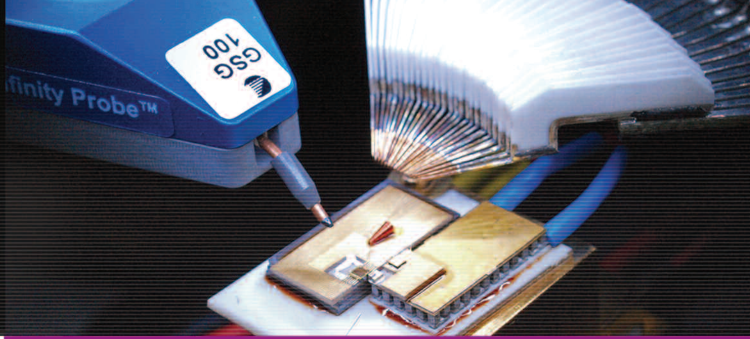


Photonic Integrated Circuits for Optical Gyroscope Systems

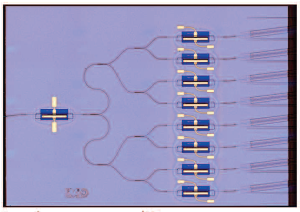
Optical gyroscopes

Modern airplanes, drones, guided missiles and spacecrafts require highly accurate and reliable inertial navigation systems. One of the essential components of such systems is the gyroscope, a device that measures the angular velocity of a flying object. Gyroscopes can be realized utilizing various techniques of rotation rate detection – mechanical, microelectromechanical or optical. Nowadays, the optical gyros are widely deployed due to their compact dimensions combined with an excellent performance in terms of excellent stability and low power consumption, which are essential parameters in aviation and space applications.

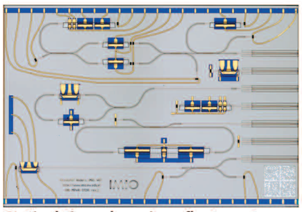
An optical sensor of the angular velocity can be developed using two basic configurations, both employing the Sagnac effect. The first one is the interferometric fiber-optic gyroscope (IFOG), in which the rotation rate is detected by measurement of the interference signal of two waves counter-propagating through an optical fiber loop.

On the other hand, ring laser gyroscopes (RLG) employ a laser operating in a ring resonator configuration. In such a laser, the oscillation frequencies for the clock-wise (CW) and counter-clockwise (CCW) directions are split under rotation. The difference between the two frequencies can be extracted from the recorded beating signal.

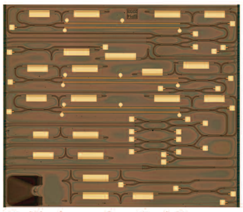
Contemporary devices are typically constructed from discrete optoelectronic and fiber-optic components – lasers, light modulators, fiber couplers and photodiodes. In spite of many attempts to miniaturization and realizing an integrated device, so far there is no such a product available on the market.



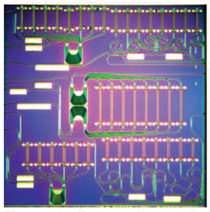
Lossless power splitter



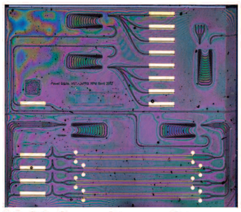
Optical time domain reflectometer



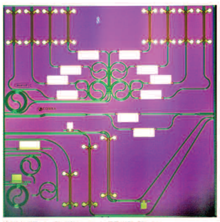
Multi-channel optical time domain reflectometer



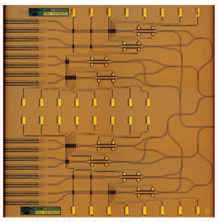
Photonic data readout units



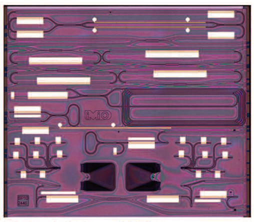
Multi-channel transmitter for FTTH networks



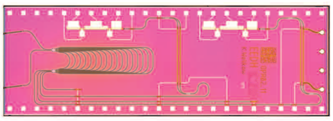
Optical time division multiplexer



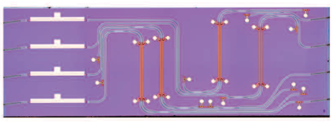
2 x 8 optical switch for fiber-optic access systems



Discretely tunable laser



Photonic transceiver for metrology applications



Photonic integrated transceiver for data readout units

Co-funded by the European Union

Photonic integrated circuits

Photonic integrated circuits (PICs) are considered as one of the most attractive and promising solutions for modern optoelectronics, with the potential impact similar to integrated electronic revolution While microelectronic devices consist of transistors, capacitors and resistors, a PIC comprises lasers, modulators, photodetectors and passive waveguides, all monolithically integrated on a single substrate.
The PICs are nowadays extensively developed for commercial use, with a specific focus on telecom, datacom and sensing applications.

PIC technology has now become accessible to users without cleanroom facilities, through so-called multi--project wafer runs and open foundries. Indium phosphide based technology is commercially available through SMART Photonics and Heinrich Hertz Institute. Access is coordinated by the JePPIX platform: http://www.jeppix.eu/.

It seems that exploring the potential of photonic integration technologies may enable further reduction of weight and energy consumption, while simultaneously maintaining high performance. In particular, the generic platform of indium phosphide enables fabrication of miniaturized and simultaneously highly complex optoelectronic systems, comprising both active and passive elements – light amplifiers, modulators, detectors, connected through a network of passive optical waveguides.

Since 2013 the Institute of Microelectronics and Optoelectronics (IMiO) of Warsaw University of Technology has been developing application specific photonic integrated circuits (ASPICs) for implementation in new generation of optical gyroscope systems. The monolithic optical chips have been realized in indium phosphide based generic integration technologies.

The first investigated approach is the interferometric fiber-optic gyroscope (IFOG) configuration, in which the rotation rate is measured by monitoring an interference signal using a dedicated ASPIC-based interrogator. **Figure 1** presents a microscope picture of the fabricated optical chip, which comprises a laser light source, 3 dB couplers, a phase modulator and PIN photodiodes.

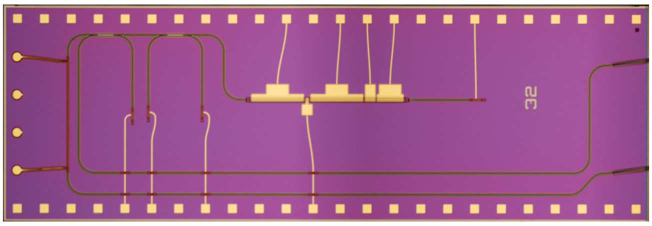


Figure 1. Microscope photograph of the ASPIC interrogator for the interferometric fiber-optic gyroscope system

First characterization results are promising with respect to implementation of ASPIC-based interrogators in optical gyroscope systems. **Figure 2** presents a characteristic of the interference signal occurring under rotation of an optical fiber coil, measured using the developed ASPIC.

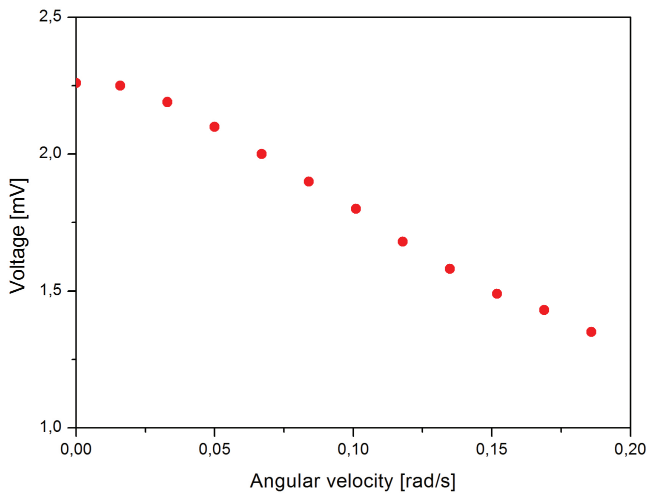


Figure 2. A characteristic of the interference signal in a rotating optical fiber coil, measured using an ASPIC-based interrogator

The second investigated approach is a fully integrated optical gyro, which can be realized by implementation of a single-frequency ring laser, together with a read-out circuit for beating signal detection. **Figure 3** presents a photograph of such an integrated device.

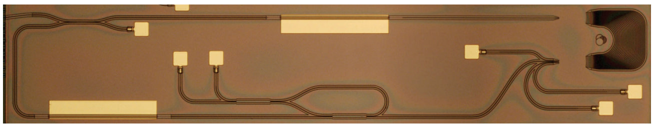


Figure 3. Microscope photograph of the fully integrated optical gyroscope based on a single-frequency ring laser

Measurement results obtained so far have proven single frequency operation of the developed ring laser (see **Figure 4**).

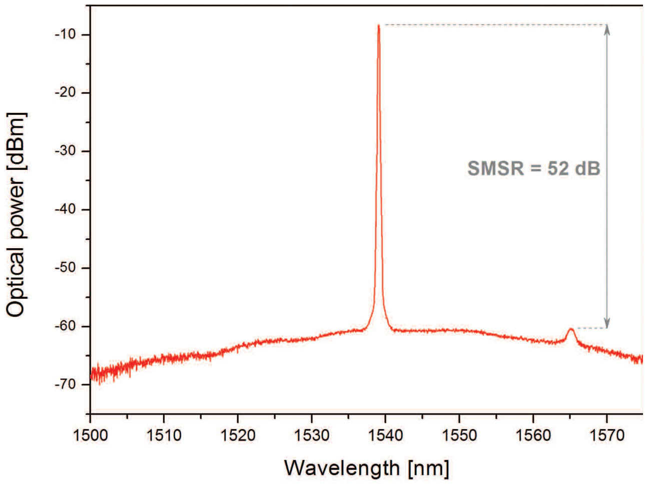


Figure 4. Recorded spectrum of the single frequency integrated ring laser

Expert support by PICs4All

If you are interested to know more about the use of PIC technology for implementation in optical gyroscope systems, as well as for use in any other application, please contact Eastern Europe Design Hub (EEDH) at Warsaw University of Technology, Poland. We are set up to help you in technical evaluation of applicability of photonic integrated circuits in your products.

For our partners we offer full design and characterization support, from the discussion of the very concept of the ASPIC, through technological consulting to the measurements in our photonics laboratories. In the framework of the EU H2020 PICs4All project EEDH offers free-of-charge guidance to companies, research institutes and academia interested in development and implementation of cutting-edge photonic devices in their commercial products.

The PICs4All consortium is funded under the EU Horizon 2020 programme and brings together expertise of nine European application support centers (ASCs) to support end-users in exploiting cutting-edge photonic integration technologies. The ASCs can guide you through the existing eco-system of designers, foundries, packaging and test services.

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