Temporal dynamics of Kerr frequency combs in whispering-gallery mode resonators

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Context
Kerr combs are optical frequency combs generated in high Q-factor resonators through four-wave mixing. While many application could rely on these combs, the dynamics of the generation of the combs is still little known. Based on a modal description, we perform numerical simulation to study the amplitude and phase behavior of the comb’s modes.

Experimental setup
- MgF₂/ CaF₂ polished disks
- FSR ~ 10 GHz
- Q-factor ~ 10⁹
- Fiber taper coupling
- CW laser pump ~ 100 mW

Modal description
Using a modal description, we can study the temporal evolution of the envelop A_η of each mode η. The model takes into account the resonator bandwidth Δω_η, the Kerr nonlinearity through the four-wave mixing gain g_0, the dispersion of the resonator ω_αβη, and the external pumping envelop F.

\[ \dot{A}_η = \frac{1}{2} \Delta ω_η A_η - ig_0 \sum_{αβη'} L^αβη_η A_α A_β A_η e^{iω_αβη' t} + \frac{1}{2} \Delta ω_η F_η e^{i(Ω_0 - ω_η)t} \]

Runge-Kutta simulations provide us with both optical spectrum and temporal evolution of the modes.

Phase-locking dynamics
- Evolution of the relative phase of the modes
- Dispersion corrected
- Pump excitation at |A_0|^2 = 1.11 |A_0|^2
  ⇒ only primary comb excited
- Phase-locking occurs between the different modes as soon as the mode is populated by four-wave-mixing
- Higher pump power: oscillations and chaos