

NEWS & VIEWS

Open Access

High Q-factor reconfigurable microresonators induced in side-coupled optical fibres

Radan Slavík ¹✉

Abstract

Recently, significant efforts have been devoted to enable light resonating inside various resonators for long time, leading to high Q factors. Achieving tunability of the free spectral range while maintaining high Q has been, however, challenging.

Interferometers are in the core of the most sensitive experiments carried out in science, ranging from famous Michelson–Morley interferometer that proved inexistence of aether to the recent proof of existence of gravitational waves. As interferometer’s resolution generally scales with the accumulated light phase (commonly characterized by the Q-factor, which is usually roughly proportional to the accumulated light delay), multi-path interferometers based on resonators such as Fabry–Perot or ring resonator are very popular, providing large delays in a small form factor. Resonators are also often behind a key tool that emerged from optical resonators: Optical Frequency Combs (OFCs).

When it comes to the question of how an ideal resonator would look like, one of the key items on the “wish list” is its tunability, in particular its spectral period, a.k.a. free spectral range (FSR) or comb spacing in OFCs. Tunability would allow to tailor the resonator for various fields or enable its continuous change, of interest in a range of applications such as optomechanics^{1,2} or lasing^{3,4}. However, FSR tunability requires the resonator’s length to be altered, e.g., when targeting one order of magnitude tunability, the length should be changeable by an order of magnitude. This is a requirement that most resonators, especially those with very high Q, struggle with.

In the newly published paper in *Light: Science & Applications*, Victor Vassiliev with Misha Sumetsky from the Aston Institute of Photonic Technologies, Aston University, Birmingham, UK, have proposed how to make FSR tuneable in a particular configuration of high-Q coupled microresonators⁵. To enable this, they chose very flexible platform in which two 3D microresonators are formed in two optical fibres, each exciting so-called Surface Nanoscale Axial Photonics (SNAP) microresonator⁶, Fig. 1. These are a special type of bottle resonators, where the bottle is formed by sub-micron fibre radius changes along the length due to the fabrication imperfections. The authors use two degrees of freedom to achieve wide continuous tuneability in FSR (over an order of magnitude) while keeping high Q factor (in excess of 1 million), which is very challenging to achieve for any high-Q resonators. These two degrees of freedom are the bend radius, which modifies the SNAP resonator shape and relative distance between the two fibres.

As with any proof-of-concept demonstration, it will be interesting to see which direction(s) this coupled special type of bottle resonator configuration will take. The authors make some suggestions in this regard, perhaps most exciting is replacing pure silica fibres with a material with high non-linearity or to use fibre twist as the third degree of freedom to achieve even more complex coupled-resonance systems, enabling to realize complex “photonics molecules”⁷. The authors also suggest to introduce a gap between the exciting fibre and the microresonators to boost the already-high Q by another

Correspondence: Radan Slavík (r.slavik@soton.ac.uk)

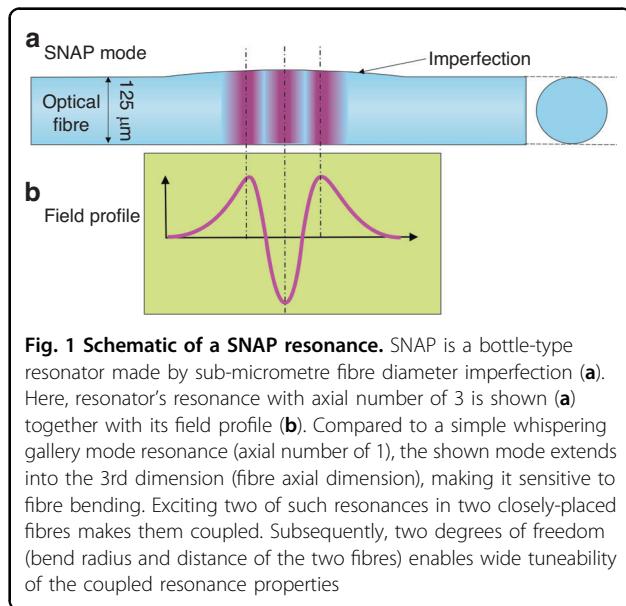
¹Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, UK

© The Author(s) 2023



Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.





two orders of magnitude. Such ultra-high Q in excess of 100 million are not necessary for a range of applications such as delay lines⁸, signal processors⁹, and microlasers^{3,4}, but may open door to new applications such as tuneable repetition rate OFCs, cavity quantum electrodynamic (QED)^{10,11}, and optomechanical applications^{1,2}. In the future, it will be also interesting to see whether and how this research could be adopted to platforms that are more

akin to integration and mass production such as photonics integrated circuits.

Conflict of interest

The author declares no competing interests.

Published online: 23 November 2023

References

- Bahl, G. et al. Stimulated optomechanical excitation of surface acoustic waves in a microdevice. *Nat. Commun.* **2**, 403 (2011).
- Lambert, N. J. et al. Coherent conversion between microwave and optical photons - an overview of physical implementations. *Adv. Quantum Technol.* **3**, 1900077 (2020).
- Zhu, S. et al. All-optical tunable microlaser based on an ultrahigh-Q erbium-doped hybrid microbottle cavity. *ACS Photonics* **5**, 3794–3800 (2018).
- Zhu, S. et al. Tunable Brillouin and Raman microlasers using hybrid microbottle resonators. *Nanophotonics* **8**, 931–940 (2019).
- Vassiliev, V. & Sumetsky, M. High Q-factor reconfigurable microresonators induced in side-coupled optical fibres. *Light Sci. Appl.* **12**, 197 (2023).
- Sumetsky, M. Theory of SNAP devices: basic equations and comparison with the experiment. *Opt. Express* **20**, 22537–22554 (2012).
- Boriskina, S.V. Photonic molecules and spectral engineering. in *Photonic Microresonator Research and Applications* (eds. Chremmos, I., Schwelb, O. & Uzunoglu, N.) 393–421 (Springer, 2010).
- Sumetsky, M. Delay of light in an optical bottle resonator with nanoscale radius variation: dispersionless, broadband, and low loss. *Phys. Rev. Lett.* **111**, 163901 (2013).
- Sumetsky, M. Optical bottle microresonators. *Prog. Quantum Electron.* **64**, 1–30 (2019).
- Buck, J. R. & Kimble, H. J. Optimal sizes of dielectric microspheres for cavity QED with strong coupling. *Phys. Rev. A* **67**, 033806 (2003).
- Pfeifer, H. et al. Achievements and perspectives of optical fiber Fabry-Perot cavities. *Appl. Phys. B* **128**, 29 (2022).