Time-domain observation of strong coupling between counter-propagating ultra-high Q whispering gallery modes

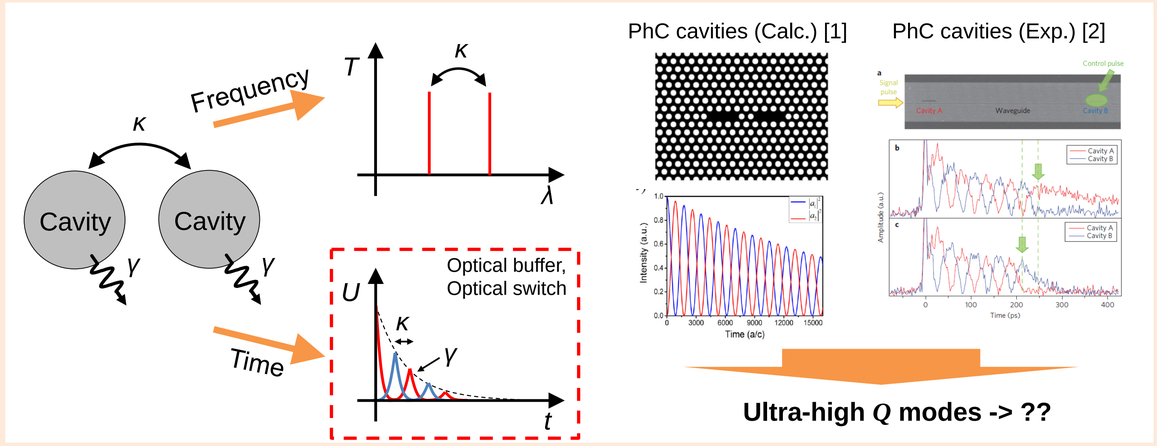
W. Yoshiki, A. Chen-Jinnai, T. Tetsumoto, S. Fujii & T. Tanabe (Keio University, Japan)

☺ Abstract

We observed strong coupling between ultra-high Q modes in the time domain for the first time. We employed two counter-propagating modes that couples each other via surface scattering in a silica toroid microcavity. We employed two tapered fibers (add-drop configuration), one for excitation and the other for observing the energy oscillation between two cavities. This configuration allows us to observe energy in a cavity directly. The results showed clear oscillatory behavior, which was induced by the strong coupling. In addition, the oscillation period in the time domain precisely matches that inferred from the mode splitting in the frequency domain, and the measured results showed excellent agreement with those calculated with the numerical model.

1. Background

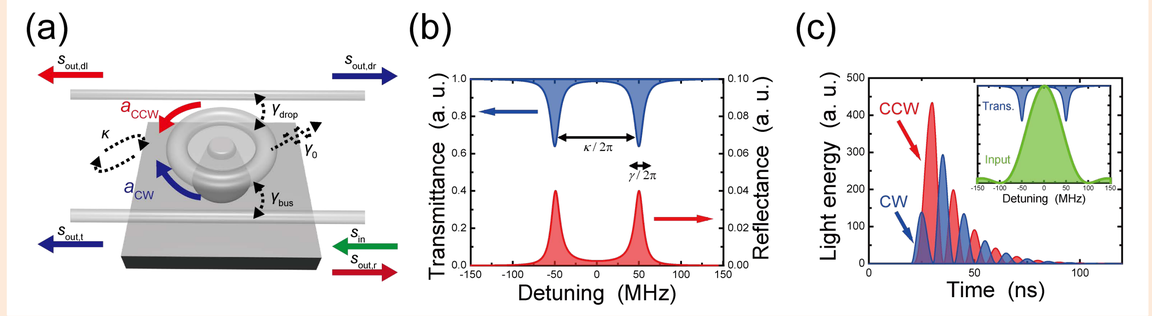
Aim: Observing strong coupling between ultra-high Q modes in time domain for dynamic control of the coupling.



[1] Y. Sato et al., Nat. Photonics **6**, 56-61 (2012), [2] Y. Zhao et al., Opt. Express **23**, 9211-9220 (2015).

2. Numerical analysis

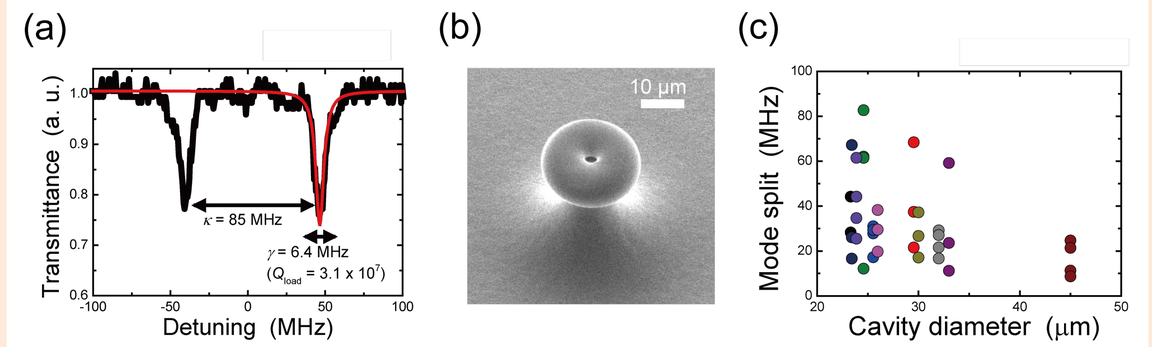
- **CW and CCW modes in a silica microtoroid was employed.**
- **Static and transient behavior of the coupling between two modes were modeled with coupled mode theory.**



(a) Schematic illustration of the model. (b) Calculated transmission & reflection spectra. (c) Calculated time-domain energy oscillation between CW and CCW modes.

3. Fabrication & Characterization

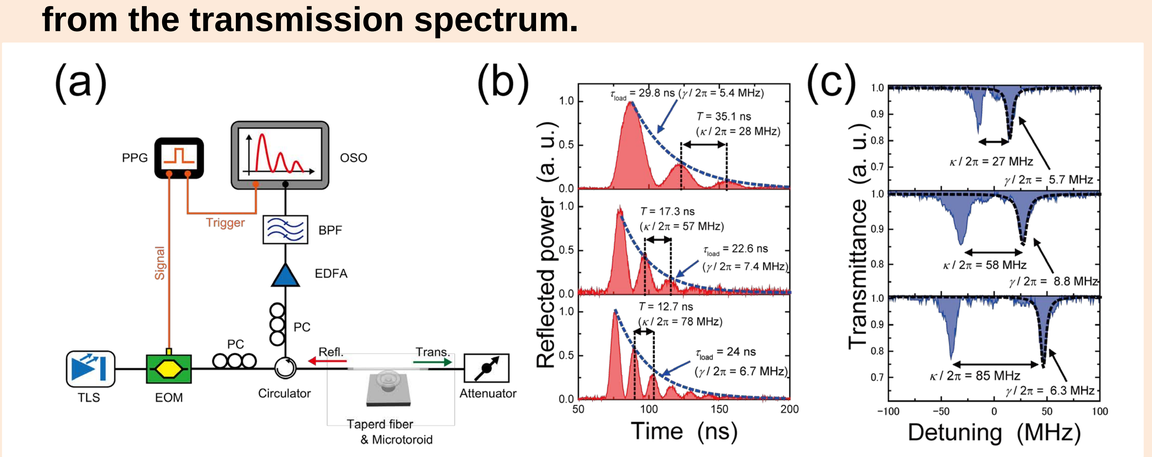
- **Silica microtoroid w/ a smaller diameter was fabricated.**
- **Γ ~ 13 was achieved with a silica microtoroid w/ a small diameter.**



(a) Scanning electron microscope image of the fabricated cavity. (b) The typical transmission spectrum. (c) Measured mode split for different cavity diameter.

4. Reflection measurement

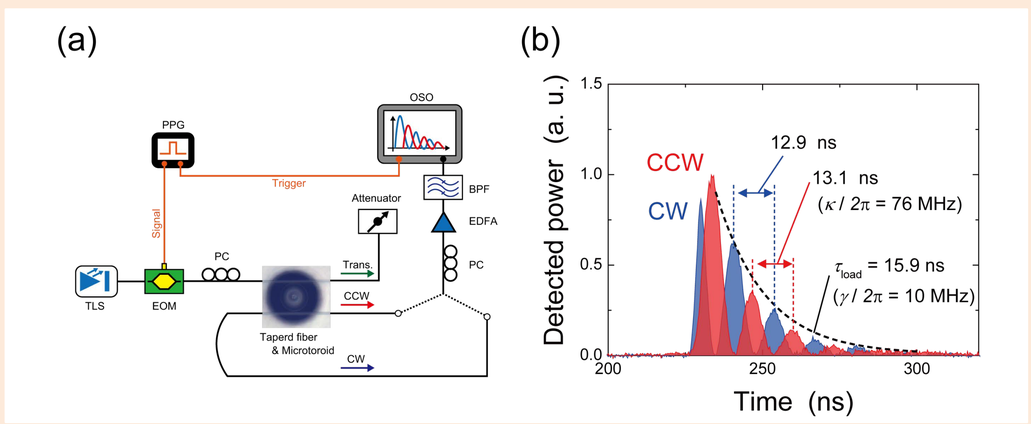
- **The reflected signal was measured for monitoring CCW mode.**
- **Energy oscillation in CCW mode was directly measured & the oscillation period and decay rate were matched w/ those inferred from the transmission spectrum.**



(a) Experimental setup for the reflection measurement. (b) The reflected signals and (c) transmission spectra for different modes.

5. Drop-port measurement

- **CW and CCW modes were directly measured with the drop-port.**
- **Energy oscillation between ultra-high Q modes was directly observed for the first time.**



(a) Experimental setup for the drop-port measurement. (b) The outputted signal from the drop-port fiber. The energy oscillates each other with the fixed period.

☺ Conclusion

We reported the first time-domain observation of strong coupling between ultra-high Q whispering gallery modes. We confirmed that the oscillation periods in the time domain agrees well with those inferred from the mode splitting in the frequency domain. Moreover, we observed the energy oscillation between the CW and CCW modes simultaneously and directly by employing drop-port measurement.

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For more information: W. Yoshiki, A. C.-Jinnai, T. Tetsumoto, and T. Tanabe, Opt. Express **23**, 30851-30860 (2015).