Dissipative Kerr solitons in a warm atomic vapor system

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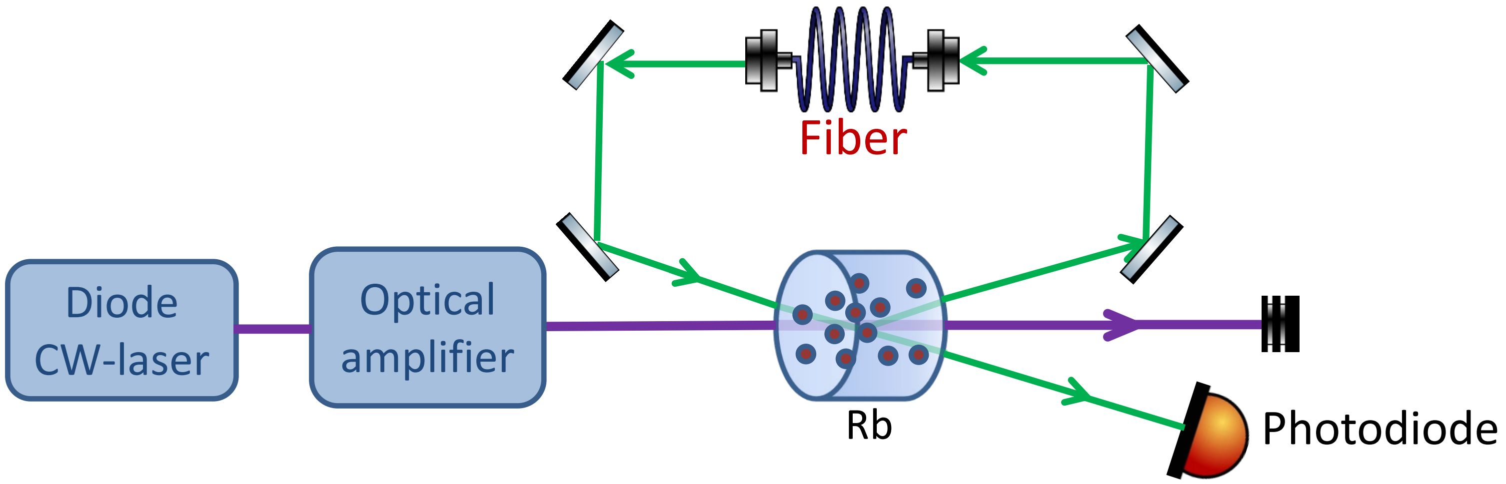
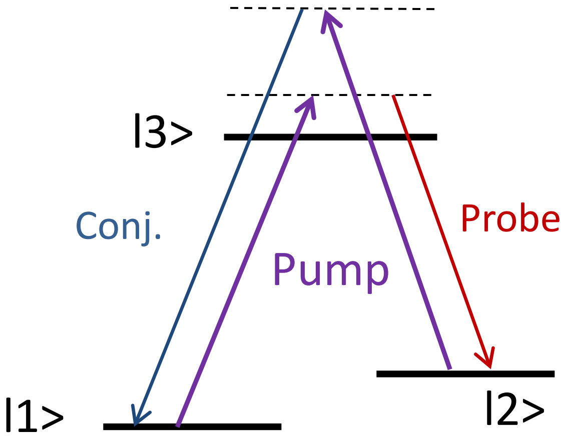
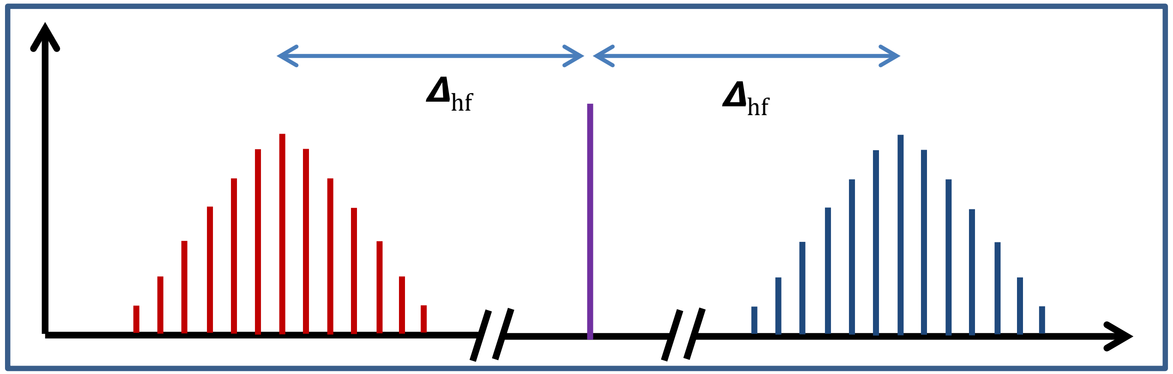
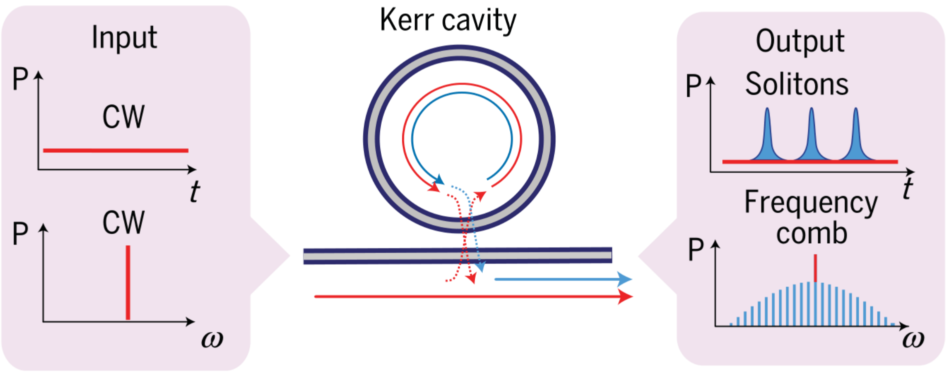




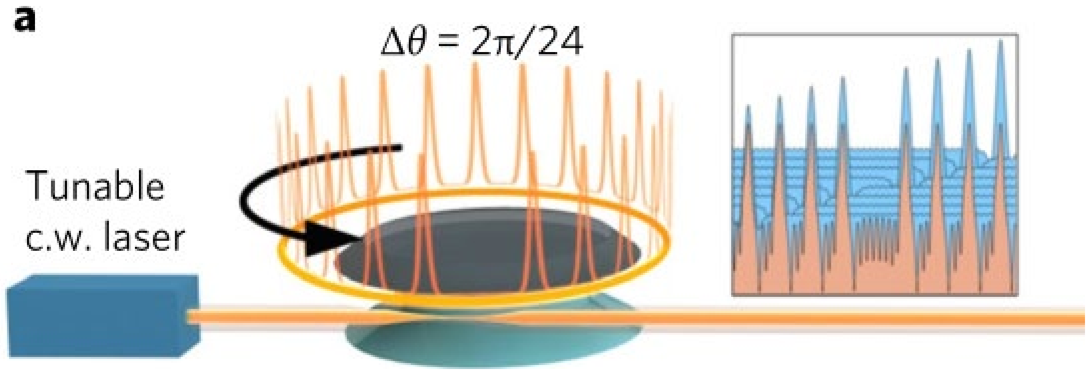


Dissipative Kerr solitons: gain in an open system

Solitons are robust waveforms that preserve their shape.



T. Herr et al., Temporal solitons in optical microresonators. Nat. Photonics 8, 145–152 (2014).



Depiction of the generation and measurement of a soliton crystal.

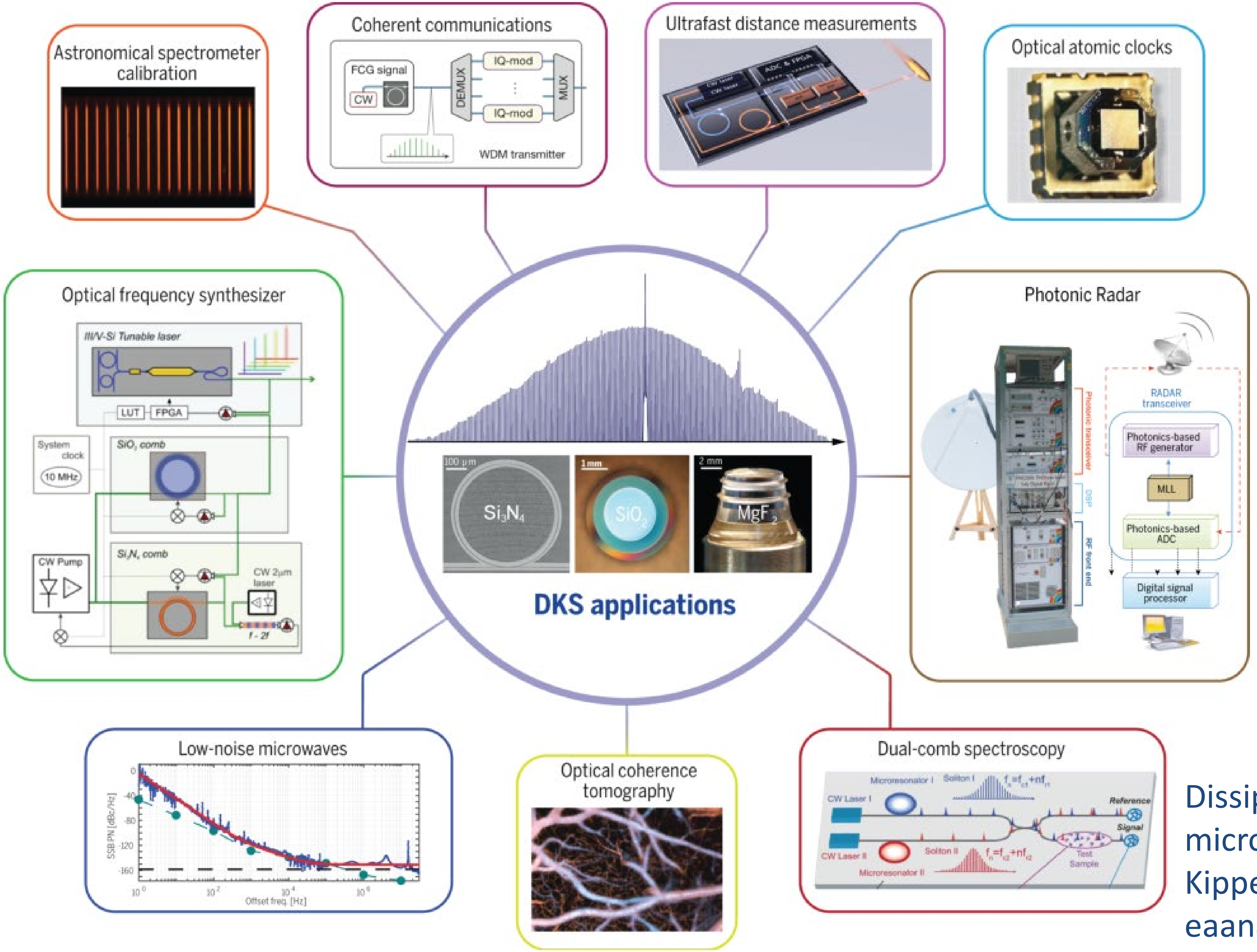
Dissipative Kerr solitons happen in an open system with parametric gain.

Dissipative Kerr solitons in optical microresonators, Tobias J. Kippenberg, et al. Science, 361, eaan8083 (2018).

Soliton crystallization, Raman-Stokes solitons, and previously unseen soliton breather dynamics.

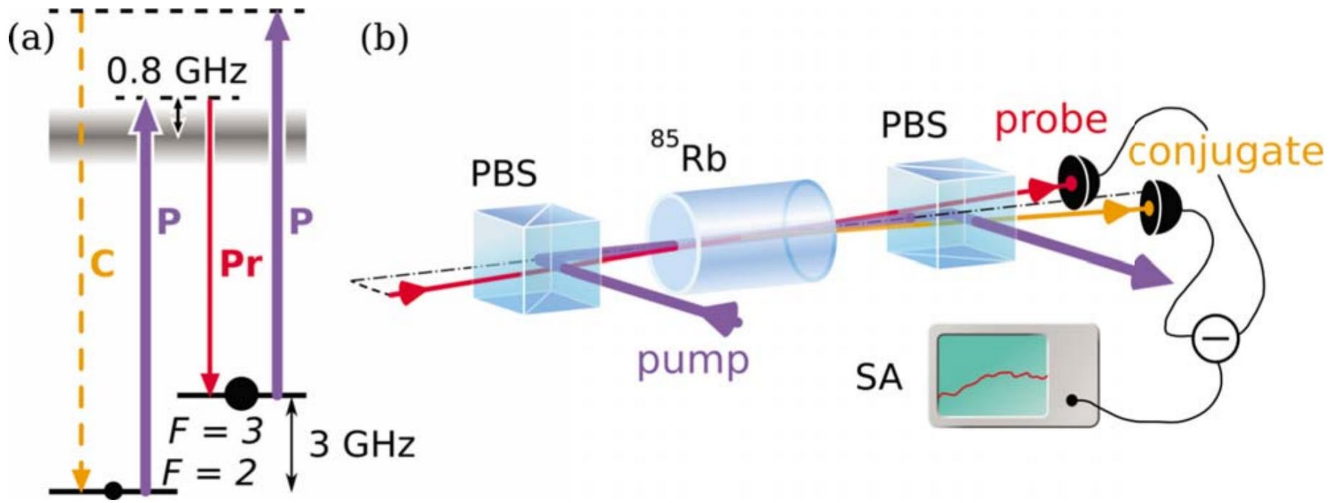
D. C. Cole, et al., Soliton crystals in Kerr resonators. Nat. Photonics 11, 671–676 (2017).

Wide range of Applications

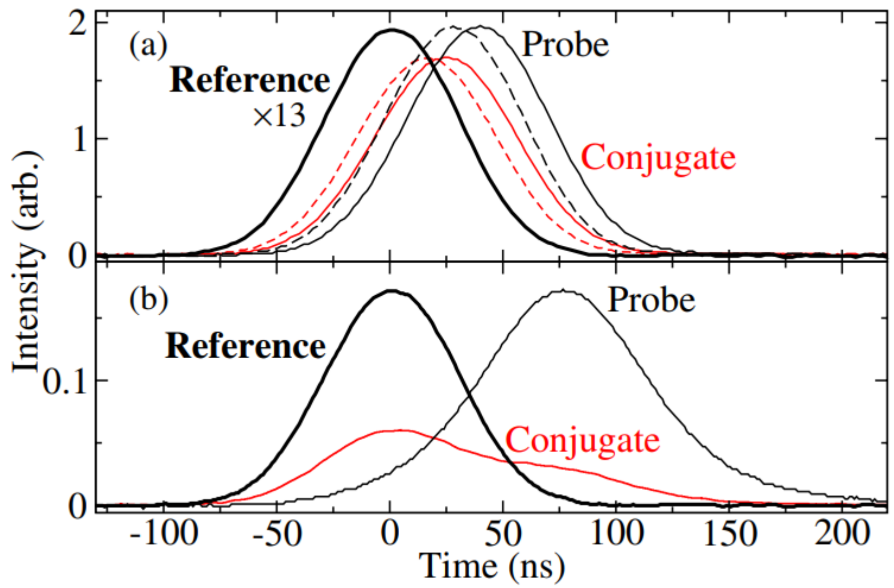


Dissipative Kerr solitons in optical microresonators, Tobias J. Kippenberg, et al. Science, 361, eaan8083 (2018).

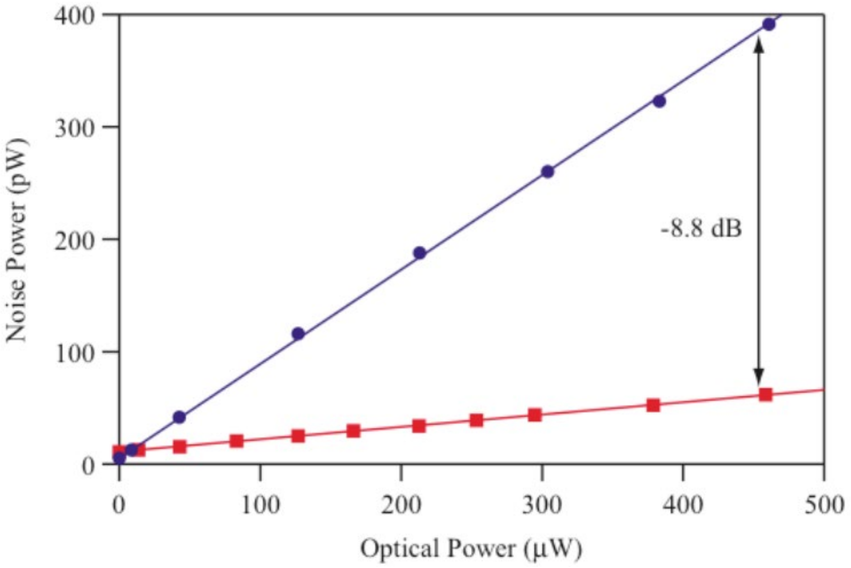
Four-wave mixing in warm rubidium



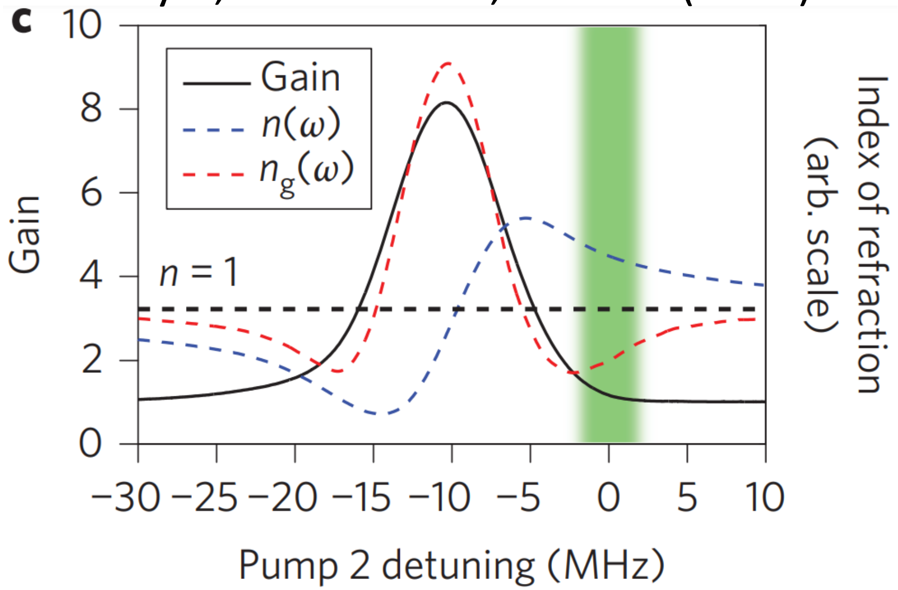
C. McCormick, et al., Phys Rev A 78, 043816 (2008).



V. Boyer, et al. PRL 99, 143601 (2007).

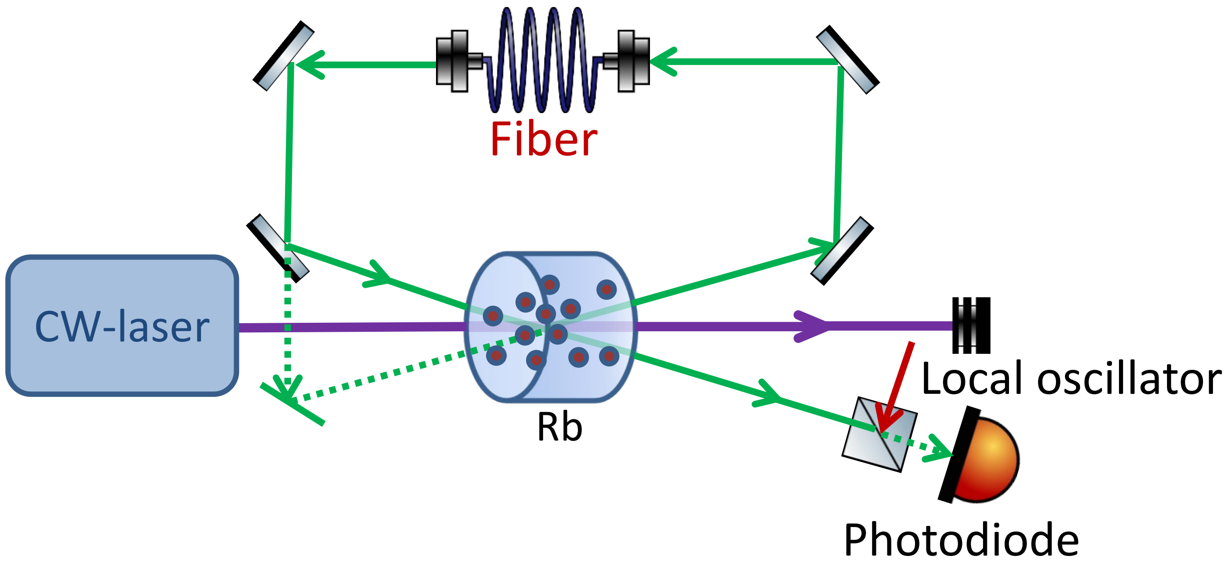


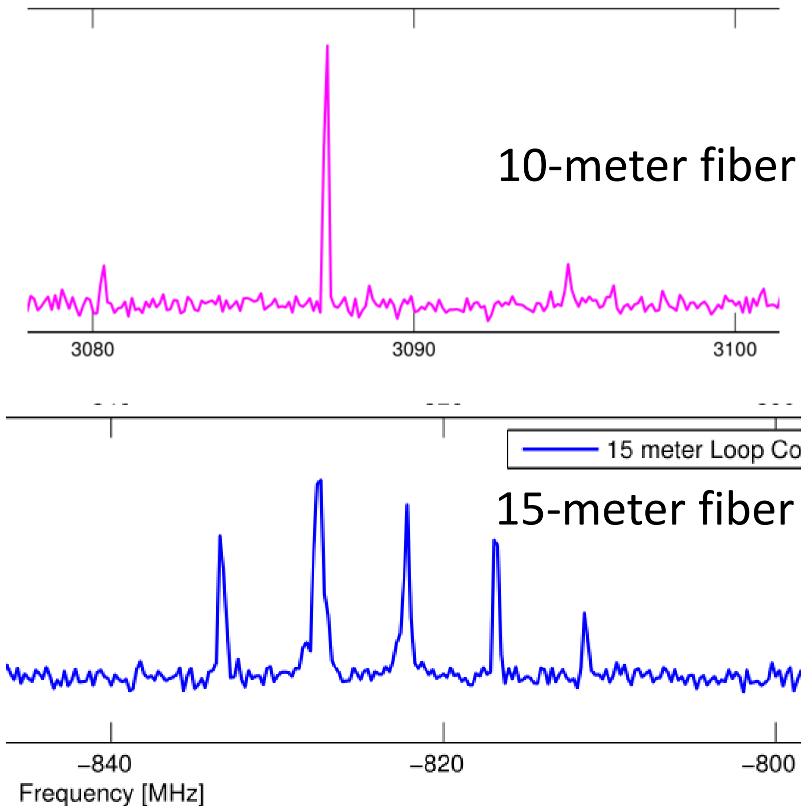
Good resources of strong and tunable nonlinearity, dispersion, and large parametric gain.

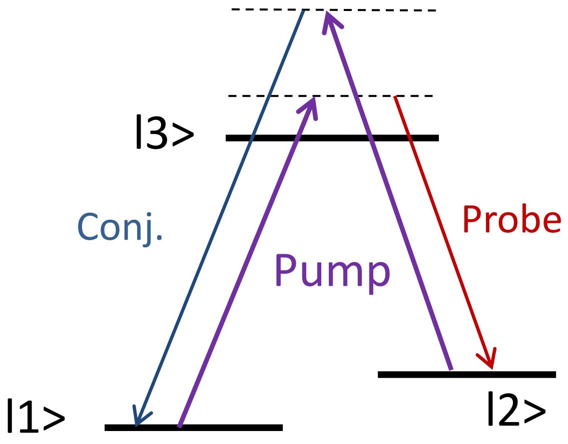


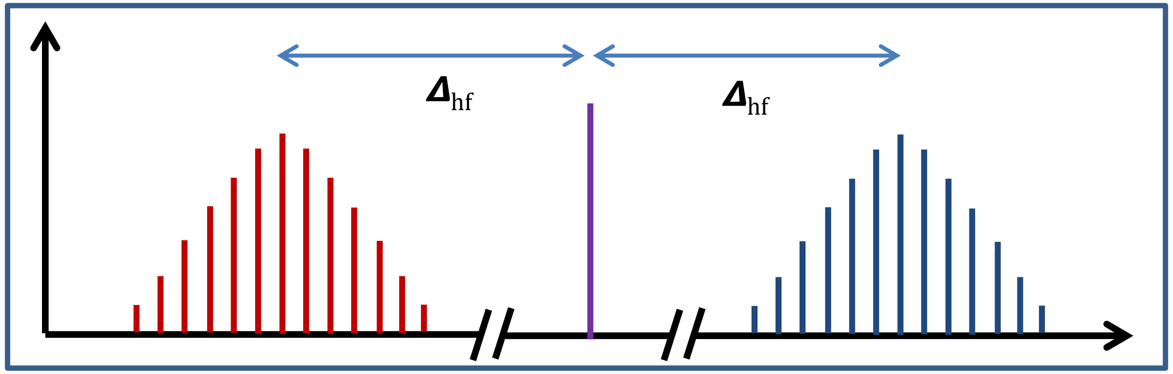
J. Clark, et al., Nature Photonics 8, 515 (2014).

Phase-conjugate resonator and frequency comb



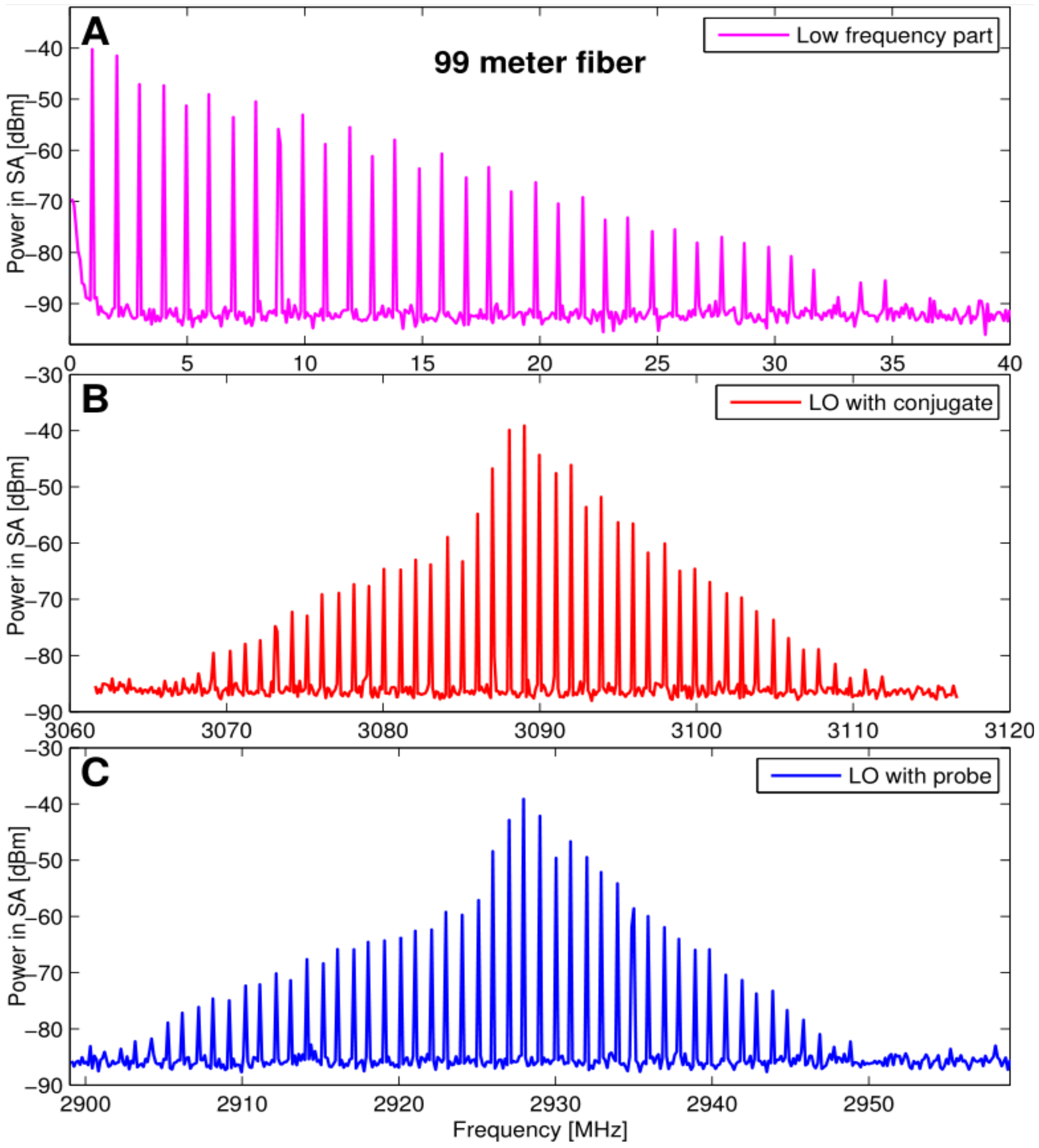




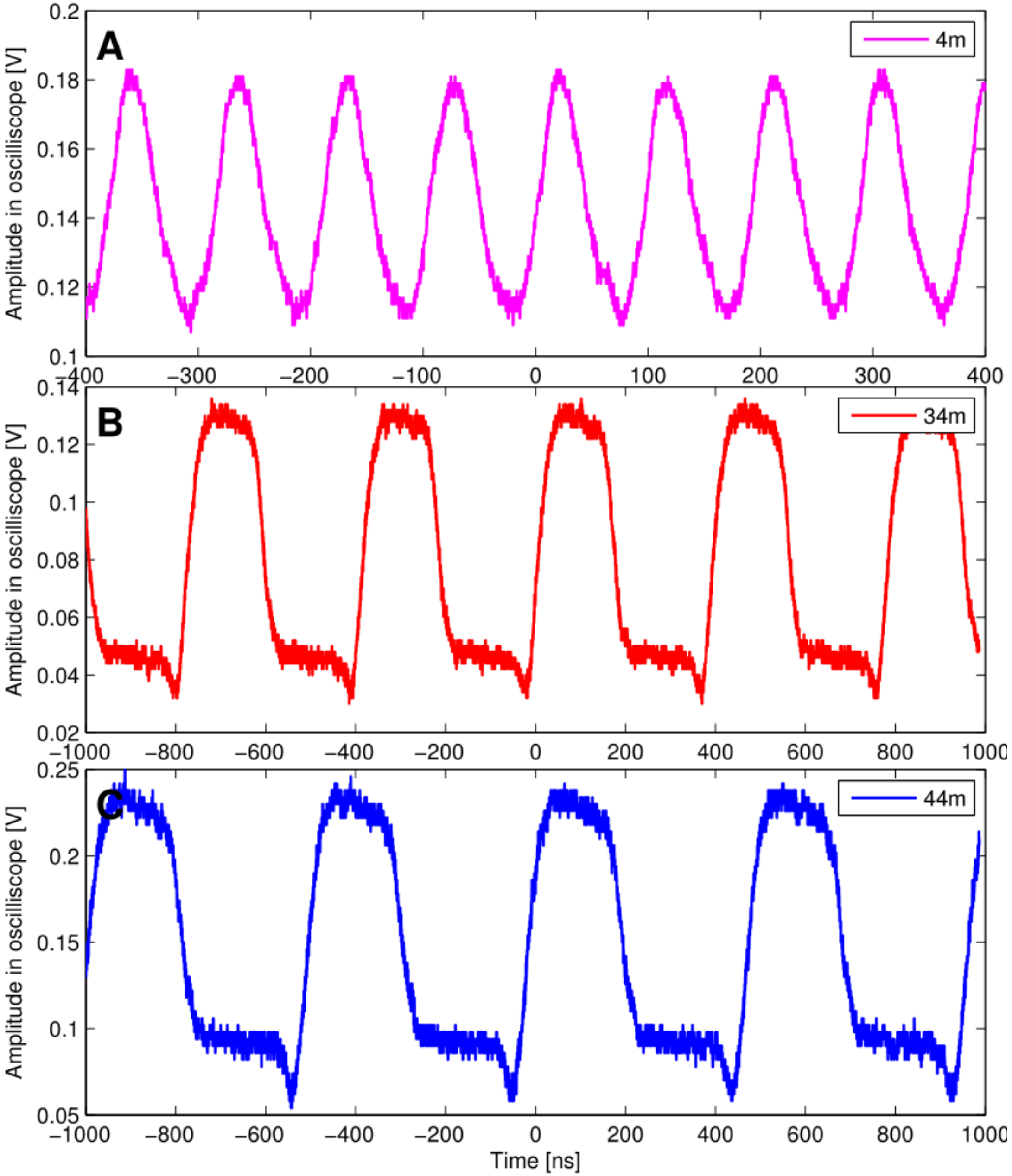


Z. Zhou, J. Zhao, R. W. Spiers, N. Brewer, M.-C. Wu, and P. D. Lett, A self-oscillating phase conjugate resonator as an optical frequency comb, CLEO 2021, paper JTu3A.48.

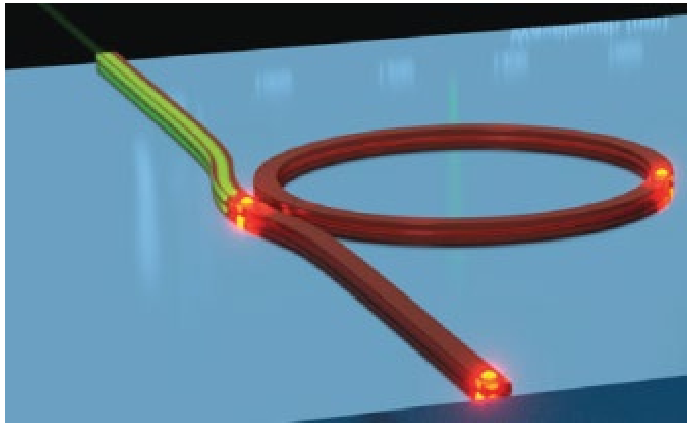
Large scale of comb structure

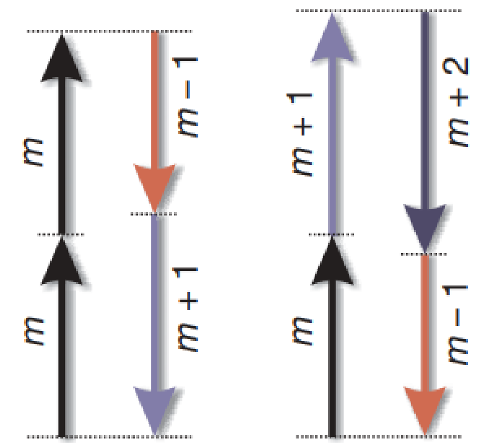


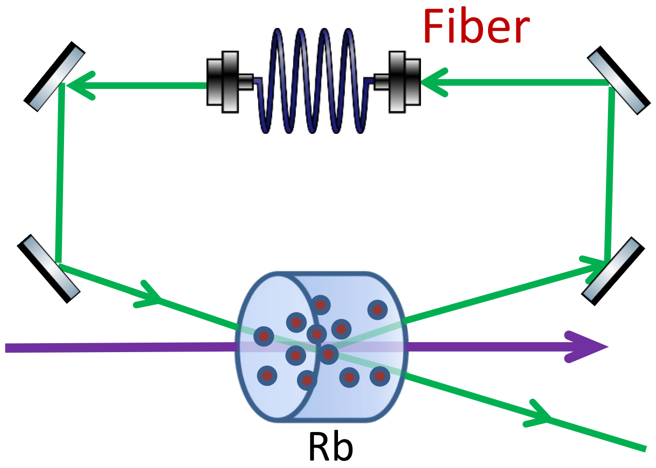
Temporal pulsing of the comb

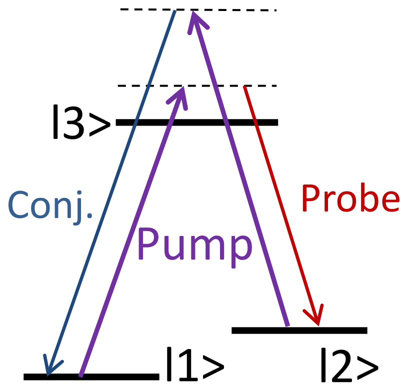


Universality of Lugiato-Lefever equation in a different system

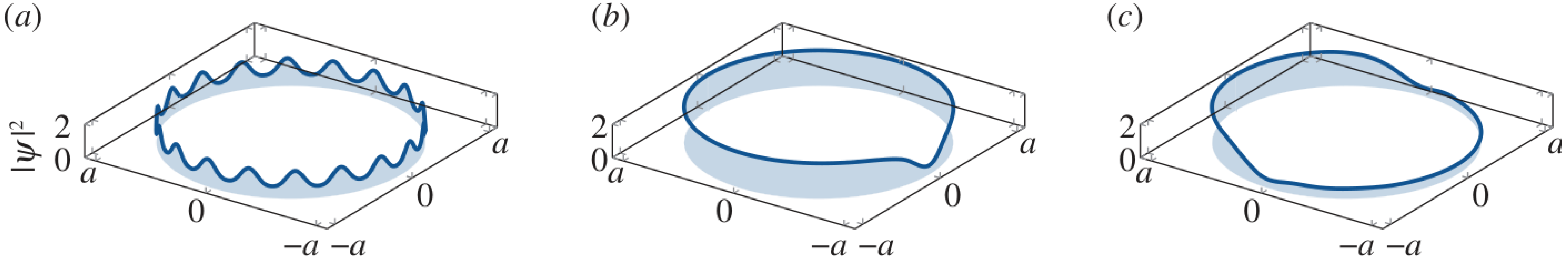








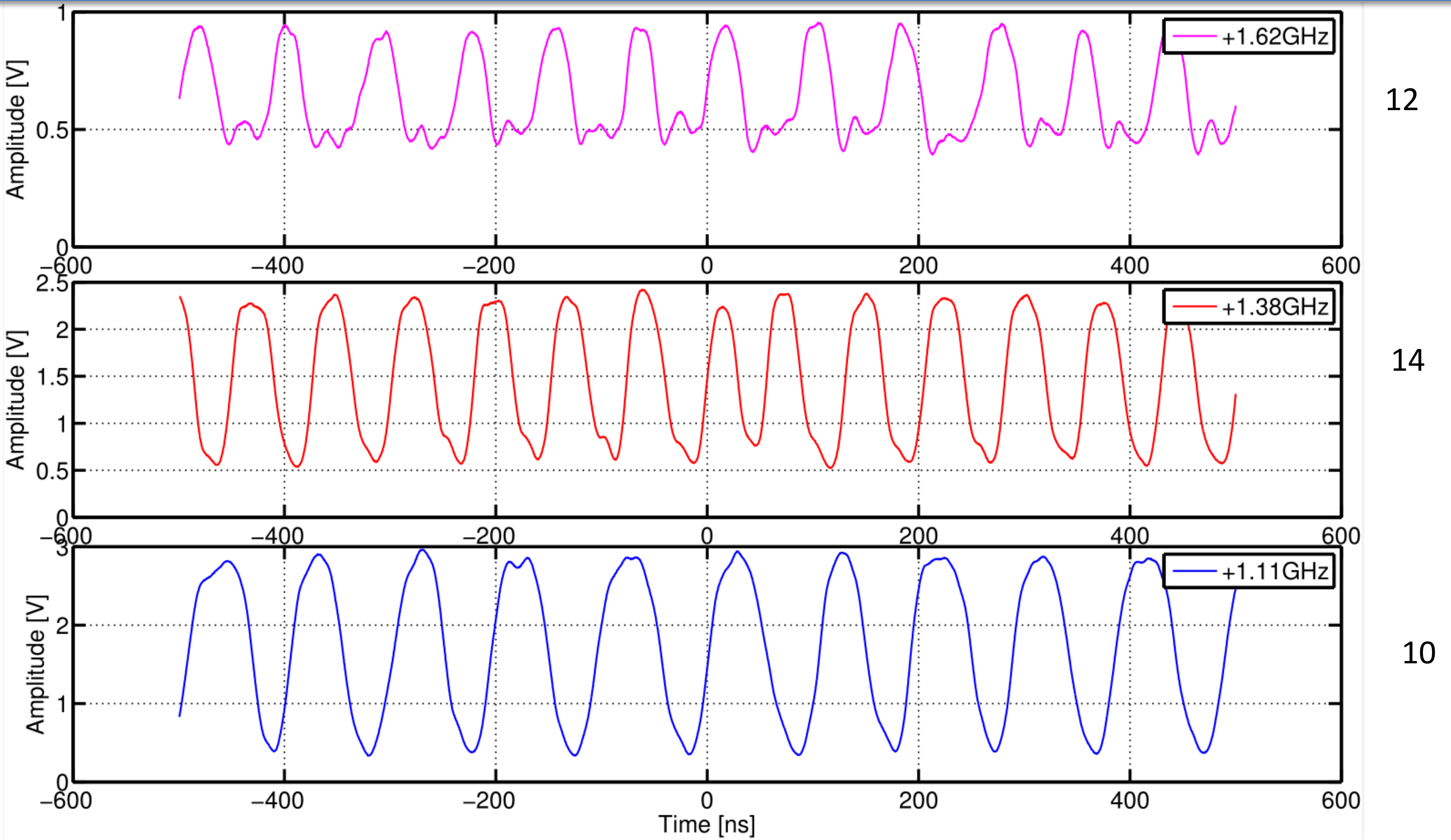
$$\frac{\partial \psi}{\partial \tau} = -(1+\mathrm{i}\alpha)\psi - \mathrm{i}\frac{\beta}{2}\frac{\partial^2 \psi}{\partial \theta^2} + \mathrm{i}|\psi|^2\psi + F$$



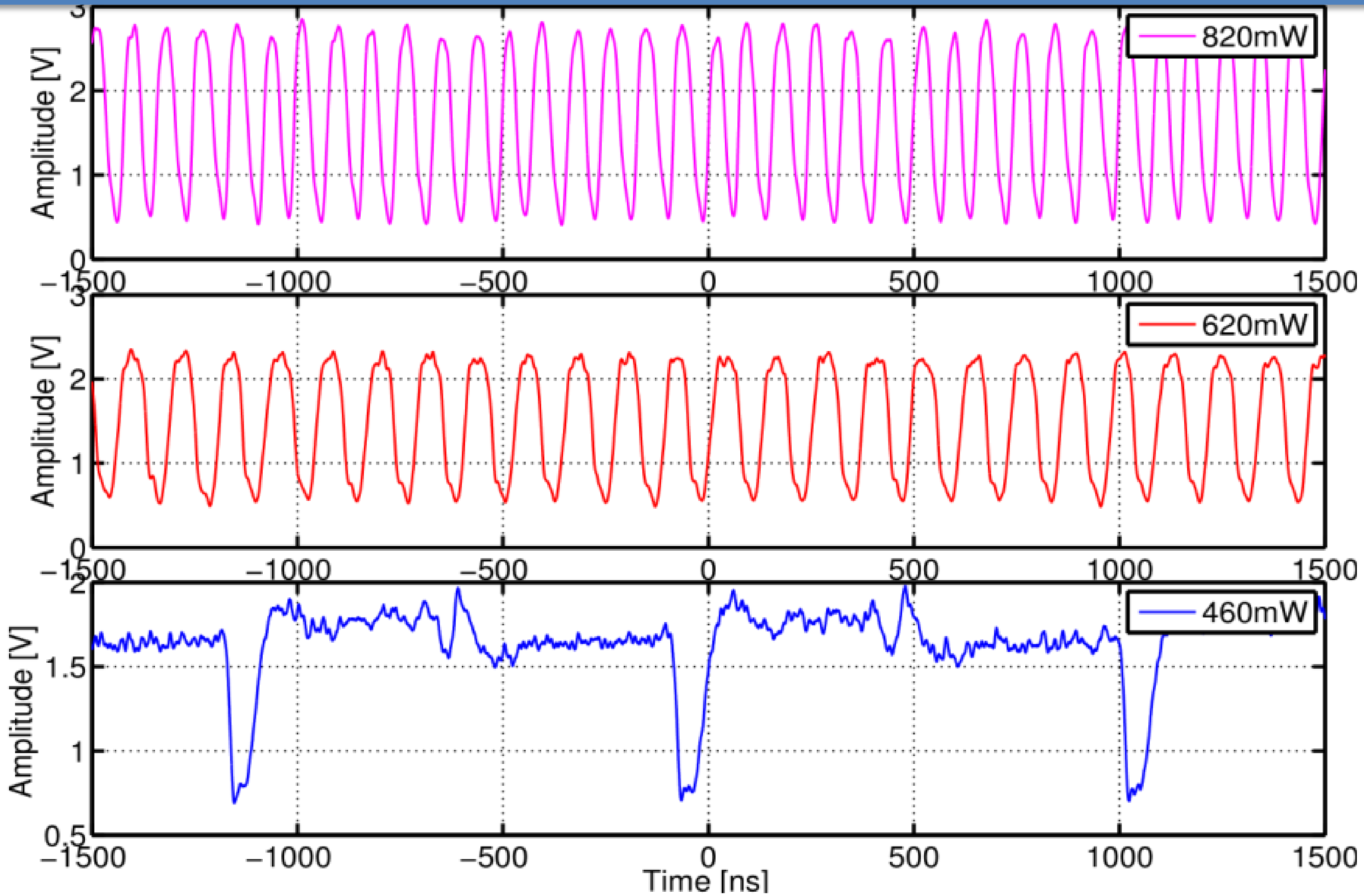
Stationary dissipative patterns in the normal dispersion regime (β > 0). (a) Rolls, (b) dark soliton and (c) platicon.

A taxonomy of optical dissipative structures in whispering-gallery-mode resonators with Kerr nonlinearity, Irina Balakireva, Yanne Chembo, Phil. Trans. R.Soc.A 376: 20170381(2017).

Different pulsing periods depending on pump frequency (107meter)



Different pulsing depending on the pump power (107meter)



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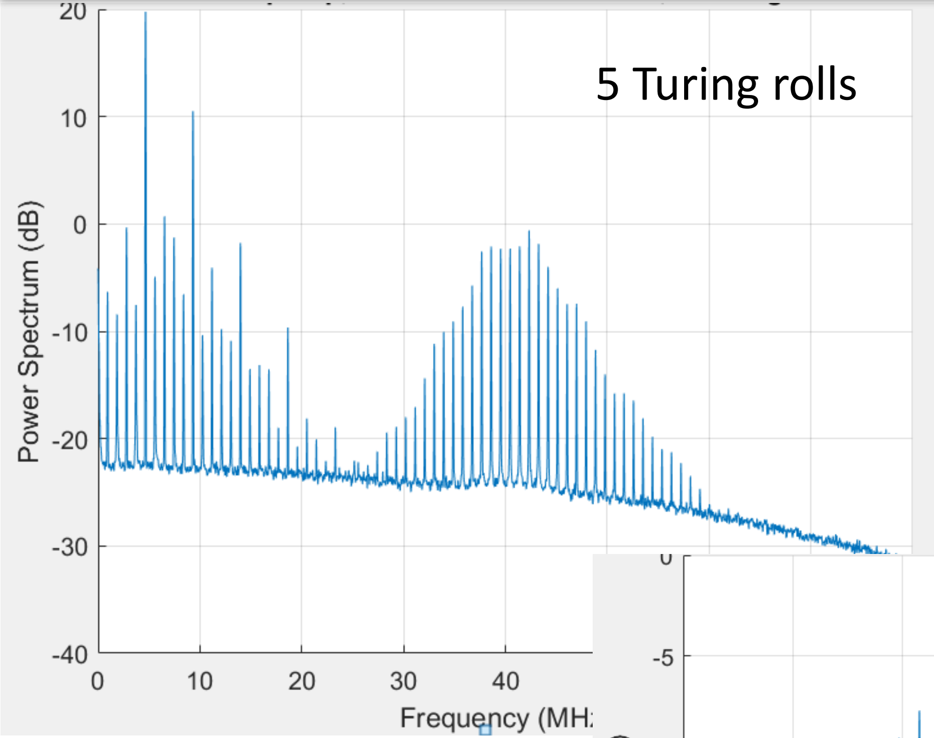
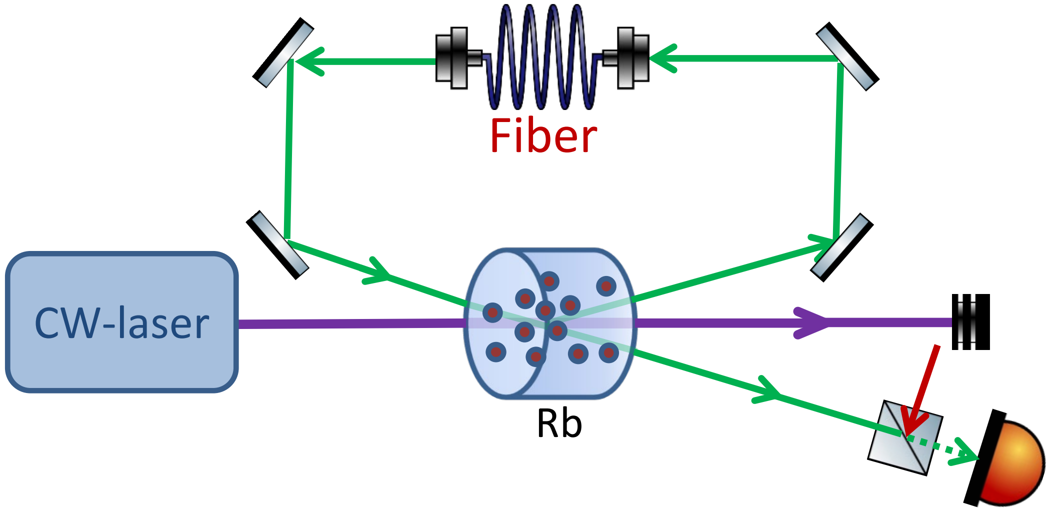
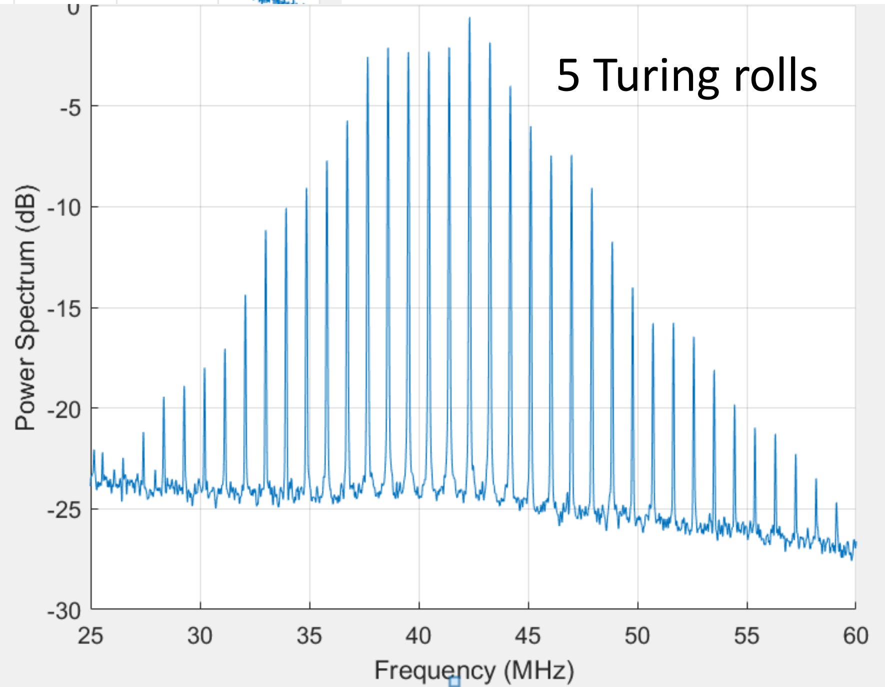
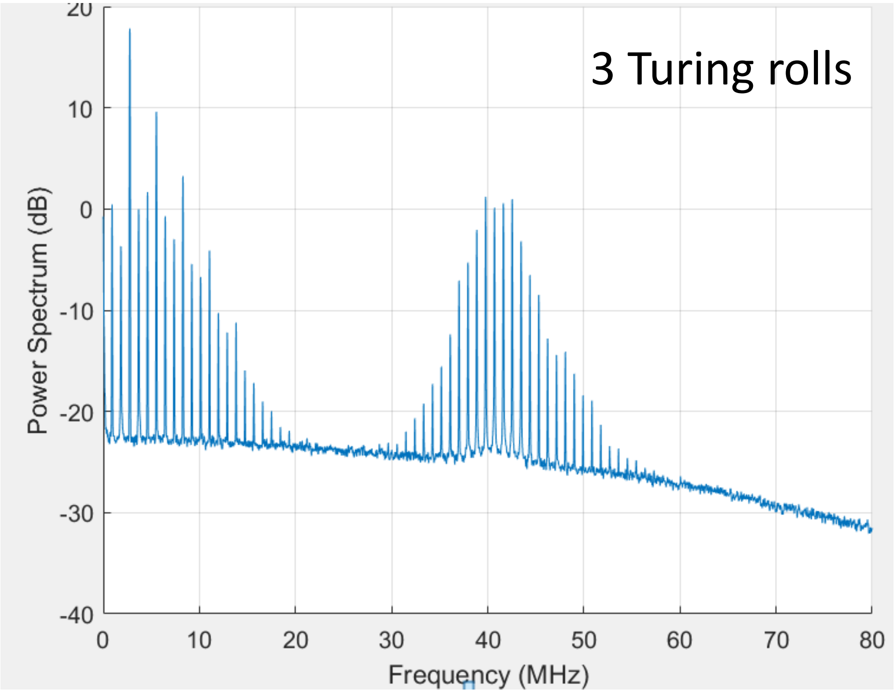
Heterodyne spectrum for Turing rolls – flat-top structure



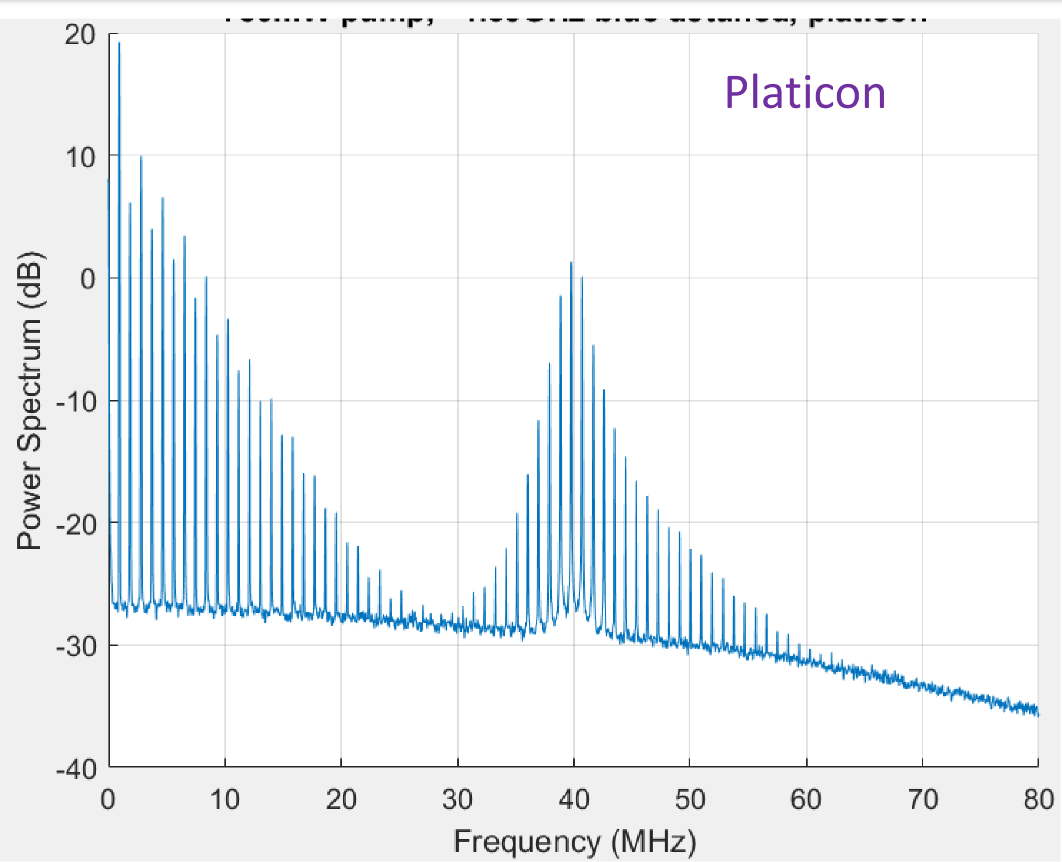


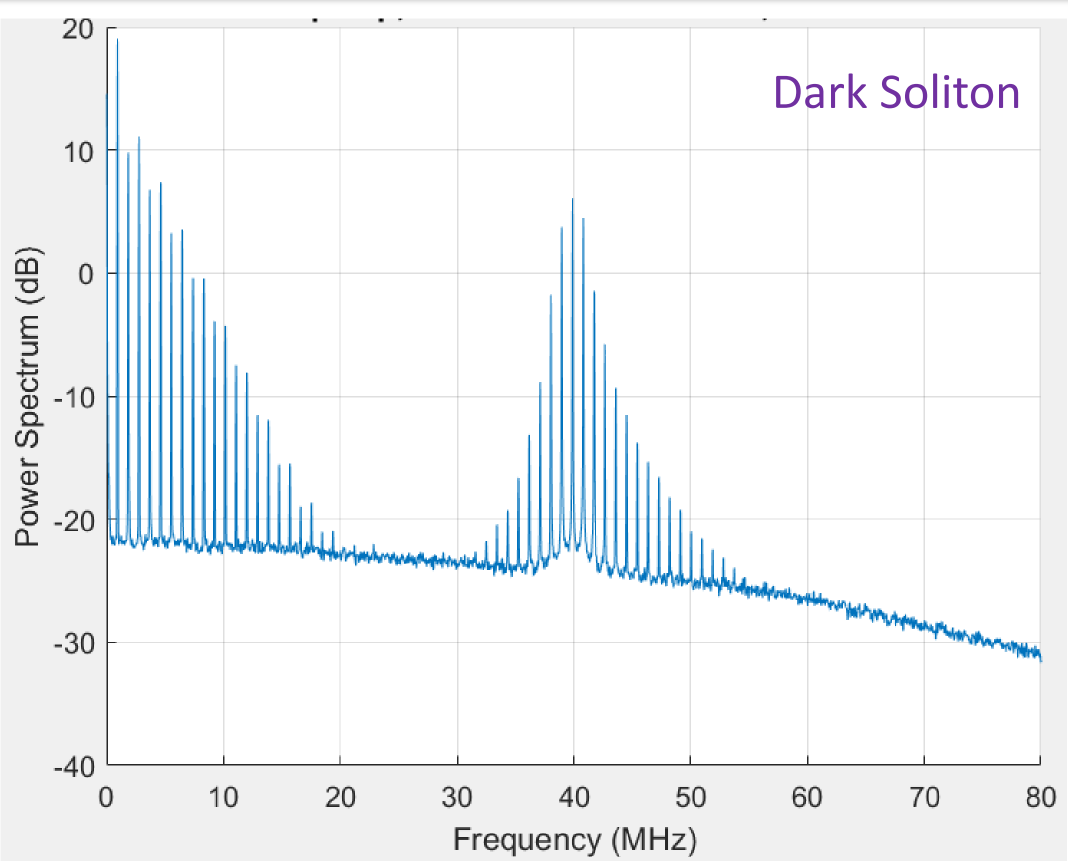
Local oscillator
(40MHz away
from the
conjugate).

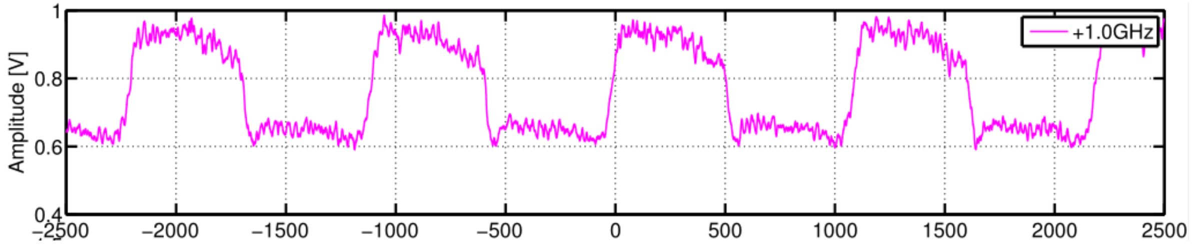


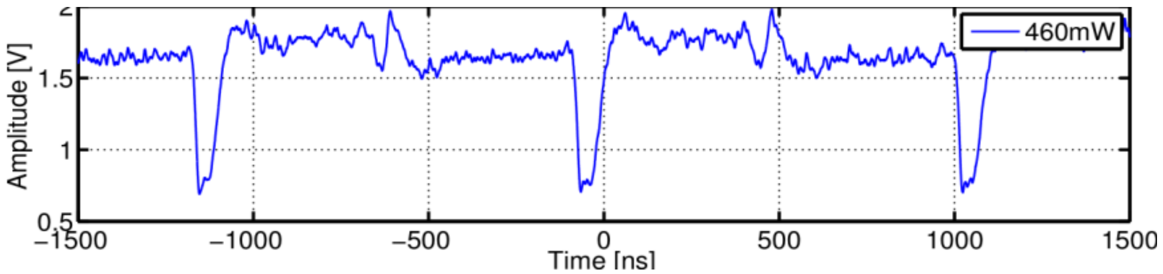


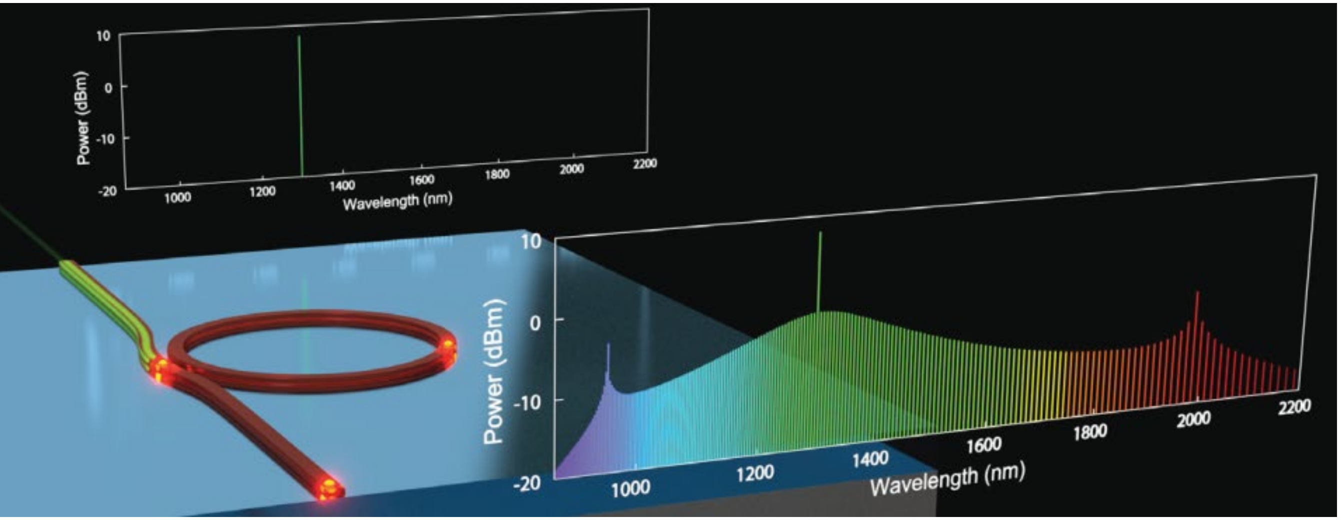
Heterodyne spectrum for Platicon and dark solitons

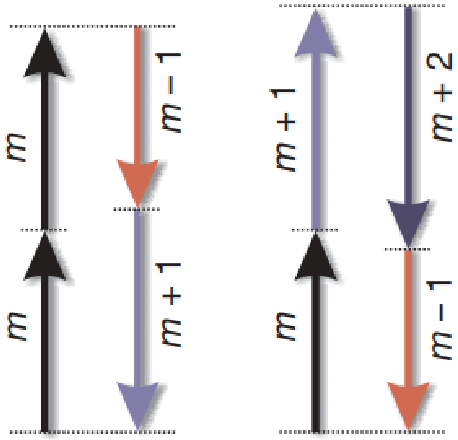


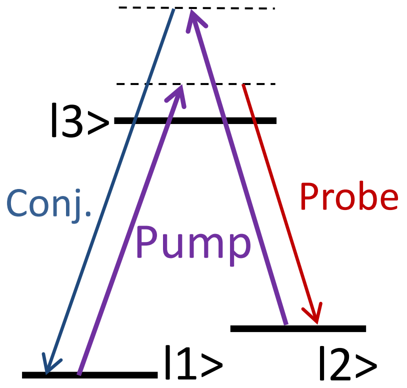












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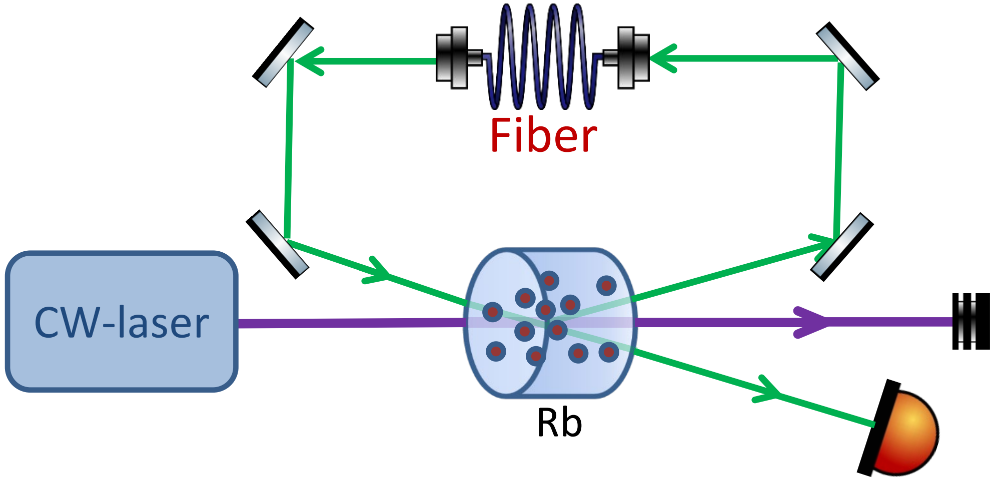

DKSs in an atomic system provide an experimental platform to study dissipative Kerr soliton physics, e.g. tunability with atomic transitions and direct observation of temporal pulses.

The third-order nonlinearity is strong, that the pump light does not circulate within the resonator.
…not suffer from thermal issues and stability issues.

… and more flexibility. The scheme allows for the phase conjugate resonator where the time-reversal property compensates various phase disturbances so that coherent optical combs and DKSs are stably observed without any active locking; cavity modes are tied to the pump frequency.

Summary & outlook

- Dissipative Kerr solitons in hot rubidium vapor, dynamics of soliton collision, formation
- Atomic interface: synthetic dimension, spatial multimode
- Quantum comb, artificial quantum comb.