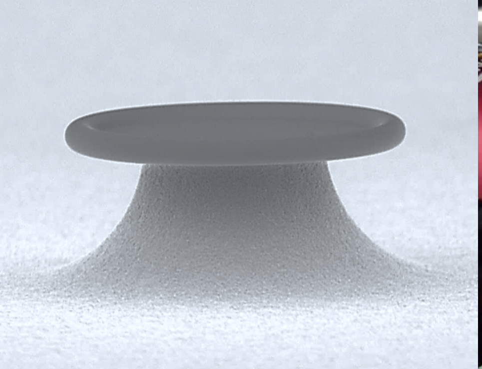

Keio University

CLEO: 2016
STu3Q.7 (June 7, 2016)

Kerr comb generation with suppressed cavity-optomechanical oscillation in toroid microcavity

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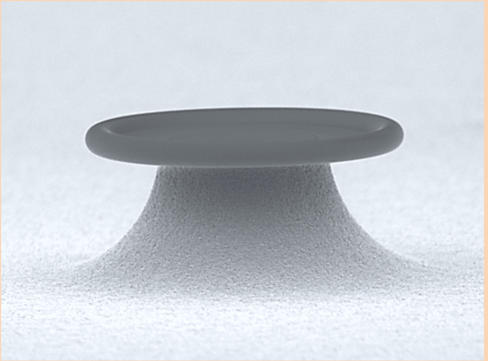
Takumi Kato, Akitoshi C. Jinnai, Takuma Nagano, Tomoya Kobatake, Takasumi Tanabe

Faculty of Science and Technology,
Keio University

Kerr frequency comb

Kerr comb

Microcavity



- ✓ Small & Inexpensive
- ✓ High repetition rate (10GHz-1THz)
- ✓ Large bandwidth
- ✓ Low threshold pump

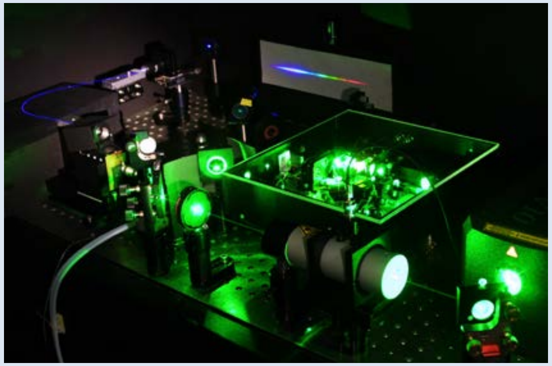
Threshold pump power for four-wave mixing

$$P_{\text{threshold}} \propto V/Q^2$$

V : Mode volume
Q : Quality factor

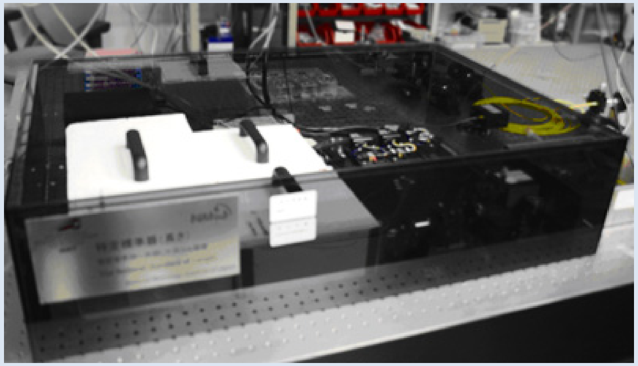
Conventional frequency comb sources

Ti:Sapphire laser



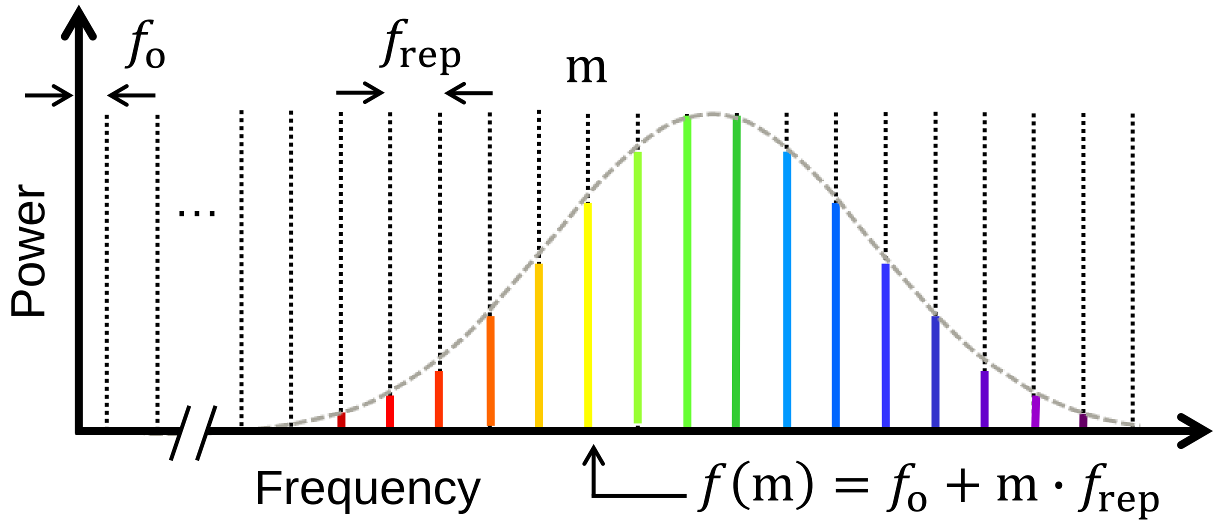
http://www.mpq.mpg.de/~haensch/comb/index.html

Fiber laser

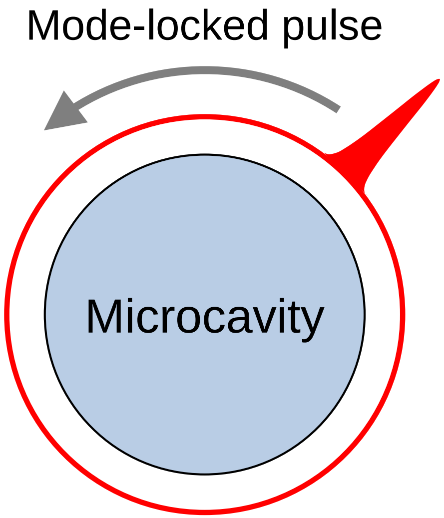


https://www.aist.go.jp/index_ja.html

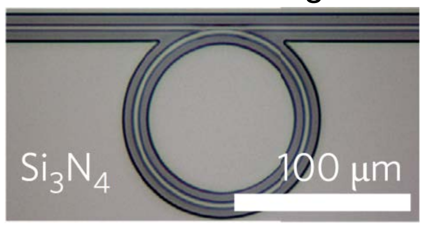
Large & Expensive



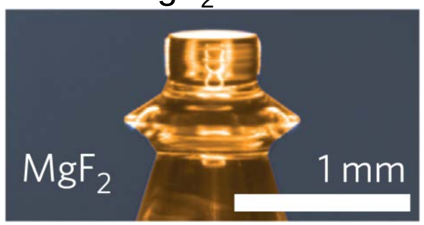
Motivation



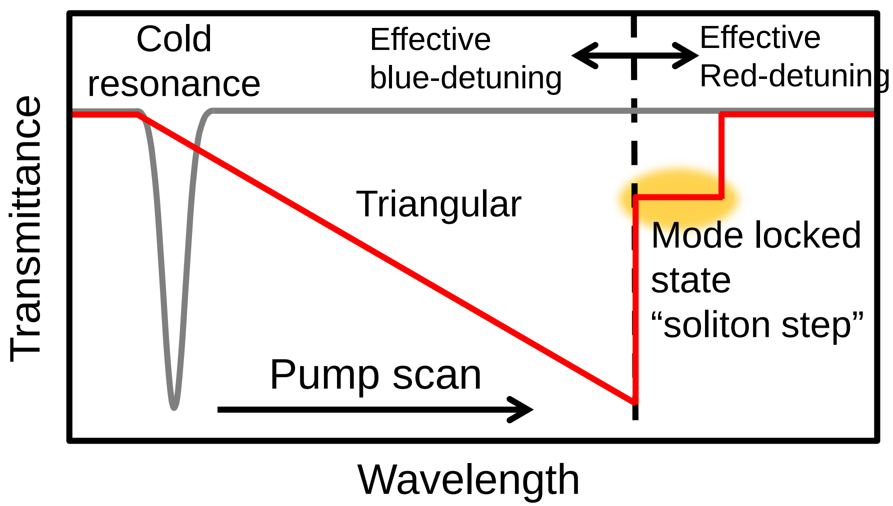
SiN microring



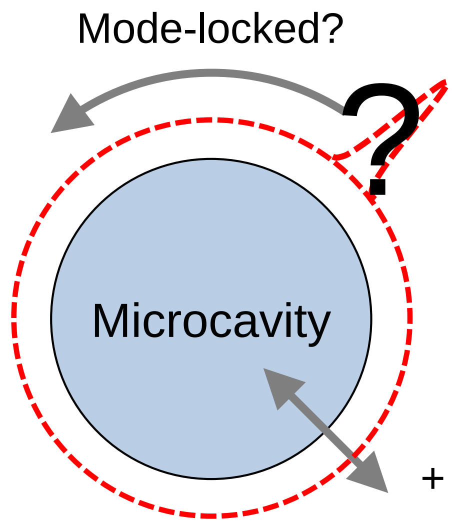
MgF_2 bulk



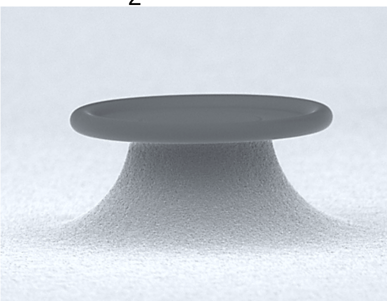
T. Herr et al., Nat. Photon. **6**, 480 (2012)



w/o cavity optomechanics

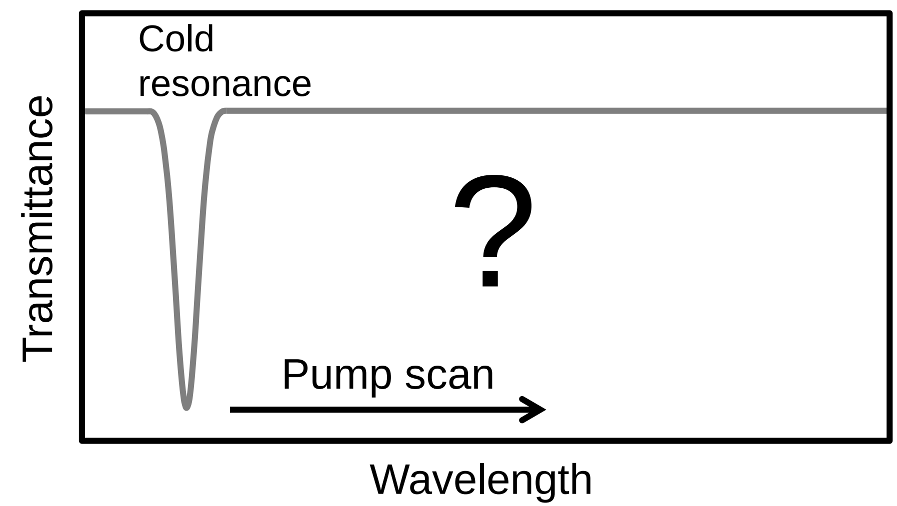


SiO_2 microtoroid



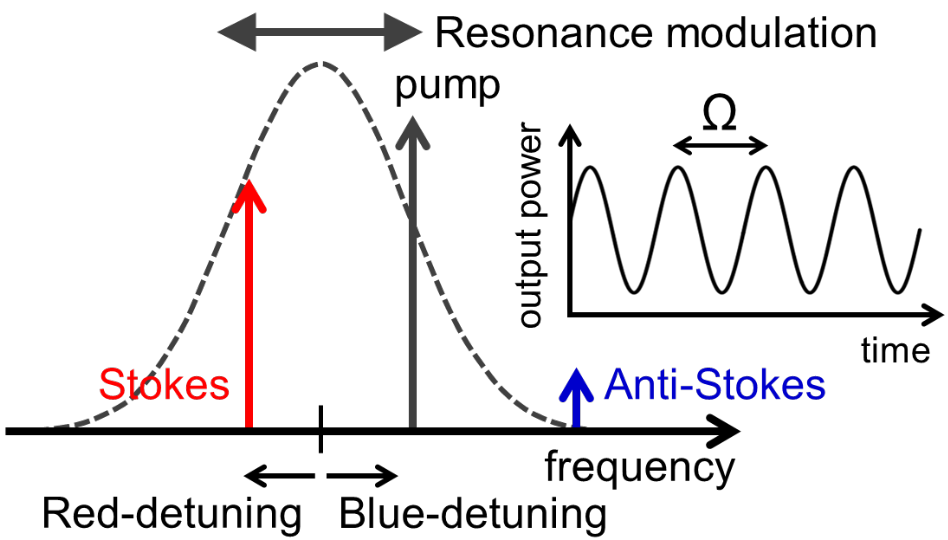
Strong nonlinear effect, but…

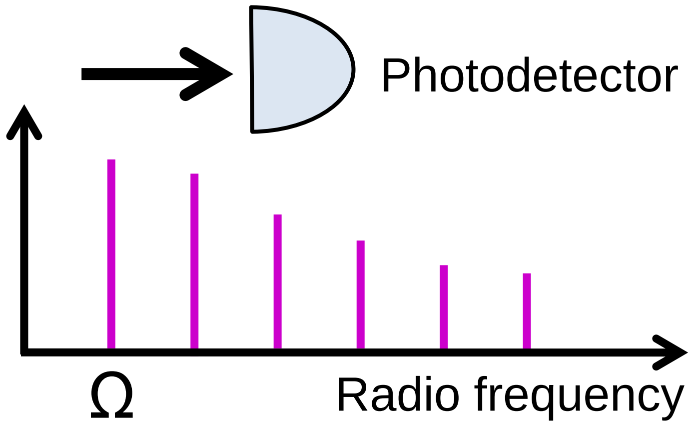
+ optomechanical noise



w/ cavity optomechanics

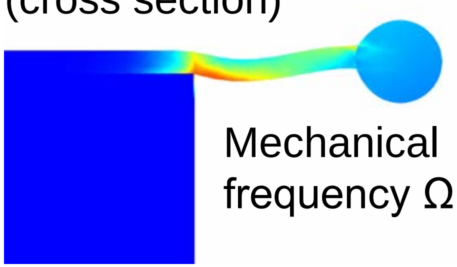
Cavity optomechanical oscillation



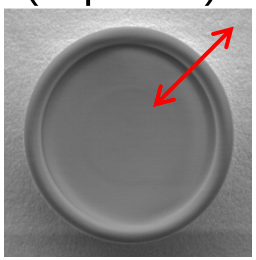


Can observe optomechanical oscillation by measuring RF signal

SiO_2 microtoroid
(cross section)



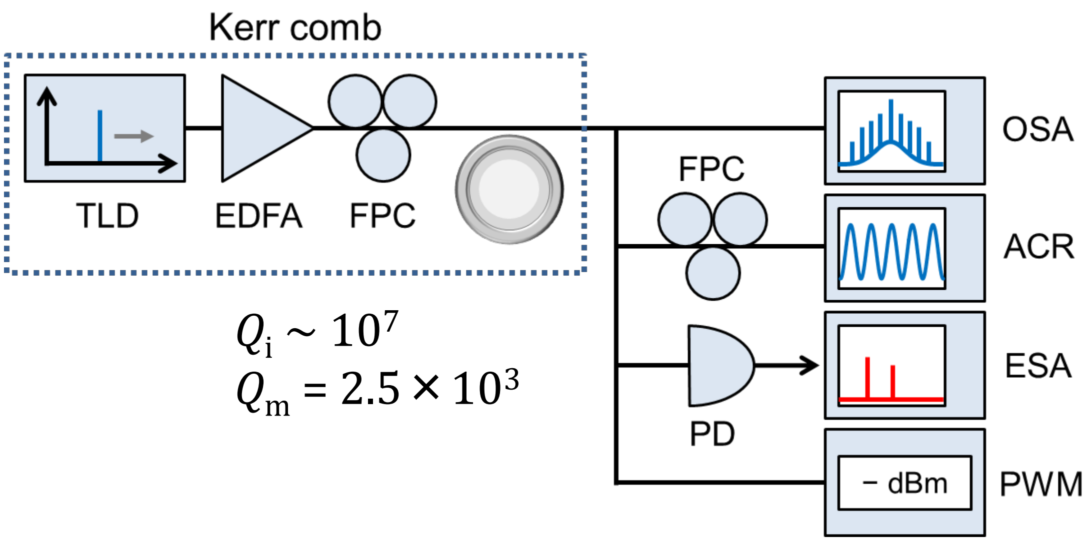
(Top view)

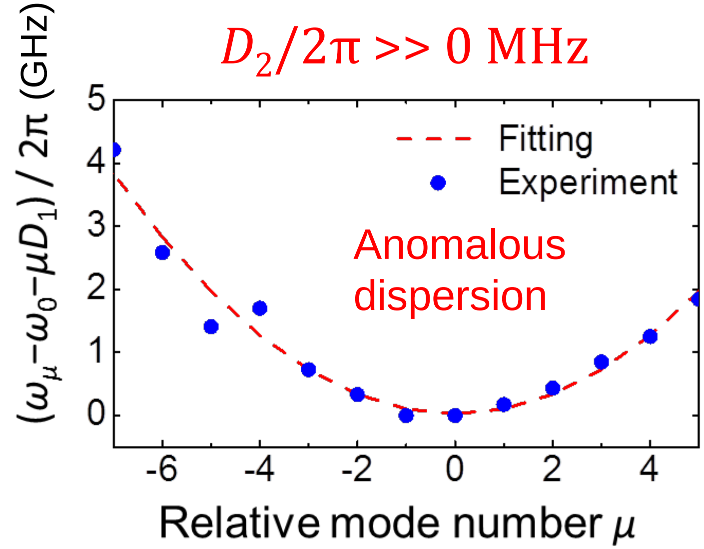


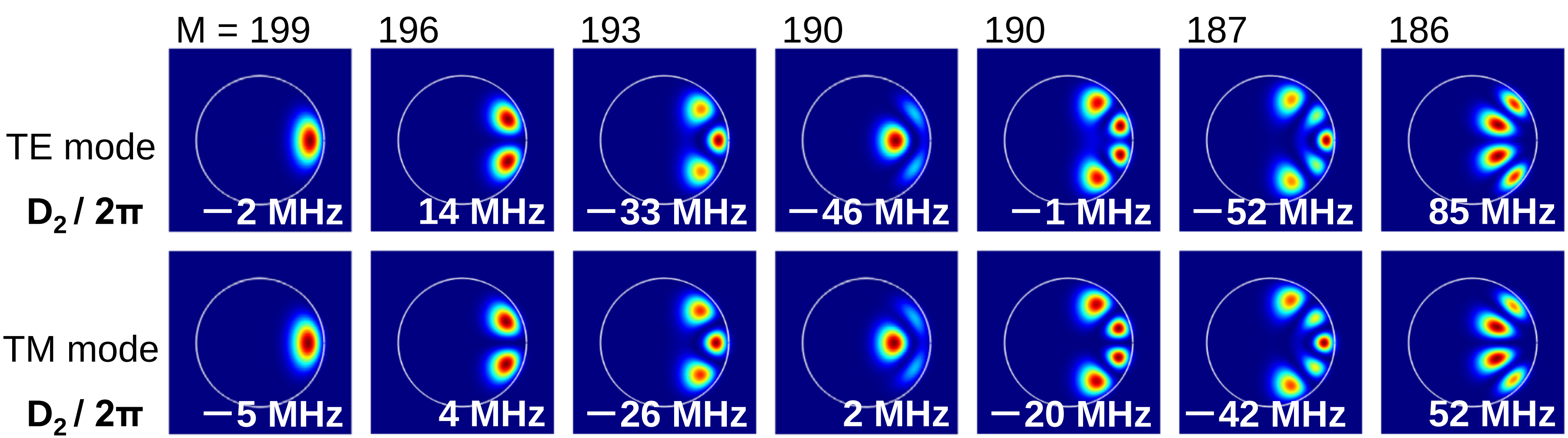
Blue-detuning
Amplify optomechanical oscillation

Red-detuning
Suppress optomechanical oscillation

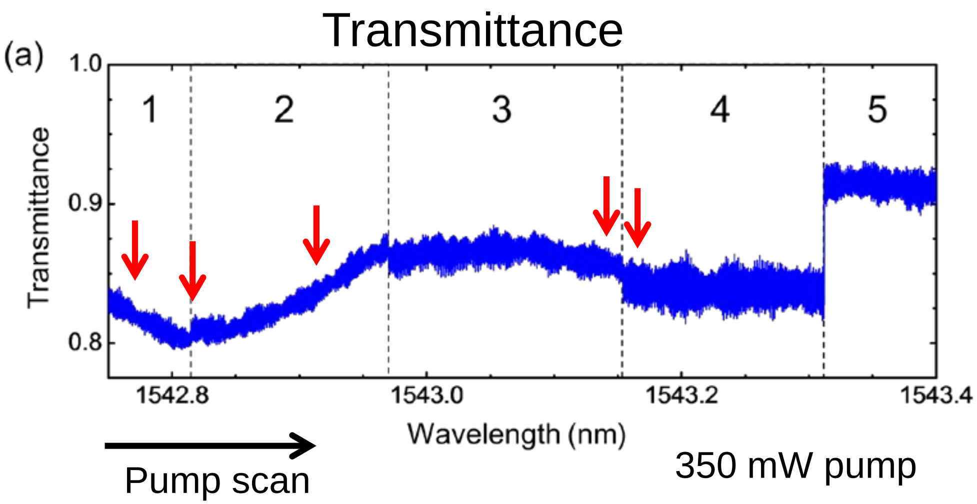
Experimental setup & Dispersion

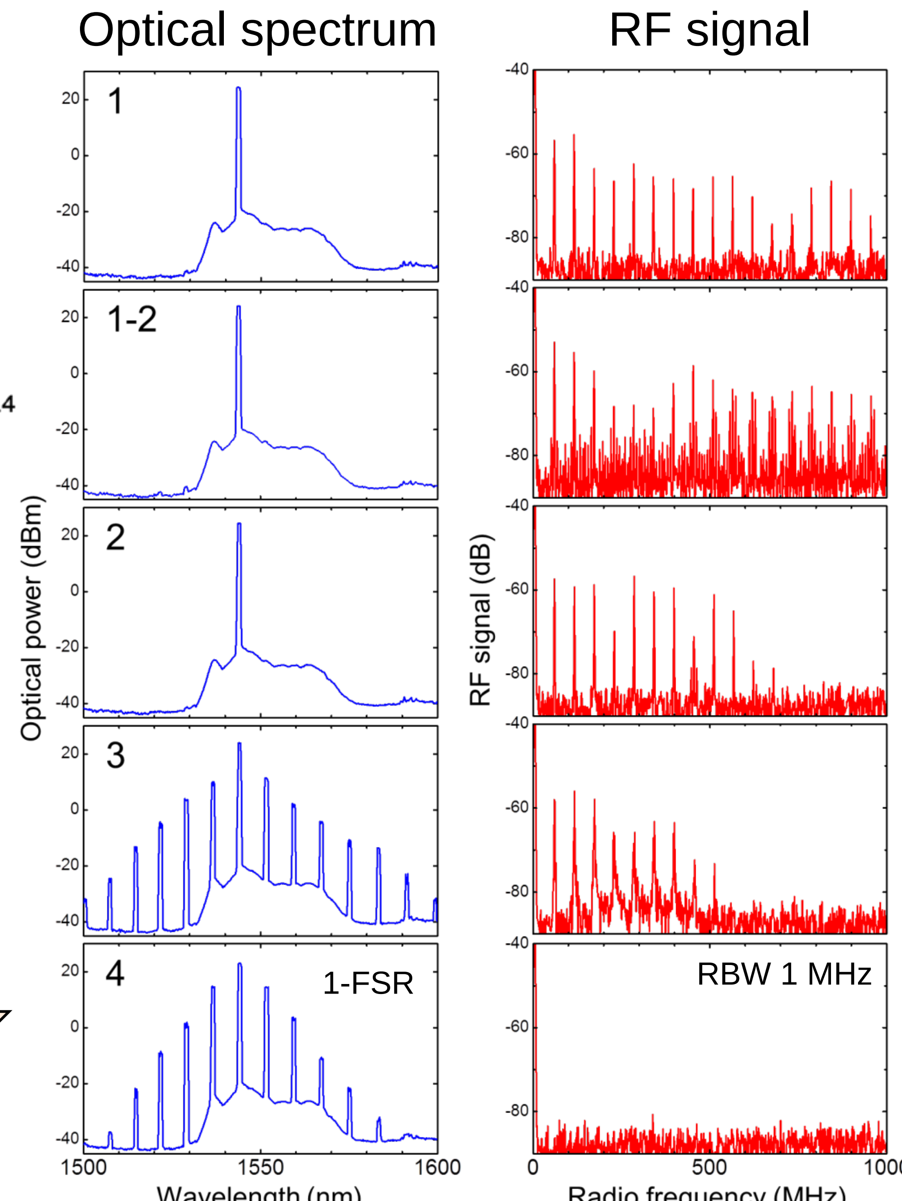






Kerr comb generation with single-FSR





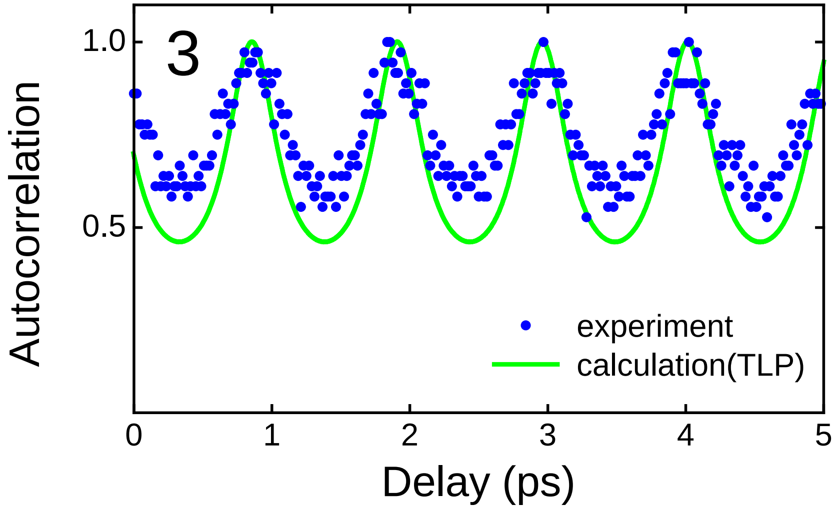
Multiple of 60 MHz signals were caused by optomechanical oscillation

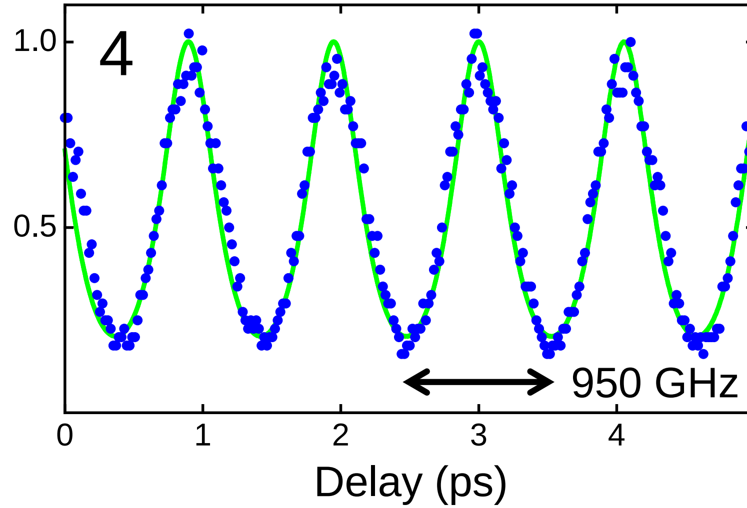
RF signal disappeared

In terms of cavity optomechanics, state-4 is into effective red-detuning

Autocorrelation waveform measurement

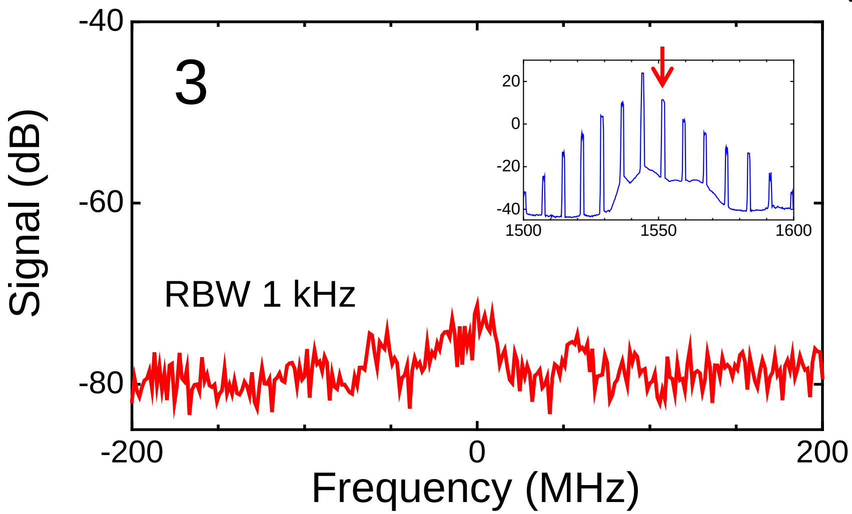
Transform limited pulse (TLP) of single-FSR comb was generated

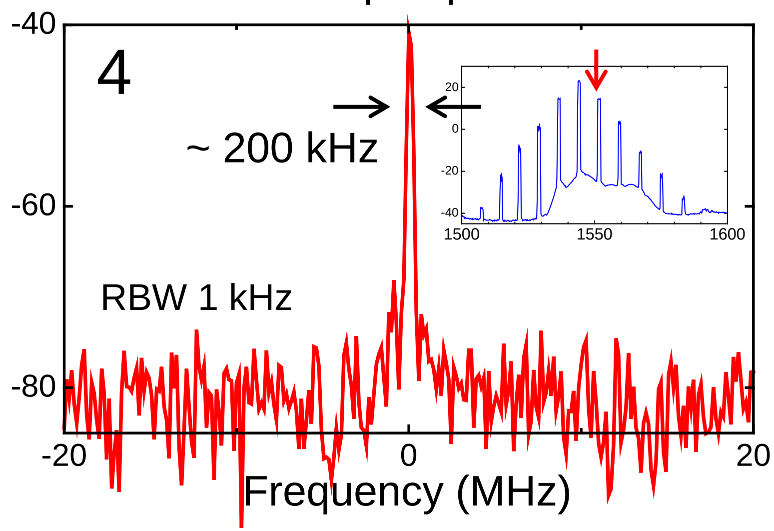




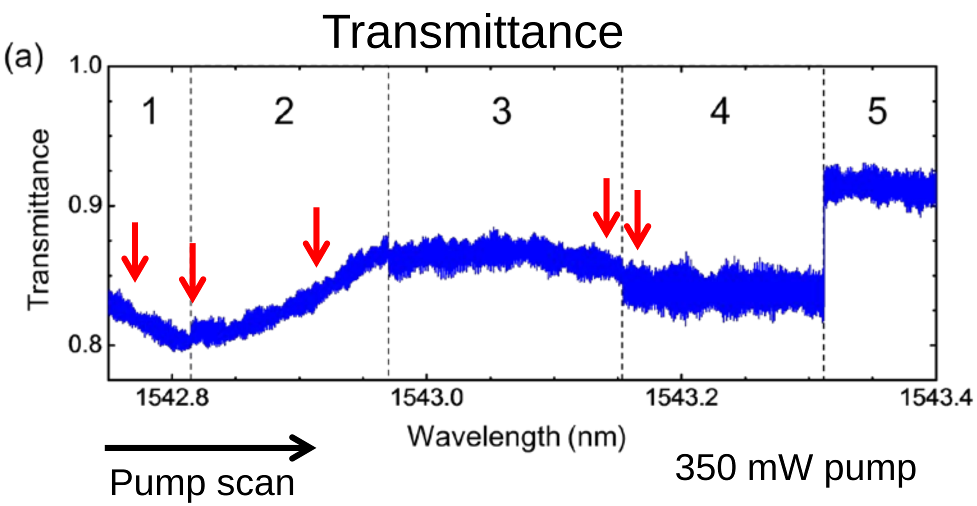
Linewidth of comb line

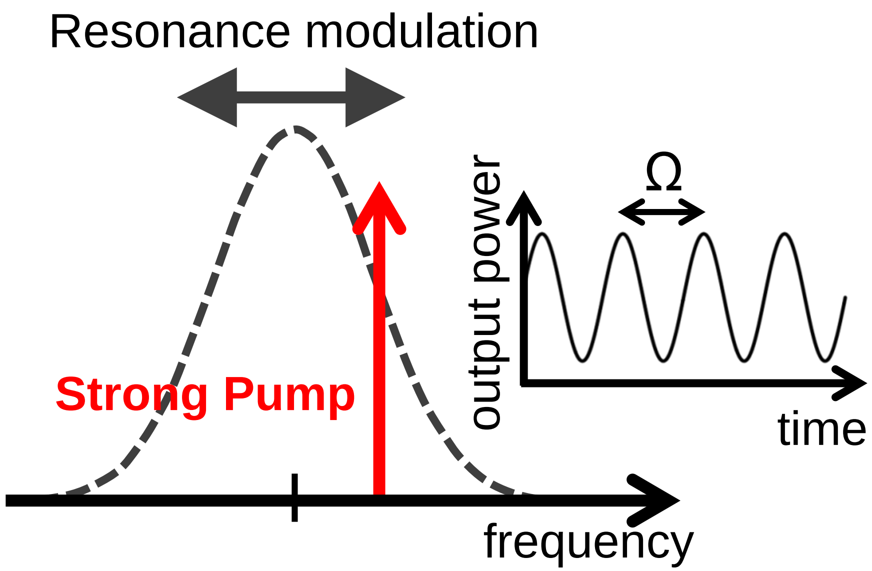
(same order as that of pump and reference lasers)





Transmittance affected by oscillation



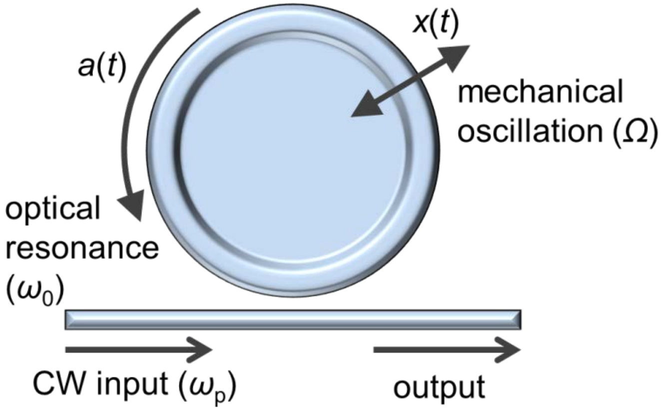


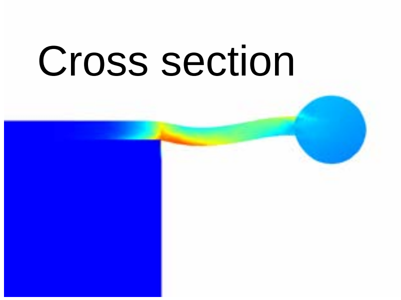
Resonance modulation
by optomechanical oscillation

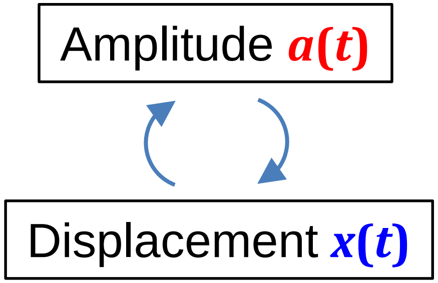
⇒ Chang transmittance?

Simulation of transmittance

Simulation model







Previous research

T. Carmon et al., Phys. Rev. Lett. 94, 223902 (2005).

Slowly varying field amplitude in microcavity $\boldsymbol{a(t)}$:

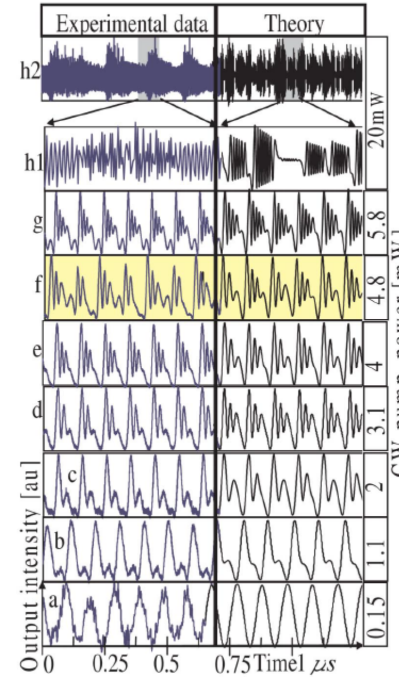
$$\frac{d\boldsymbol{a(t)}}{dt} = -\boldsymbol{a}(t)\left(\frac{\omega_0}{2Q_t} - i\left(\omega_p - \omega_0 + \boldsymbol{x(t)}\frac{\omega_0}{R}\right)\right) + s_{in}\sqrt{\frac{\omega_0}{Q_c}FSR}$$

Optomechanical oscillation (resonance modulation)

Displacement in radial direction $\boldsymbol{x(t)}$:

$$\frac{d^2\boldsymbol{x(t)}}{dt^2} + \frac{\Omega}{Q_m}\cdot\frac{d\boldsymbol{x(t)}}{dt} + \Omega^2\boldsymbol{x(t)} = \frac{2\pi n}{m_{eff}c}|\boldsymbol{a(t)}|^2$$

ω_0: resonance frequency, ω_p: pump frequency, Q_t: total Q, Q_c: coupling Q, s_{in}: input pump field, *FSR*: cavity FSR, *R*: cavity radius, *n*: refractive index,, *c*: speed of light, *Ω*: mechanical frequency, Q_m: mechanical Q, m_{eff}: effective mass



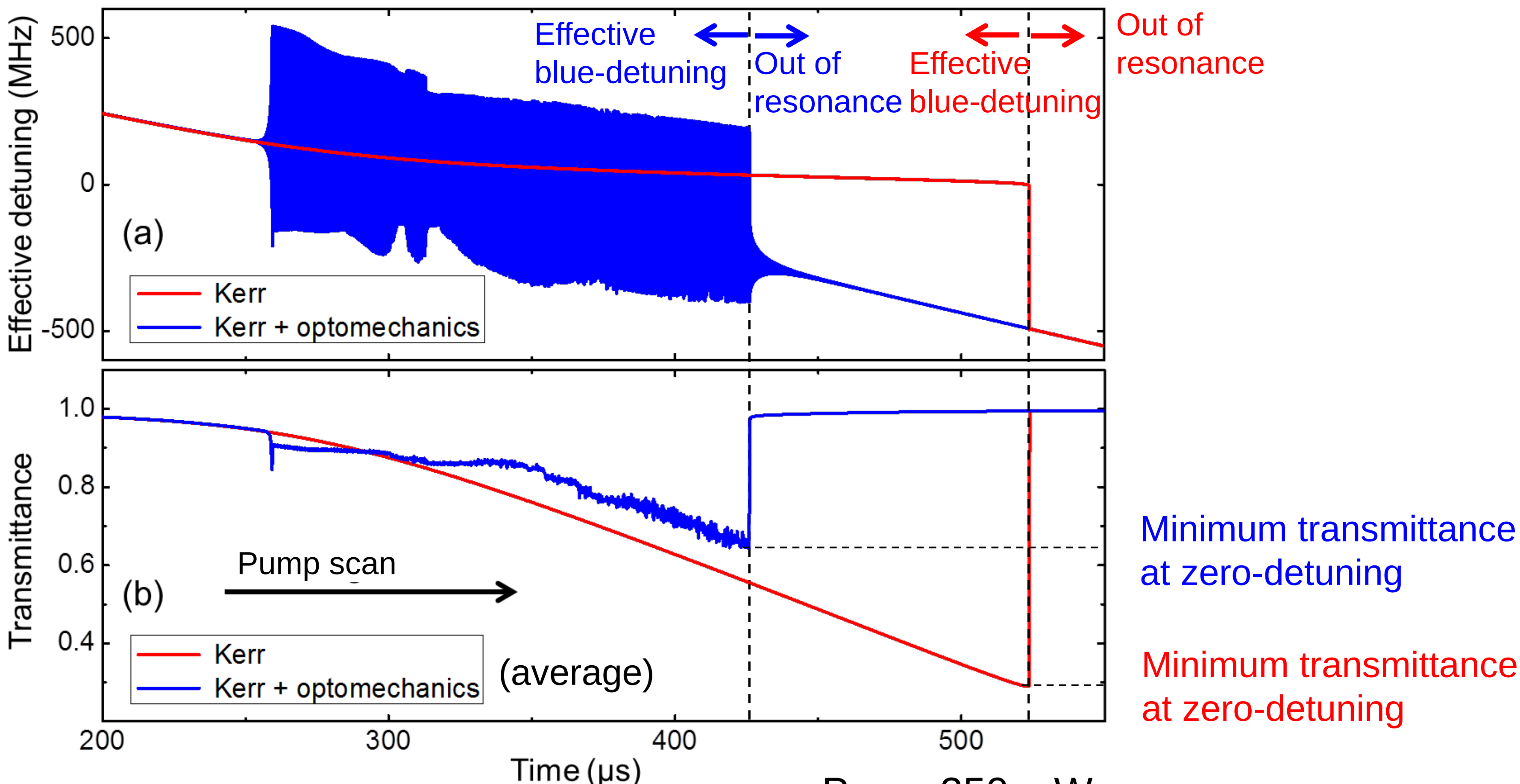
Effective detuning & Transmittance with high power pump

Slowly varying field amplitude in microcavity *a*(*t*):

$$\frac{da(t)}{dt} = -a(t)\left(\frac{\omega_0}{2Q_t} - i\left(\omega_p - \omega_0 + \Delta n_{Kerr}(t)\frac{\omega_0}{n} + x(t)\frac{\omega_0}{R}\right)\right) + s_{in}(t)\sqrt{\frac{\omega_0}{Q_c}FSR}$$

Kerr effect Optomechanical oscillation

(Not including FWM process)



Pump 350 mW

Summary

- A mode-locked pulse with a single FSR was generated from a toroid microcavity although no “soliton step” was observed.
- A Kerr comb in a low noise state had a linewidth of 200 kHz, which is same order as that of a pump and a reference lasers.
- We calculated the influence of optomechanical oscillation on transmittance by considering Kerr and optomechanical effects.

Acknowledgements

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