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Miniature Light-Guided Gyroscopes for Navigation

Sarah Michaud

Gyroscope-based navigation systems are not new, but a group of U.S. researchers have discovered a detection scheme that may lead to the world's smallest light-powered gyroscopes—instruments that would be of great interest to aerospace engineers who want to keep the weight and cost of their technologies to a minimum. The proposed 10-micron-wide optical gyroscope design consists of an optical cavity with a pair of light waves travelling in opposite directions (Optica, doi: 10.1364/OPTICA.2.000323). Movement would be measured not with changes in light color, as is done with traditional optical gyroscopes, but with changes in far-field light emission patterns. The authors believe the chip-scale optical gyroscopes could usher in a new generation of small inertial guidance systems.

Optical gyroscopes are based on two designs: an optical fiber to guide light, or an optical cavity to confine light. To measure movement, both designs rely on the Sagnac effect which is based on interference between two counter-propagating beams of light that have phase-shifted with respect to one another owing to rotational motion. The optical-cavity approach is better suited for small-scale gyroscopes because the design isn't limited by fiber length or potential fiber damage. However, researchers still have to overcome the decrease in sensitivity that occurs with scaled-down optical microcavities—it gets harder to observe the Sagnac effect as the cavity gets smaller.

The research team, led by Yale University's Hui Cao, numerically and theoretically demonstrated a potential solution to this problem using a principle based on far-field emission: Instead of detecting the Sagnac effect interference patterns directly, they suggest detecting motion using rotation-induced changes in the far-field emission patterns that are produced when light exits the cavity.

The proposed optical gyroscope design involves pumping light into a microcavity, creating waves that travel clockwise (CW) and counter-clockwise (CCW). The cavity design allows for some light to escape, which produces far-field emission patterns. When the gyroscope moves, the balance between the CW and CCW waves is broken, resulting in a different far-field emission pattern. The patterns are captured by detectors positioned at different angles that move with the cavity. The authors showed that light wave asymmetry increases linearly with gains in rotation speed, which suggests that tracking changes in emission patterns is a potentially reliable method of measuring motion.

The team acknowledges that their proposed designs would detect motion in only one plane, but they hope that with further research they can increase the number of sensors and place them at different locations to give a more complete, 3-D picture of on-chip optical gyroscope movement.

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