# Mid-infrared semiconductor laser frequency combs: From FM-combs to Nozaki-Bekki solitons

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Optical frequency combs (OFCs) stand as the cornerstone of modern optics, with applications ranging from fundamental science to sensing and spectroscopy. Generation of short optical soliton pulses in passive media such as optical fibers and microresonators has been an established technique for stable OFC formation with a broad optical spectrum – however these platforms are driven by an external optical signal and often rely on additional bulky elements that increase the complexity of the system.

Here, we aim to overcome these difficulties by direct OFC generation in mid-infrared semiconductor lasers, such as quantum and interband cascade lasers. After a general introduction to such combs and their nonlinear dynamics, the soliton concept from microresonator Kerr combs will be generalized to active media that are electrically-driven and a new type of solitons in free-running semiconductor laser integrated on a chip will be demonstrated.

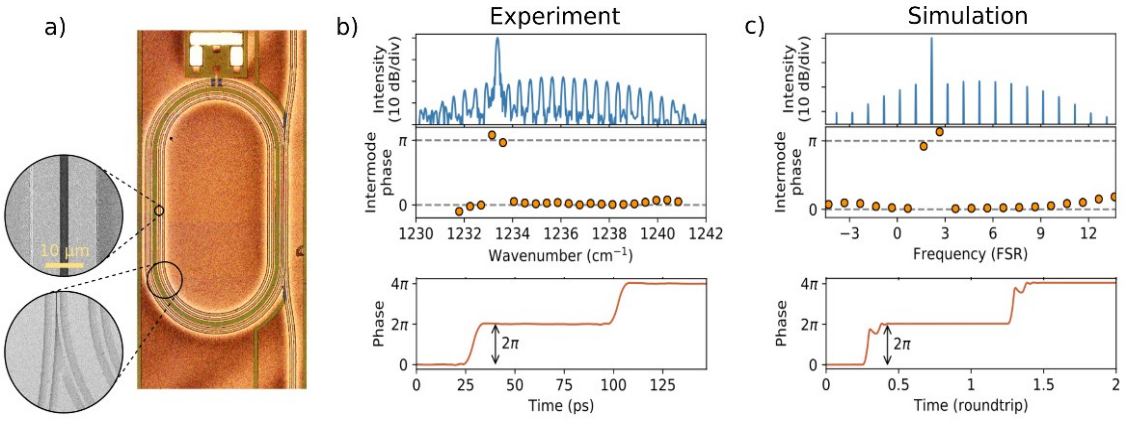


**Figure 1** a) Ring laser device with the active coupler waveguide. b) Experimental and simulated c) free-running soliton. The soliton spectrum is displayed in the top, showing a strong mode surrounded by a smooth spectral envelope comprised of weaker sidemodes. The corresponding intermodal phases, given below, indicate a π jump between the sidemodes and the strong mode. The temporal phase profile is plotted in the bottom.

[1] D. Kazakov, et al., arXiv:2206.03379 (2022).
[2] N. Opačak, et al., Phys. Rev. Lett. 127, 093902 (2021).
[3] M. Piccardo et al., Nature 582, 360 (2020).

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