# Ringing in a new way to measure and modulate trapped light

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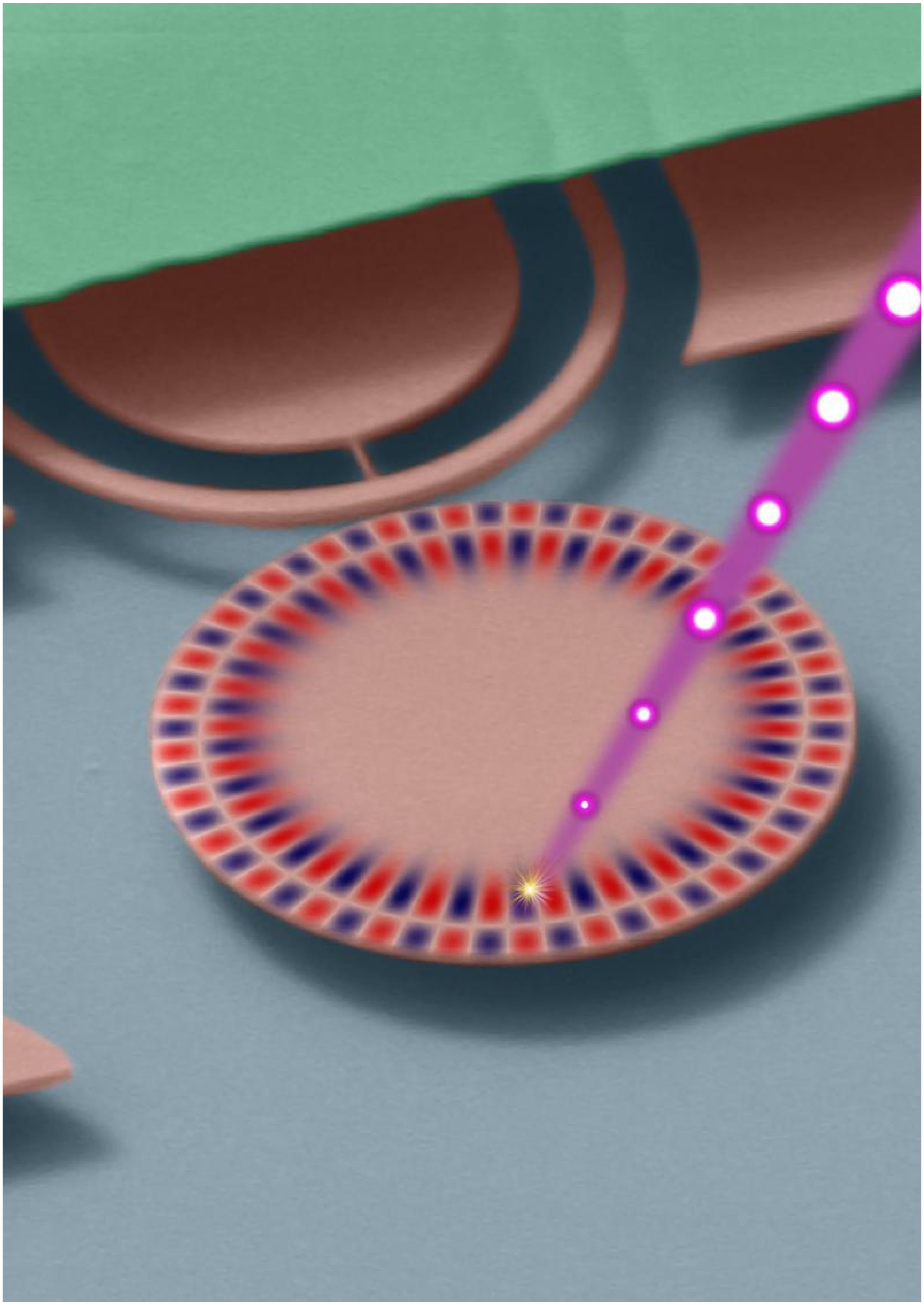

The focused ion-beam tool developed at the NIST Center for Nanoscale Science and Technology can inject ions into the resonator, creating tiny bulges that affect the structure's resonant properties—akin to how a bell maker can change the sound a bell makes by adding material and changing its shape. Credit: NIST

Researchers working at the National Institute of Standards and Technology (NIST) have developed a novel way to noninvasively measure and map how and where trapped light vibrates within microscale optical resonators.

The new technique not only makes for more accurate measurements but also allows scientists to fine-tune the trapped light's frequency by subtly altering the shape of the resonator itself.

Visualizing the vibration patterns will help scientists to perfect ultrasensitive optical sensors for detecting biomolecules and even single atoms. The fine-tuning capability will also open the door to creating optical resonators with identical resonances, a feat now impossible to achieve during manufacturing, but necessary for applications such as quantum information processing with single photons.

Microscale optical resonators are like tiny bells that ring not with sound, but with light. Just like a bell's tone, the frequency with which an optical resonator "rings" is determined by its size and shape, so that it amplifies and sustains some frequencies of light and diminishes others.

The devices are so tiny that the light actually extends outside their outer surfaces where they form "near-fields." Where these vibrating near-fields are strongest, the resonator is hypersensitive to changes in the environment. Any perturbation of a near field, say by a stray molecule or atom, will affect the light inside the resonator in a detectable way, much in the same way that touching a ringing bell will change its tone or volume or silence the bell altogether.

Mapping these vibration patterns of light in real devices will help scientists to make them even more sensitive.

At present, the vibrational profiles of these resonators are measured using sharp, needle-like probes. The problem with using a probe is that it strongly disturbs the near-fields before it is able to get close enough to the surface to do high-resolution imaging. High-resolution imaging of the microresonator requires a probe that is able to reach the surface without disturbing the near fields.

Fortunately, the new focused lithium-ion-beam technique—developed at the NIST Center for Nanoscale Science and Technology (CNST)—can do just that.

"We map out the oscillation pattern by focusing the ion beam on different locations on the resonator's surface and noting the change in the vibration," says CNST physicist Vladimir Aksyuk. "If the vibration at that spot is strong, the vibration is strongly affected. If the vibration there is weak, then the perturbation has no effect."

The focused ion beam injects ions into the resonator, which is made of silicon. This "tapping" creates tiny bulges and affects the structure's resonant properties, influencing the pattern of the light trapped within, sort of how a bell maker can change the sound of a bell by adding material and changing its shape. The sharply focused ion beam essentially gives researchers the ability to edit the tone of a resonator and makes it possible to tune two resonators to have the same vibrational qualities. Aksyuk believes that the lithium ions the group used are particularly well suited for this kind of work because of their low mass.

In the meantime, however, he is as wowed by the result as everyone else.

"I just think that it's really cool that we can use a beam of lithium ions to measure and even change the resonant properties of these tiny structures in a very fine-grained way," says Aksyuk. "Given that it is presently impossible to manufacture identical resonators or measure them with great precision, I'm hoping that this technique will be of great use to the micro- and nanophotonics community."

Jie Zou, a former NIST guest researcher who co-authored the paper describing this research, is interested in what resonators could teach them about lithium ion beams.

"In this paper, we used the lithium focus ion beam to map the subtle light fields in the microresonators," Zou says. "But we can also use the microresonators to investigate how the lithium ions interact with the resonator's silicon lattice with unprecedented sensitivity—work that may offer important insights for the lithium-ion battery and semiconductor industries."

**More information:** Kevin A. Twedt et al. Imaging nanophotonic modes of microresonators using a focused ion beam, *Nature Photonics* (2015). DOI: 10.1038/nphoton.2015.248

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