New method enables superior light confinement in low-refraction-index microcavity

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The trapping of photons in low-refraction-index materials is thought to be difficult in conventional photonic structures that employ total internal reflection. Specifically, the whispering gallery mode (WGM) microcavity, which is an important optical component, has to rely on a refraction index with high contrast to the surrounding environment to manifest excellent light confinement. A team led by Professor Yun-Feng Xiao at Peking University collaborated with researchers from the Harbin Institute of Technology, and demonstrated that an optical microcavity structure consisting of a low-refraction-index silica microtoroid that was directly bonded on a high-refraction-index silicon substrate supports high-Q fundamental WGMs. This work has been published in a recent issue of *Optica*.

Among on-chip resonators, high-refraction-index microcavities usually have quality factors no more than a million, which becomes an obstacle to applications in the fields of on-chip nonlinearity and quantum manipulation, etc. In contrast, low-refraction-index materials have advantages in many aspects, especially in the fabrication of high-Q devices. In the publication, the authors demonstrated experimentally excellent light confinement in low-refraction-index material.

The photonic microstructure consists of a donut-shaped silica microcavity with a circular cross section bonded on a silicon substrate. The refraction indices of silicon and silica are 3.48, 1.44, respectively.

"The circular cross section of the microresonator remarkably reduces the electric field distribution area in the vertical direction compared with traditional rectangular cross-section, resulting in a better light confinement in the silica," said Li Wang, one of the first co-authors of this work.

In the transmission spectra, high-Q fundamental modes are observed while most higher-order modes are suppressed due to much stronger energy leakage into the substrate, which produces a very clean mode spectrum. The resonant structure supports high-Q fundamental WGMs in both visible and communication bands. In the communication wavelength band, the quality factors increase exponentially as the minor diameter of the microcavity increases. With a larger minor diameter, the highest quality factor can be even up to 10 million. In the visible wavelength band, the quality factors always maintain large values more than 10 million.

"Low-threshold microcavity Raman lasing was demonstrated to show the potential of the resonant structure in the low-power-consumption integrated photonics," said Prof. Xiao. "This mechanism of light confinement in the photonic microstructure applies to various low-refraction-index materials besides silica, such as polymer. Furthermore, the unique microstructure may open up new possibilities for on-chip applications in fields including nonlinearity and quantum manipulation."

More information: Li Wang et al. Light confinement in a low-refraction-index microcavity bonded on a silicon substrate, *Optica* (2016). DOI: 10.1364/OPTICA.3.000937

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