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Two-Photon Machining of Sensors on Fiber Tips

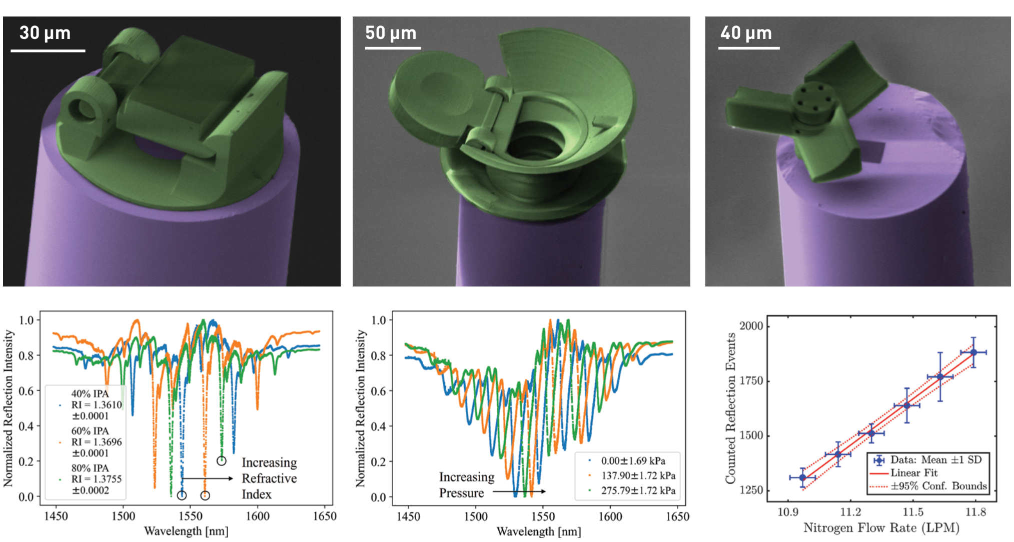
Two-photon lithography (TPL) has helped drive forward the advancement and miniaturization of 3D functional microsystems. Optical fibers integrated with advanced optomechanical components represent a promising approach to scale down a variety of novel sensors essential in modern engineering systems. While TPL has been used to fabricate a mechanically suspended Fabry–Pérot cavity (FPC) sensor with curved surfaces on a fiber tip, the inner optical surfaces that form the cavity are shadowed by the top structure, which prevents reflective-coating deposition. Thus the fabricated FPC yields a low quality factor.[1]

To solve this issue, we recently used TPL to monolithically integrate dynamic micromechanical features into an FPC sensor on a fiber tip (see accompanying figure).[2] These features, we believe, signify a breakthrough in the integration and fabrication capabilities of micro-optomechanical devices and systems.

Our method leverages rotation of a movable mirror to deposit a thin reflective coating onto the inner surfaces of an FPC with curved geometry. The dynamic optical surface enables directional thin-film deposition onto obscured areas. The reflective coating, coupled with the rotatable mirror, greatly improves the FPC quality factor and enables a new class of highly integrated, multipurpose sensor systems. We used the fiber tip sensor to demonstrate liquid refractive-index sensing with a sensitivity of 2045 nm per refractive-index unit.[2]

In other work published this year, we further exploited TPL to create a unique spring-body FPC that is also equipped with a hinged, multipositional mirror to facilitate reflective-coating deposition onto the inner surfaces of the cavity.[3] After the thin reflective coating is sputtered onto the cavity's inner surfaces, the rotatable mirror is locked into its final position. The spring-body FPC demonstrated pressure sensing with a sensitivity of 38 pm/kPa over a range of −80 to 345 kPa.[3]

Finally, we used TPL to produce a flow sensor consisting of microblades that spin in response to an incident flow.[3] Light exiting the optical-fiber core is reflected back into it at a flow-dependent rate as the blades pass by. The fiber-tip flow sensor operated successfully over a range of 9–25 liters per minute (LPM) using nitrogen gas, achieving a linear response of 706 reflections/LPM over a range of 10.9–12 LPM.[3] OPN



Top: False-color scanning electron microscope (SEM) images of fabricated FPC sensor, with multipositional hinged mirror in the closed position (left), spring-body FPC pressure sensor in the half-open position (center) and flow sensor (right). Bottom left: Three reflection spectra from the top-left FPC sensor in different solutions. Bottom center: Three reflection spectra from top-center spring-body pressure sensor at different pressures. Bottom right: Reflection response of the top-right fiber tip flow sensor.

Adapted from references 2 and 3