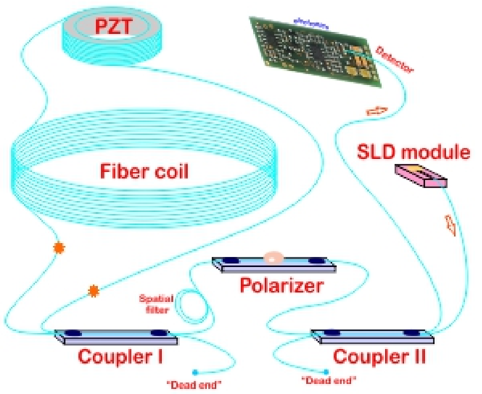
OPEN-LOOP FIBER OPTIC GYROSCOPE

Info Notes[1]

Fizoptika Fiber Optic Gyroscope (FOG) is a precision yet most miniature fiber optic rotation sensor. It comprises fiber optic "minimum configuration" sensing assembly and analog processing electronics. The FOG is a robust, reliable, maintenance-free electro-optical device offering all advantages of the optical sensing technology.

The gyro main frame is made of aluminum or hard plastic to withstand a wide temperature range and high levels of vibration and shocks. Possibility to use plastic housing gives the gyro the lowest weight in its size.

Fizoptika FOGs are produced using the ***spliceless*** technology when the entire fiber optic assembly is fabricated from a single fiber length. The technology provides the highest quality of the assembly with **ZERO** excess loss due to the *absence of joints between the components*. The fiber is of a *specialty (**40μ**) polarization maintaining* type to suppress the effects of polarization state changes that occur in the fiber. By fine optical tuning the assembly may acquire immunity to electromagnetic interference eliminating the need for heavy shielding. A single miniature analog PCB performs all necessary functions to process the optical signal and provide stability and precision conforming to the performance of the optical assembly.



Open-loop 'minimum configuration' fiber optic gyroscope assembly

Principle of Operation

The open-loop FOG architecture is illustrated by the Figure below. The broadband light-emitting diode (SLD module) couples the light into an input/output fiber coupler (II). Then the light passes through a polarizer and a spatial filter which ensure the reciprocity of the counter-propagating light beams through the fiber coil. Another coupler (I) splits the two light beams in the fiber optic coil where they pass through a harmonic modulator (PZT). The modulator is offset from the center of the coil to impress a relative phase difference between the counter-propagating light beams. After passing through the fiber coil, the two light beams recombine and pass back through the polarizer and are directed onto the photodetector. Synchronous demodulation behind the detector converts the rotationally-induced first harmonic signal into a rate proportional voltage.

Analog Output

Some general properties of the open-loop gyroscope may be deduced from fundamental physical principles.

No dead zone or hysteresis. The Sagnac phase responds to rotation nearly instantly and without distortions. That is why the relation between the output voltage and the input angular rate is perfectly proportional. In certain sense, the open-loop gyro is an ideal sensor of rotation.

Instant response. Sagnac phase delay is 0.8 μs (light transmission time) to rotation of the sensing coil. The practical limit of the gyro frequency range (~2kHz) comes from the mechanical delay between rotation of the object and rotation of the sensing coil.

Bias immunity to acceleration (gravity). Constant acceleration does not create any phase difference between counter-propagating waves of the ring interferometer.

The FOG's output voltage is a function of the angular rate and SLD temperature. The simple model of the output:

$$U = SF \cdot \Omega + U_0 \qquad SF(t°, \Omega) = SF_0 \cdot k_t \cdot k_\Omega \qquad U_0 = U_0(t°)$$

If the open-loop FOG is rotating far faster than its max input rate, its output is not a function of the input rate.

a) k_Ω - the term describing the deflection of the output characteristics from the linear function. Such natural (for the open-loop FOG) nonlinearity is larger at faster rotation.

b) k_t – the term describing temperature dependence of the scale factor. k_t – is the linear function ($T_1 \approx$ -0.05% per °C) caused by SLD wavelength temperature change.

c) The bias (U_0) has several components:

- ***"electronic"*** – the bias of operational amplifiers, dynamic detection error, interference of detection and oscillator circuits.
- ***"optical"*** - spatial and polarization filters are not perfect and residual optical waves form an erroneous signal.
- ***"magnetic"*** – the bias caused by magneto-optical phenomena.

d) The output noise appears as a little scatter of data and caused mainly by light natural fluctuations. Time-varying acceleration (such as vibration or shock) results in additional noise due to tiny mechanical distortion of the gyro frame.

Major Parts and Components

Detailed information about the FOG's major parts and components can be found in **Optical Assembly Info Notes**.

Analog Electronics Design

The open-loop sensor requires electronics to drive SLD current and PZT voltage for signal conditioning and for precise demodulation of the interferometric signal after its conversion from the optical power to the receiver voltage. For more information regarding the electronics refer to **Analog Processing Board OE141-55** and **Analog Processing Board OE141-35**.

[1] *The information presented in this document is believed to be correct. Fizoptika accepts no liability for any errors it might contain and reserves the right to alter the Info notes without prior notice.*

Production Technology

All the sensors are fabricated using specialized **in-line** technology. The basis of the technology is the fiber with a number of distinctive optical and mechanical characteristics. The fiber maintains its optical guiding ability under high elastic or even plastic deformations. This makes possible the fabrication of various fiber optic components directly on a fiber length by shaping it at high temperatures when quartz glass becomes soft. The **spliceless** fabrication of the ring interferometer components (couplers, a polarizer, an SLD module) on a single fiber length makes them naturally connected without optical losses. For fiber shaping, a fusion-tapering technology and equipment have been developed. During the couplers fabrication process the two fiber leads are held together by two moveable holders. A stabilized high-frequency arc discharge is applied to the fibers so that they melt together. Simultaneously, the fiber holders are moved apart in such a way that a fused tapered region is formed. To ensure a low-loss coupler (polarizer), it is essential that the holders move apart in a straight line with no sideways motion or vibration. The speed of separation and heating length control the taper shape which in turn has a significant influence on the resulting loss. It is necessary to use an optimal arc length and arc current not to disturb the taper. The quality of the single-mode fiber is extremely important. Its core and cladding must be highly circular and concentric with one another. Inferior quality fibers can result in high losses in the resulting coupler. It is also possible to monitor the coupler's power-splitting ratio during fabrication and to make a coupler with any required splitting ratio at a given wavelength.

The fabrication of the polarizer begins with a similar tapering process but with bigger elongation to achieve fiber waist diameter 5 microns. Next, the fiber waist is placed into the melted material from which tiny birefringent crystal is grown around the fiber.
To fabricate SLD-module the soldering process is used. The SLD chip and fiber lead are soldered to the separate copper blocks. After precise mutual alignment the blocks are soldered to each other. Both major technologies (fusion and soldering) produce temperature and mechanically stable components that bring the gyroscope reliable and stable performances in a wide range of environments. Optical components are mounted on the gyro main frame and covered with protecting silicone gel. The electronics is mounted on the gyro cover (for some models – on the frame).

Quality Control

When a fiber optic component is fabricated, its performance is automatically controlled and registered. The conformance of the manufactured gyroscope is verified at the functional test. The gyro's scale factor and consumption current are certified. An optional performance or screening test may be performed for specific applications.