduction for Engineers and Scientists], New Jersey (2011).
[2] Lefevre, H. C., Culshaw, B., [The Fiber-Optic Gyroscope], Artech House Publishers, Boston (1993).
[3] Andronov, I., and Malykin, G., "Physical problems of fiber gyroscope on the Sagnac effect (in Russian)," Physics-Uspekhi 172(8), 850-872 (2002).
[4] Sedlacek, M., and Krumpholc, M., "Digital measurement of phase difference - a comparative study of DSP algorithms," Metrology and Measurement Systems 12(4), 427-442 (2005).
[5] Kang, J. U., [Fiber Optic Sensing and Imaging], Springer, Baltimore, 203-256 (2013).