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Soliton combs in chip-integrated standing-wave photonic crystal cavities

Microcombs are usually generated in travelling-wave ring or whispering-gallery-mode resonators [1]. In one mode of operation, femtosecond temporal dissipative Kerr solitons (DKS) [2] are generated with vast opportunities for novel studies, applications, and markets [3]. A main challenge in the design of microresonators arises from the simultaneous needs for a high-quality (Q) factor as well as a suitable group delay dispersion (GDD) in support of ultra-short pulses. Only very few design parameters (such as waveguide cross-section) are available to address this challenge and, in consequence, the spectral operation window of microcombs, and more broadly speaking, the control of nonlinear optical processes is restricted. Inspired by the transformational success of dielectric Bragg-mirrors in addressing similar challenges in mode-locked lasers, microcombs have been explored in unconventional standing-wave cavities with Bragg-type reflectors: A fiber-based cavity, achieved formation of DKS, however, only under pulsed driving condition due to low effective nonlinearity [4]. Further, a chip-integrated cavity with chirped mirrors achieved cascaded four-wave mixing [5].

Here, we show for the first time DKS formation in a chip-integrated standing-wave microresonator. The solitons form under continuous-wave driving and both single and multiple soliton states can be generated (implying counter-propagating solitons). The chip-integrated resonator with a free-spectral range of 20 GHz is formed by a silicon nitride waveguide with two photonic crystal reflectors (here: highly reflective from 1560 to 1590 nm) and supports a directly detectable repetition rate signal. The cavity's loaded Q-factor exceeds 1 million and is only limited by the waveguide propagation loss, on par with ring resonators implemented in the same platform. In contrast to the usual ring-type resonators, the new resonator offers a dramatic increase of design space and may in the future contribute to extending microcomb technology into new wavelength domains relevant for sensing, quantum photonics and astronomical spectrograph calibration.

References

[1] P. Del'Haye, A. Schliesser, O. Arcizet, T. Wilken, R. Holzwarth, T.J. Kippenberg, Nature, 450 (2007)
[2] T. Herr, V. Brasch, J.D. Jost, C.Y. Wang, N.M. Kondratiev, M.L. Gorodetsky, T.J. Kippenberg, Nature Photonics, 8 (2014)
[3] T. J. Kippenberg, A.L. Gaeta, M. Lipson, Science, 6402 (2018)
[4] E. Obrzud, S. Lecomte, T. Herr, Nature Photonics, 11 (2017)
[5] S.P. Yu, H. Jung, T.C. Briles, K. Srinivasan, S.B. Papp, ACS Photonics 6 (2019)