Gyroscopic effect in the bidirectional femtosecond erbium-doped fiber ring laser

Dmitry S. Chernykh, Alexander A. Krylov
Fiber Optics Research Center of RAS
Moscow, Russia
dmitry_s_chernykh@rambler.ru; sokolak@mail.ru

Abstract—We have demonstrated for the first time to the best of our knowledge the gyroscopic effect in the rotating erbium-doped bidirectional ultrashort pulse fiber ring laser. Detected angular velocities ranged from 0.1 to 90 deg/sec at the equivalent gyroscopic sensitivity of 7 KHz/(deg/sec).

Bidirectional generation; mode-locked laser; ultrashort pulses; gyroscopic

The idea of mode-locked lasers application for the significant improvement of laser gyroscopes has been discussed since their origination. One of the main problems of laser gyroscopes is a frequency locking of the counter-propagating radiation, leading to the so called “dead band” origination – the area of angular velocities which the gyroscope is not capable to measure.

It was shown [1] that a problem of a frequency locking can be solved with using ultrashort pulse (USP) ring lasers. In this case the counter-propagating radiation interacts only in two localized points of the ring providing the “dead band” narrowing.

In this paper we have demonstrated for the first time to the best of our knowledge the gyroscopic effect in the rotating erbium-doped bidirectional fiber ring laser generating stable picosecond and femtosecond pulses in both directions of the ring. The rotation sensitivity measurement also with 1.5-day duty cycle has been performed.

The gyroscopic setup is shown on Fig. 1a. Ultrashort pulses propagating along 4.6-m-long fiber ring in the clockwise (CW) and counterclockwise (CCW) directions coupled out through a 50% coupler, then passed via the controllable delay line and, finally, mixed in the other 50% coupler to give a beat-note signal. The laser was located at the 126-cm diameter rotating platform (the delay line was static) with possible angular velocities ranged from 0.021 to 360 deg/sec.

To suppress the interaction of CW and CCW pulses due to their polarization states ortogonallizing we have developed and studied the polarization-sensitive laser cavity. Unlike other schemes of bidirectional USP fiber ring lasers [2, 3] we have demonstrated experimentally the polarization separation of CW and CCW channels. For the first time the polarization sensitivity was introduced with the 70-cm-long passive polarizing fiber (PZF) [4] and two polarization controllers inserted into the cavity. Herewith, it was shown experimentally that the presence of the polarizer in the cavity allowed not only to manage pulse parameters but also to vary bias frequency of the beat-note signal in the range between 60 KHz and 2.3 MHz.

The laser cavity contains 2-m-long erbium doped fiber possessing anomalous group velocities dispersion (GVD) of +18 ps/(nm·km) at the 1560 nm generation wavelength which is pumped by the 975 nm single-mode laser diode. The passive self-starting mode-locking is initiated with a saturable absorber based on single wall carbon nanotubes (SWCNT).

Fig. 1b shows typical beat-note signals of CW and CCW channels in the case of a zero (left, bias frequency) and 15 deg/sec (right) platform angular velocity. It is definitely the experimental proving of the gyroscopic effect existence in the rotating bidirectional USP fiber ring laser.

The rotation sensitivity for both small and large angular velocities was measured to be linear which is shown on Fig. 2. The lowest angular velocity that could be detected with given gyroscope was close to 0.1 deg/sec. Such a modest result may be attributed to the bias frequency instability due to the platform vibration and thermal fluctuations. The highest detected angular velocity was determined by the bias frequency value and, therefore, might be varied. The resulting rotation sensitivity was estimated to be 7 KHz/(deg/sec).

Fig. 1. The gyroscopic setup (a); beat-note signal of CW and CCW channels: $\omega=0$ (left), $\omega=15$ deg/sec (right).

![Fig. 1](image)

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![Fig. 1b](image)

Fig. 2. Beat-note frequency shift evolution with respect to the angular velocity $\omega$.

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