Non-Reciprocal Spinning Photonics

RESEARCHERS

Shai Maayani (maayani@mit.edu), Massachusetts Institute of Technology, Cambridge, Mass., USA

Raphael Dahan, **Yuri Kligerman** and **Tal Carmon**, Technion–Israel Institute of Technology, Haifa, Israel

Absar U. Hassan and **Demetrios N. Christodoulides**, CREOL, the College of Optics & Photonics, University of Central Florida, Orlando, Fla., USA

Hui Jing, Hunan Normal University, Changsha, China

Franco Nori, RIKEN, Saitama, Japan

Eduard Moses, J-Rom Ltd., Haifa, Israel

REFERENCES

1. S. Maayani et al. Nature **558**, 569 (2018).
2. R. Fleury et al. Science **343**, 516 (2014).
3. I. Shomroni et al. Science **345**, 903 (2014).

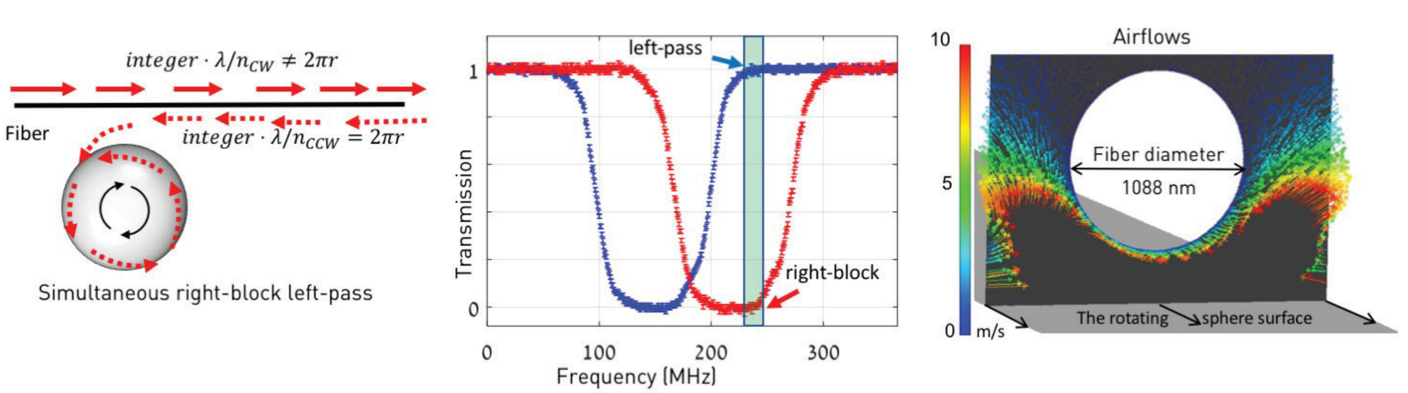
The index of refraction plays a pivotal role in governing light-matter interactions. This year, we showed that, by spinning a spherical resonator, one can differentiate the speeds of two counter-propagating light beams, which in turn enables a nearby fiber to isolate light with 99.6 percent efficiency.[1] In such a spinning-cavity system, light can be dragged, leading to a speed-up or slow-down depending on whether light travels "upstream" or "downstream." Such irreversible refraction, in conjunction with the rapidly moving elements, can bring new degrees of freedom to micro-photonics.

While sound isolation has been previously observed in moving media,[2] demonstrating similar phenomena in photonics remains challenging. This is because light travels considerably faster than sound, implying that a dielectric system would need to move at very high speeds to isolate light. At the same time, the shorter wavelength of light requires nano-positioning—even when the photonic components are moving with respect to each other at speeds faster than 350 km/hr.

For aligning and positioning the optical coupler next to the rotating resonator, we employed aerodynamic principles used in computer hard disks for self-adjusted nano-positioning of heads, applying them to optics for self-alignment of the optical coupling. In our device, a tapered fiber was nano-positioned 40 nm above the spherical resonator by hovering on the airflows generated by the resonator itself, spinning at 400,000 RPM. The speed and alignment accuracy were adjusted so as to fully split the sphere's counter-circulating resonances. As a result, a standard fiber became optically opaque from one end and simultaneously transparent from the other.

We experimentally demonstrated that our device can efficiently isolate 996 out of 1,000 photons reaching the device. This degree of isolation is required in fiber-based quantum communication systems, for which loss of data should be minimal and fiber compatibility is helpful.[3]

In addition to demonstrating isolation, we believe that our results on self-adjusted nano-positioning—as transferred from hard drives to low-loss fibers and high-Q silica resonators—might soon narrow the allowable gap between optical components to a regime in which intermolecular forces dominate and even gravity might behave differently. For example, a repulsive van der Waals force is predicted to counteract an ultra-strong Casimir attraction when approaching gaps of 300 femtometers (millionths of a nanometer). This regime, which might be referred to as "femto-technology," has heretofore rarely been experimentally accessible. OPN



Left and center: A spinning resonator, placed next to a tapered fiber makes the fiber transparent from the right-hand side while simultaneously opaque from the left. Right: The spinning resonator generates air flows (arrows) that levitate the tapered fiber at self-aligned elevation above the resonator.