Brillouin-scattering-induced transparency
and non-reciprocal light storage

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Brillouin-scattering-induced transparency and non-reciprocal light storage

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Research interest

- **quantum optics**
- **non-linear optics**
- **quantum information**

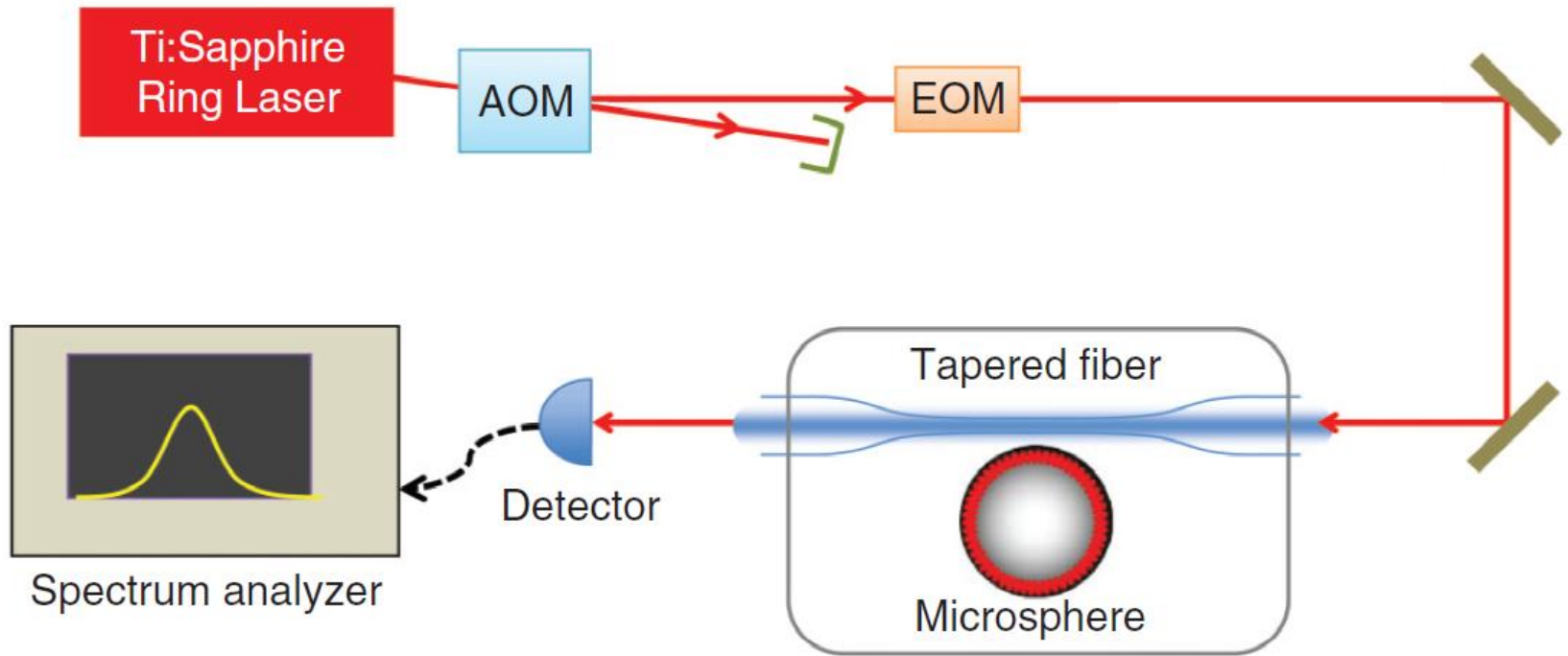http://dsxt.ustc.edu.cn/zj_ywjs.axp?zzid=113

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- Electromagnetically induced transparency

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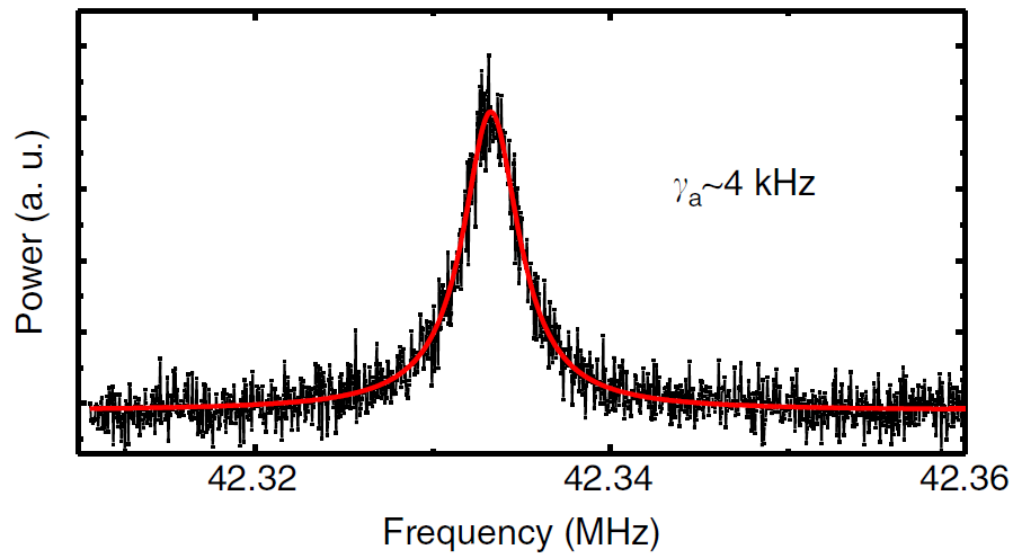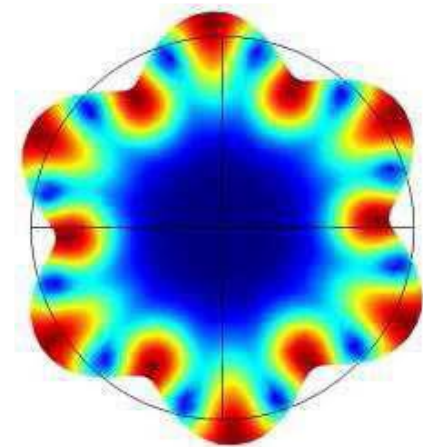# EIT (Electromagnetically Induced Transparency)

M. Fleischhauer, A. Imamoglu, and J. P. Marangos, Rev. Mod. Phys. 77, 633 (2005).
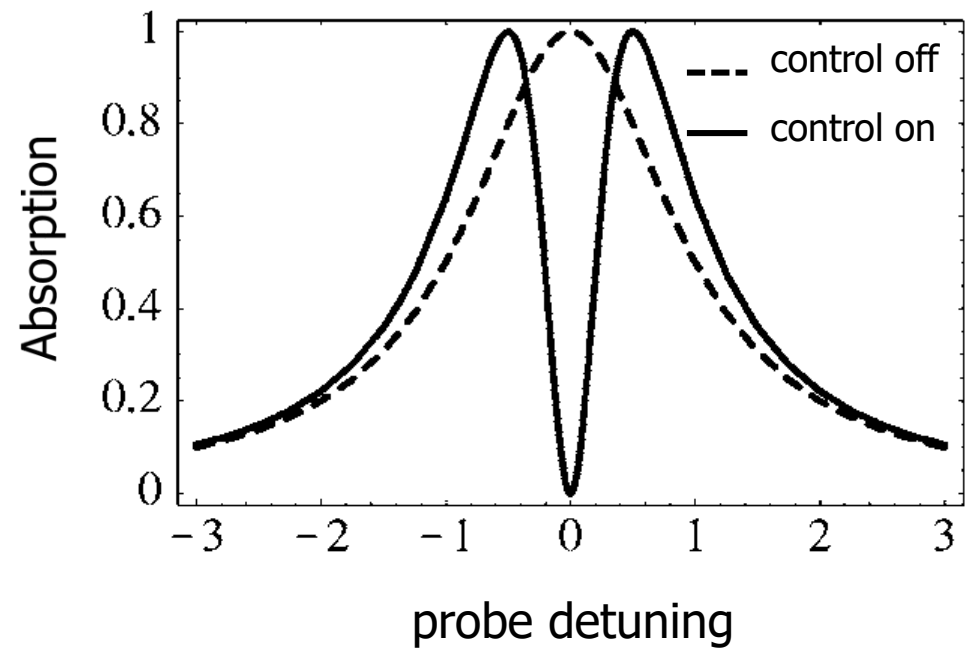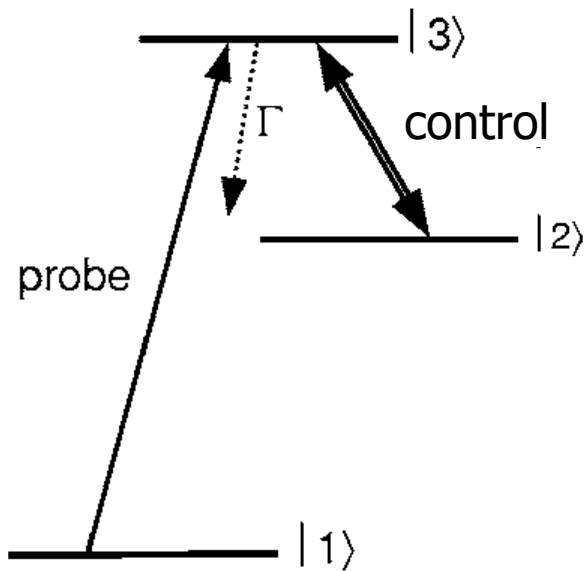
Experimental setup

The power spectral density of the beating signal is measured by a spectrum analyzer.

C. Dong, V. Fiore, M. C. Kuzyk, and H. Wang, Phys. Rev. A 87, 055802 (2013).

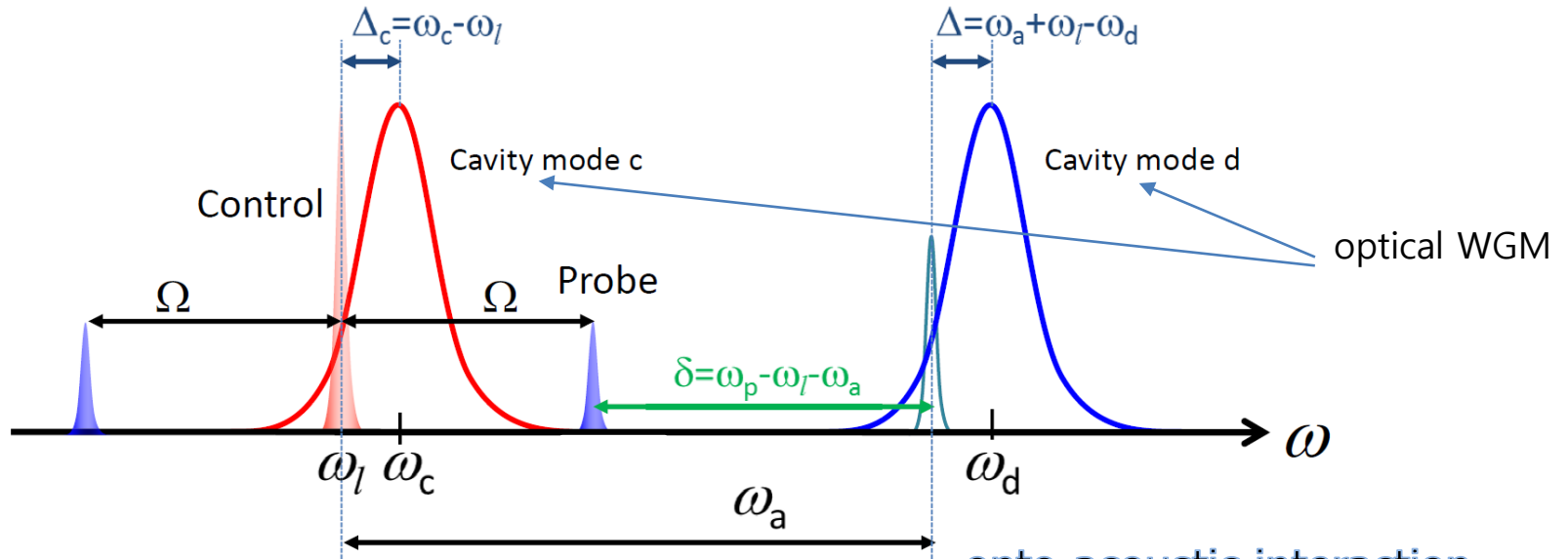# Observation of Brillouin scattering

$\gamma_a \sim 4$ kHz

The spectrum of a acoustic mode

Simulated mechanical mode

Level structure

$$H = \omega_a a^\dagger a + \omega_c c^\dagger c + \omega_d d^\dagger d + \underline{g(a^\dagger c^\dagger d + acd^\dagger)}$$

opto-acoustic interaction

$$+i\sqrt{\kappa_{c,1}}\,\epsilon_l\left(c^\dagger e^{-i\omega_l t} - c e^{i\omega_l t}\right) + i\sqrt{\kappa_{d,1}}\,\epsilon_p\left(d^\dagger e^{-i\omega_p t} - d e^{i\omega_p t}\right)$$

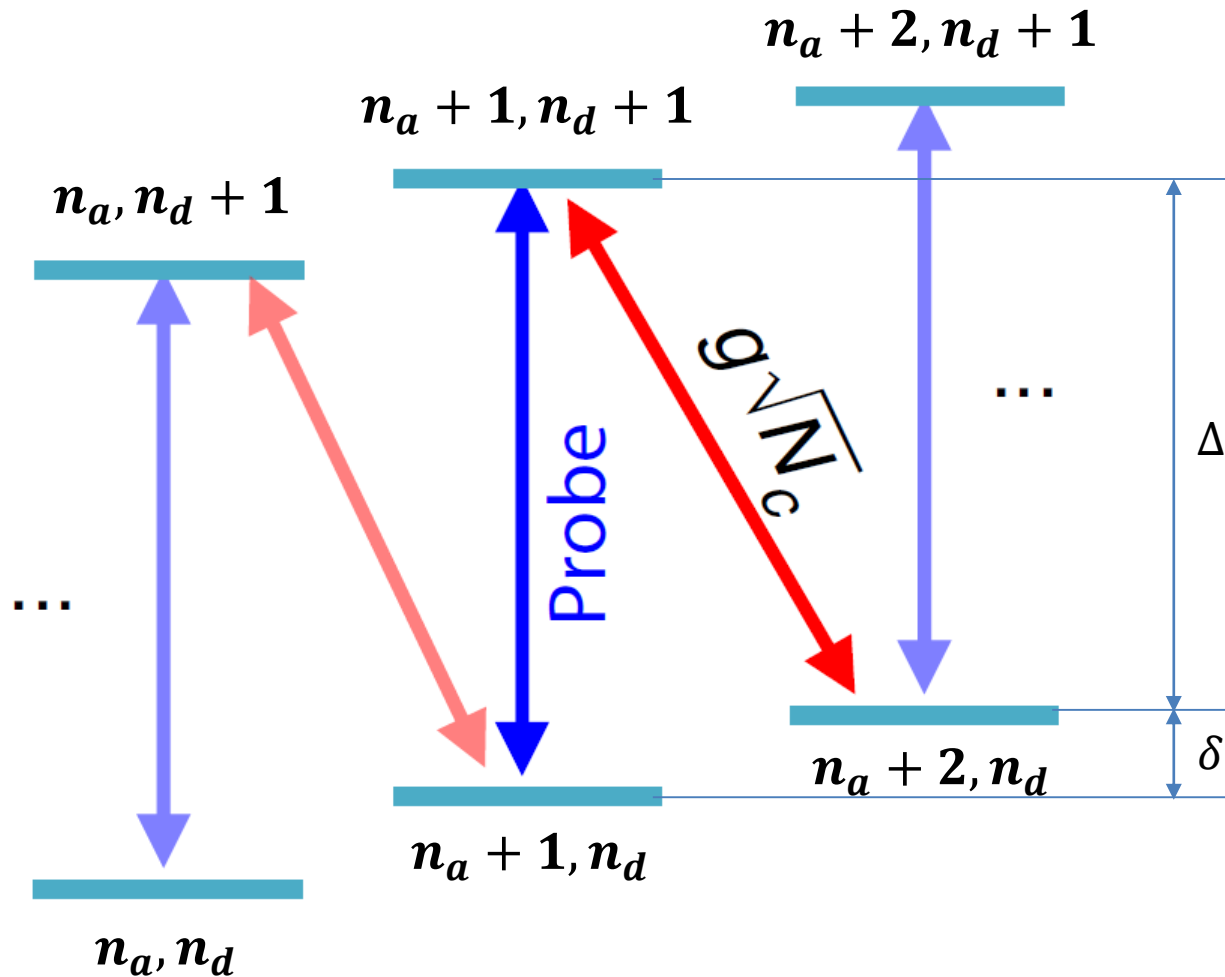driving terms :   control   probe

mode c : classical field

$$H = \omega_a a^\dagger a + \omega_d d^\dagger d + g\sqrt{N_c}\left(a^\dagger d e^{i\omega_l t} + a d^\dagger e^{-i\omega_l t}\right) + i\sqrt{\kappa_{d,1}}\,\epsilon_p\left(d^\dagger e^{-i\omega_p t} - d e^{i\omega_p t}\right)$$

$$H_0 = (\omega_p - \omega_l)a^\dagger a + \omega_p d^\dagger d$$

rotating frame

$$H = -\delta a^\dagger a - (\delta + \Delta)d^\dagger d + g\sqrt{N_c}\left(a^\dagger d + a d^\dagger\right) + i\sqrt{\kappa_{d,1}}\,\epsilon_p\left(d^\dagger - d\right)$$
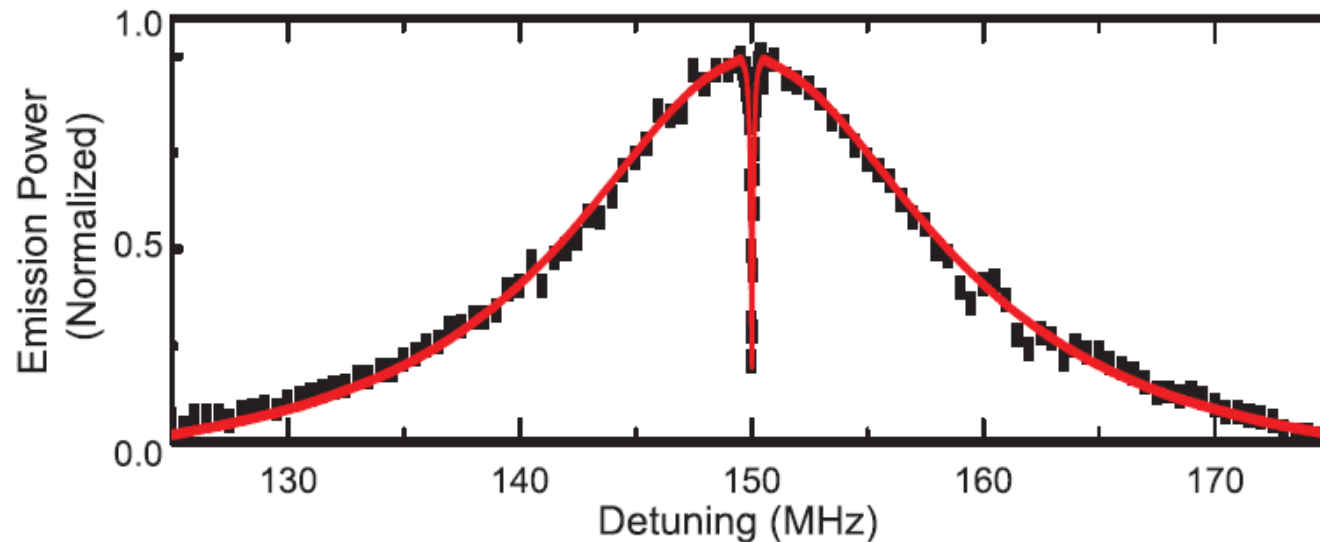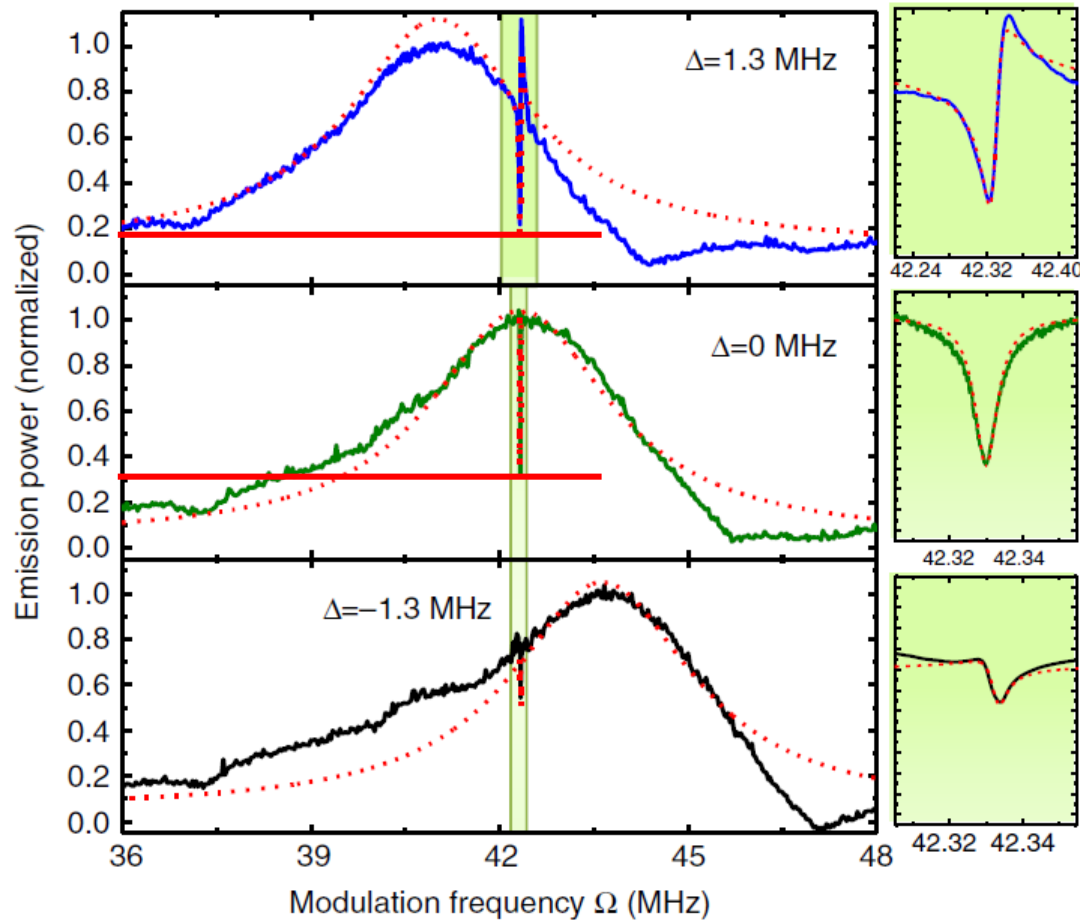
Level structure

$$H = -\delta a^\dagger a - (\delta + \Delta)d^\dagger d + g\sqrt{N_c}\left(a^\dagger d + a d^\dagger\right) + i\sqrt{\kappa_{d,1}}\,\epsilon_p\left(d^\dagger - d\right)$$

Optomechanical dark mode

C. Dong, V. Fiore, M. C. Kuzyk, and H. Wang, Science 338, 1609 (2012).

The deepest dip is observed at $\Delta = 1.3\text{MHz}$, because the triply resonant condition is not exactly satisfied.

$$\Delta = \omega_a + \omega_l - \omega_d$$
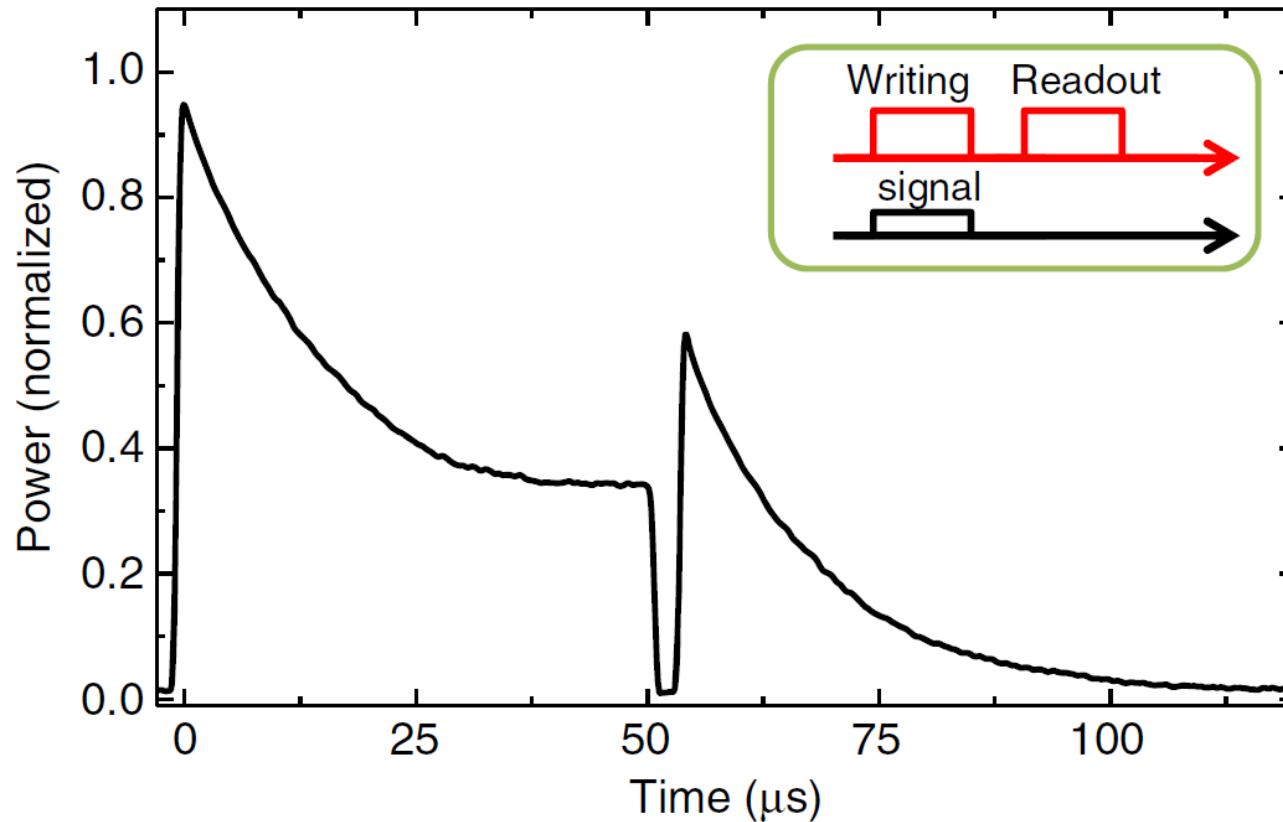
Non-reciprocal light storage
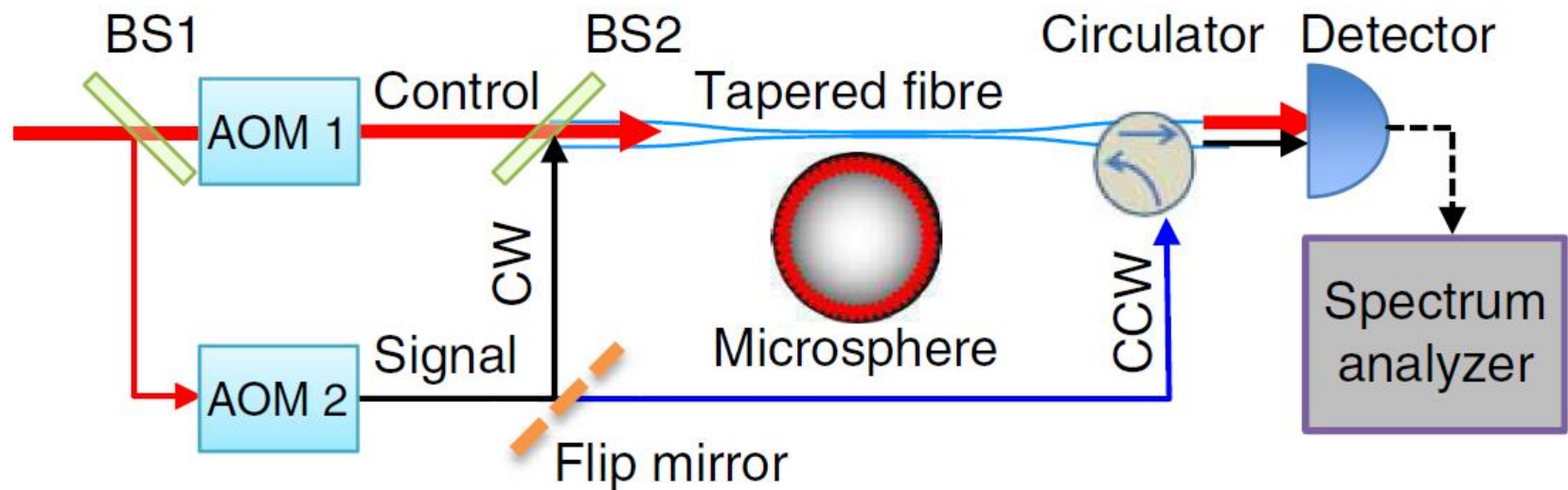
The experimental set-up for the non-reciprocal light storage.

The CW signal is combined with the CW control laser through a beam splitter (BS2). The CCW signal is launched into the fibre through a circulator.
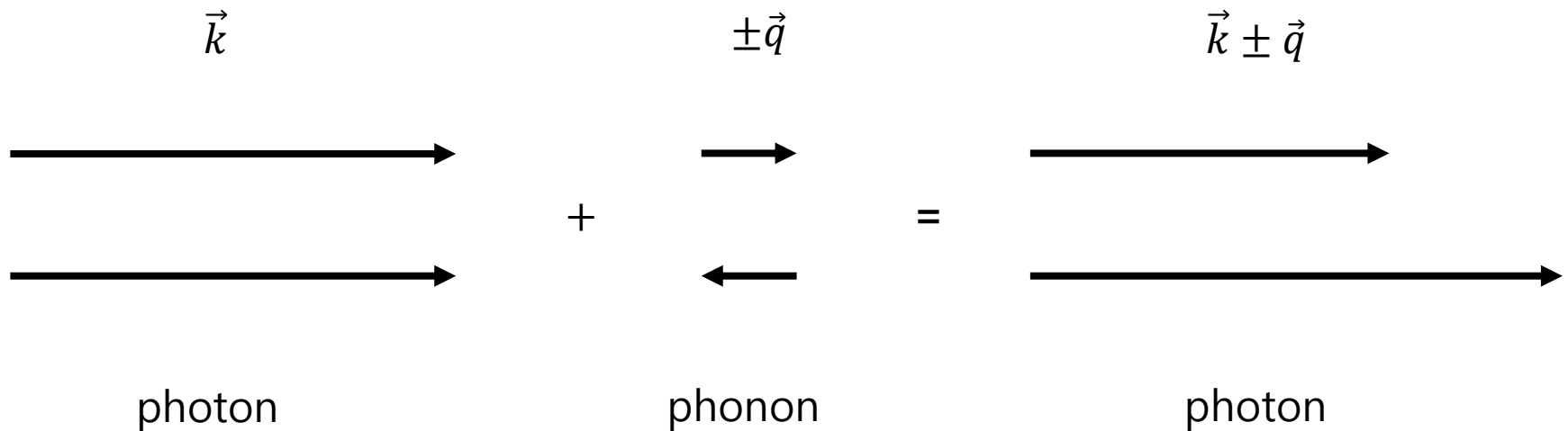
Non-reciprocal light storage
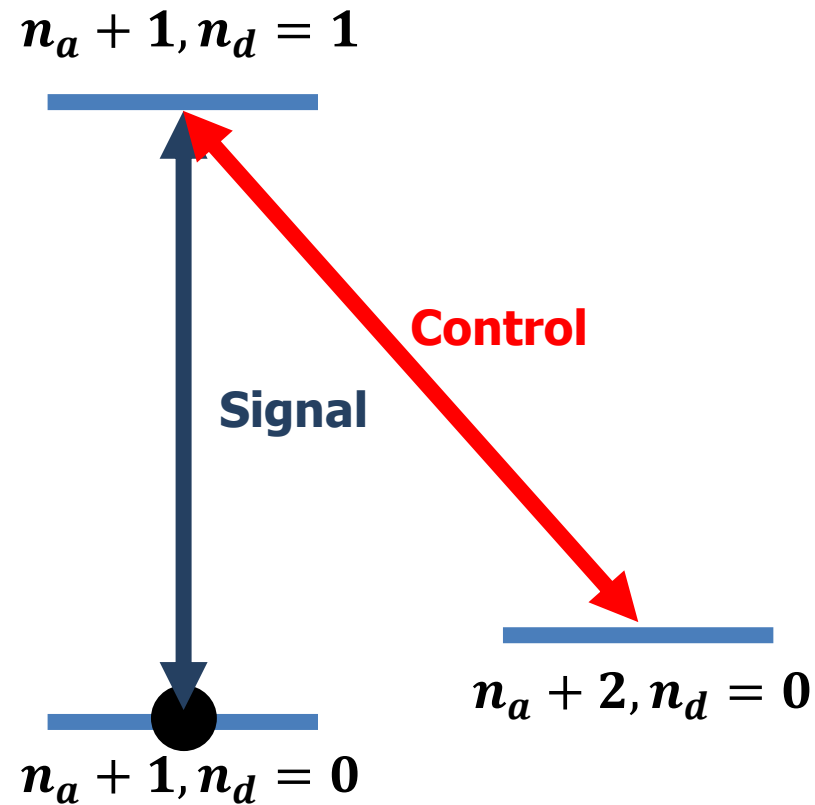
Non-reciprocal light storage

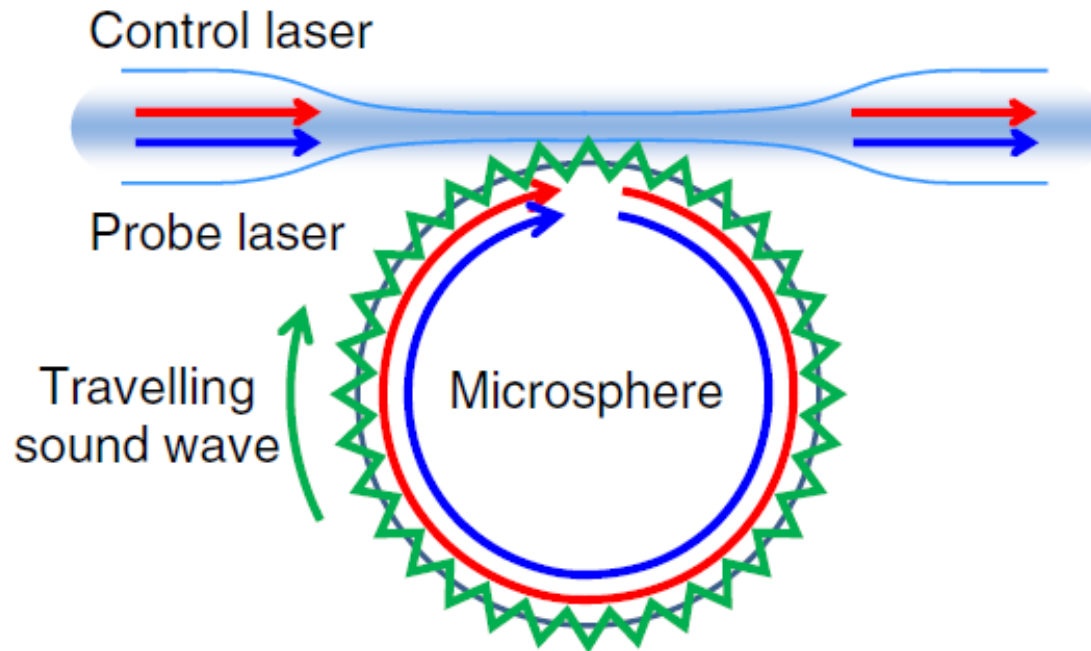The measured intracavity signal power during the storage and retrieval processes

Phase matching condition

$$\vec{k} \qquad\qquad \pm\vec{q} \qquad\qquad \vec{k} \pm \vec{q}$$

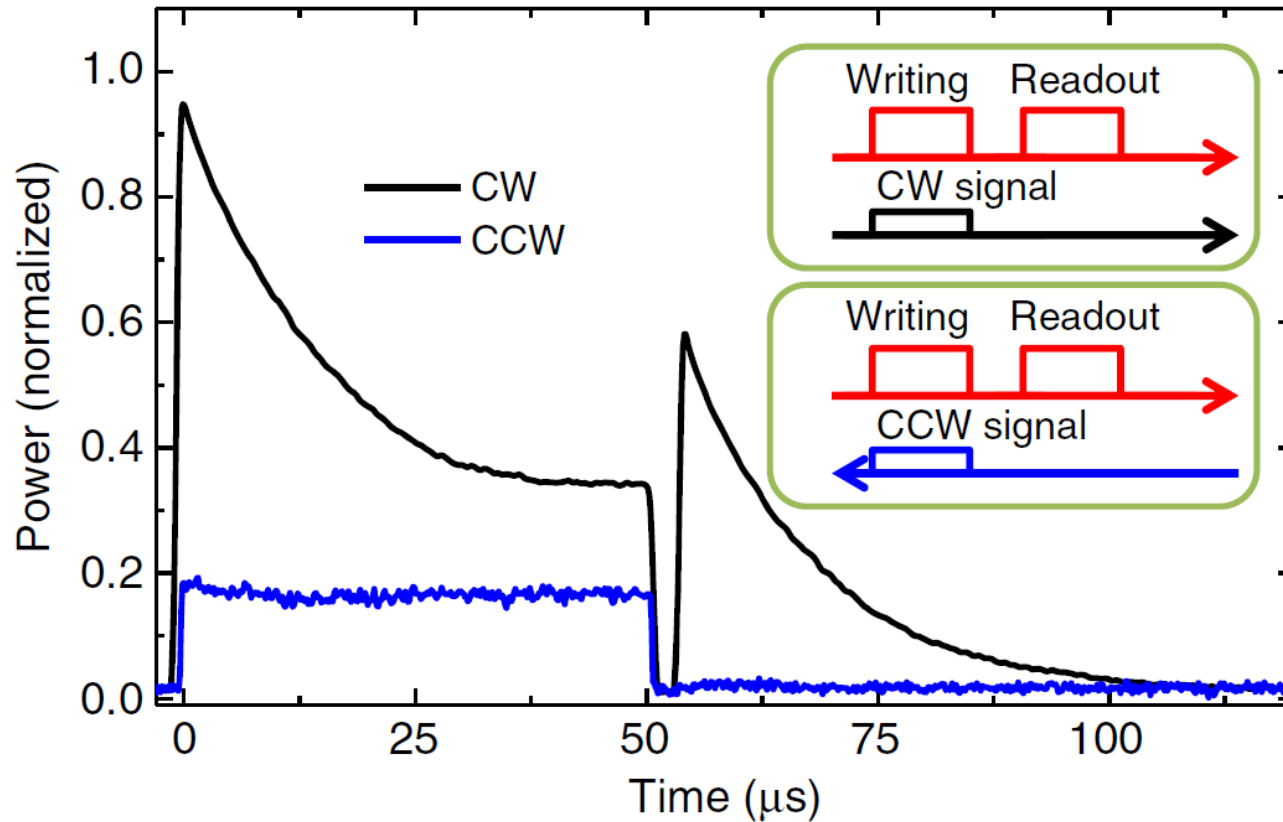photon + phonon = photon

$$|\vec{k}| \gg |\vec{q}|$$

Interacting two optical modes point in the same direction.

Phase matching condition

Interacting two optical modes point in the same direction.
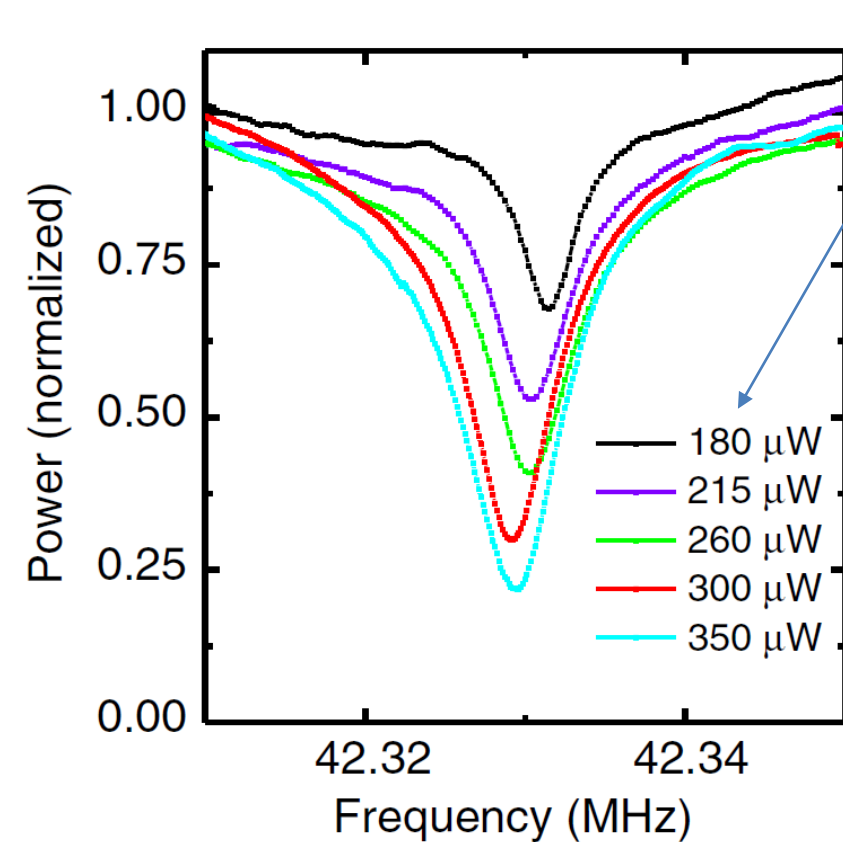
Non-reciprocal light storage

The measured intracavity signal power during the storage and retrieval processes
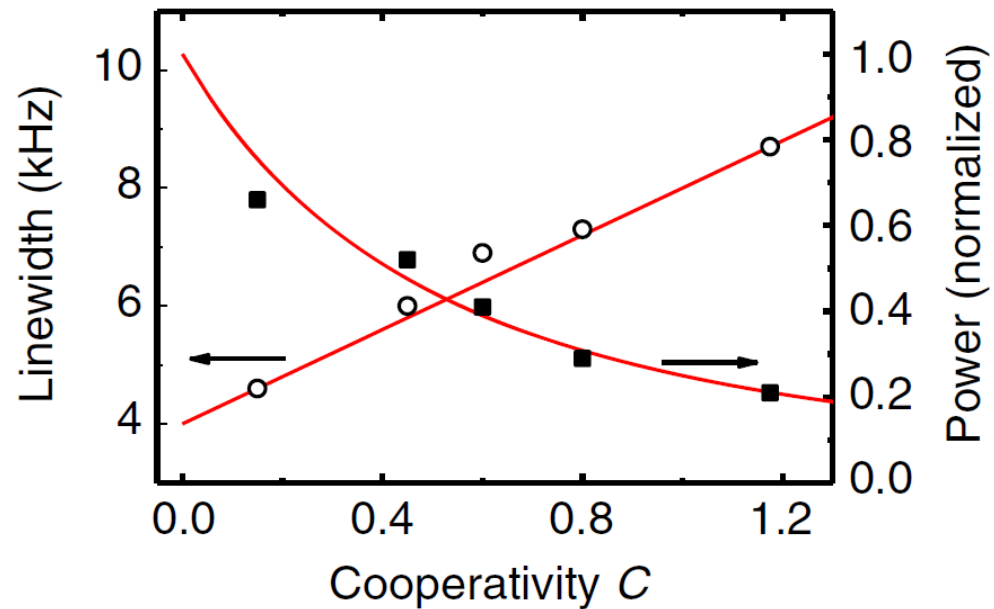
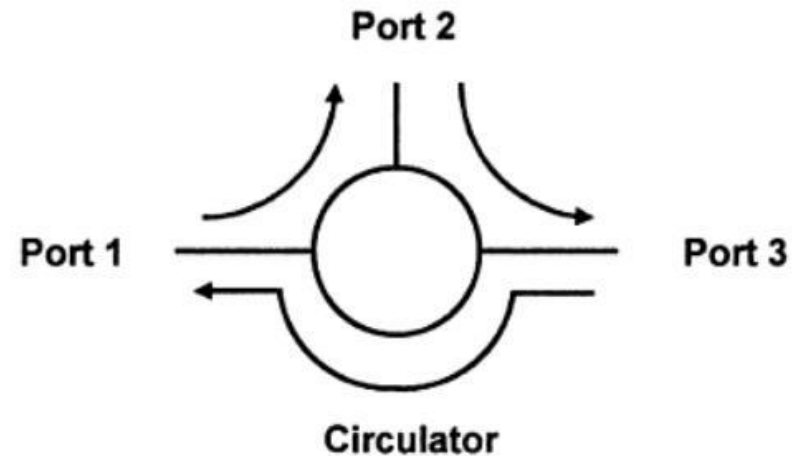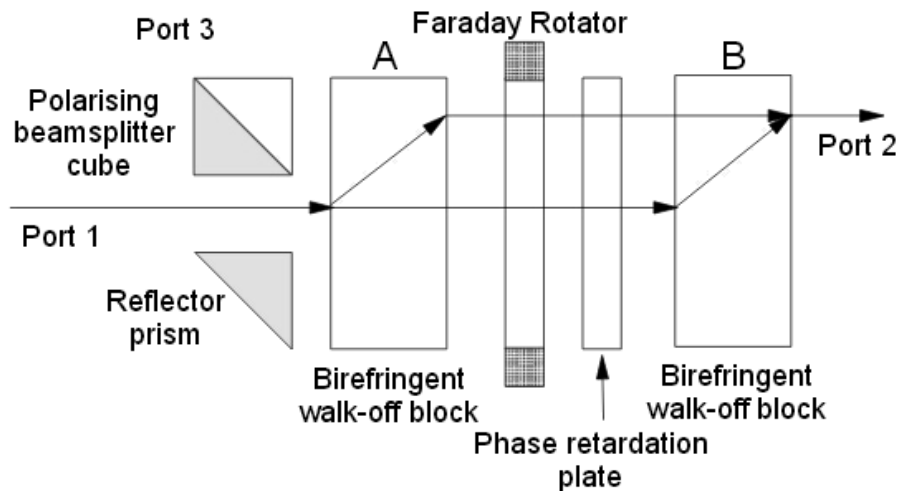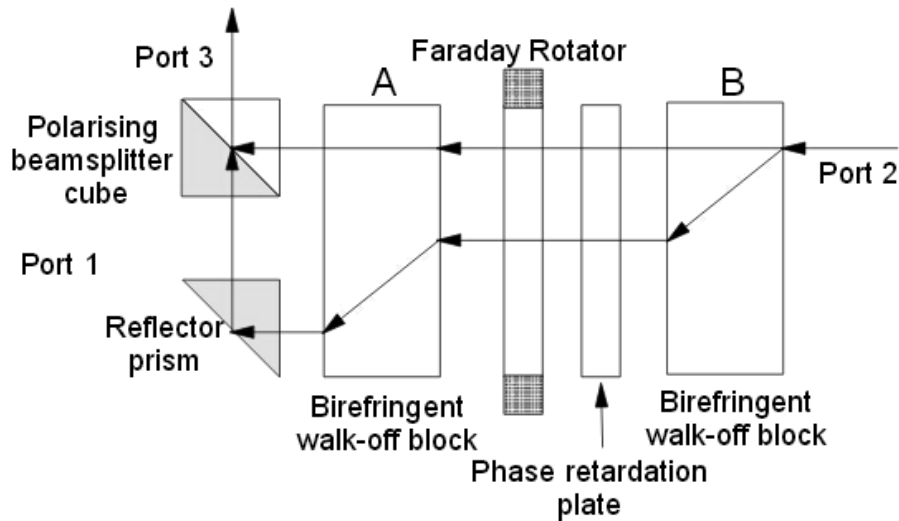# Supplementary Material

Cooperativity dependence of the BSIT dip

different powers of the control beam

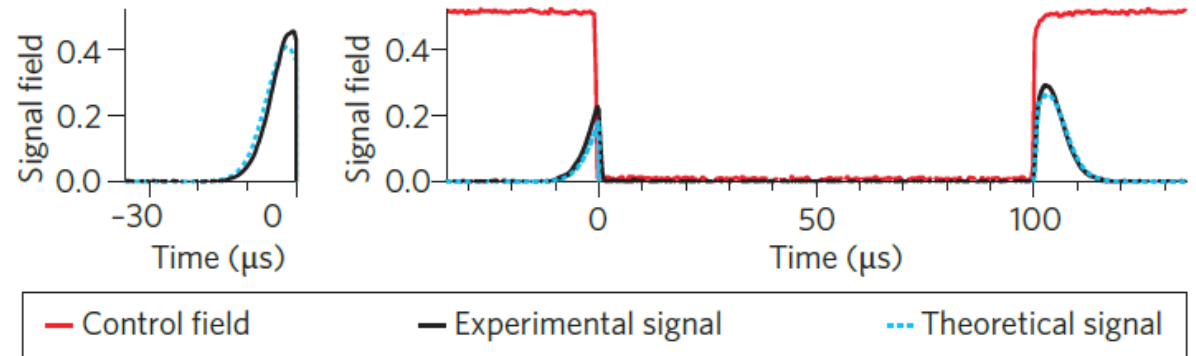depth $\propto 1/(1 + C)^2$

linewidth $\propto (1 + C)$
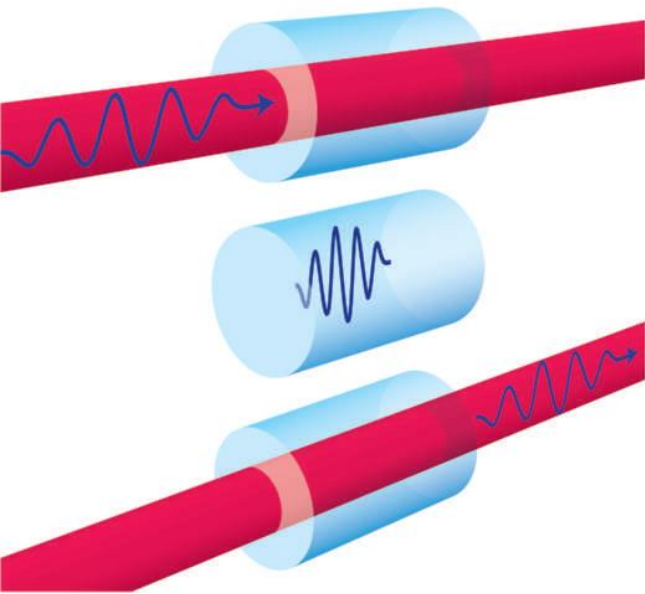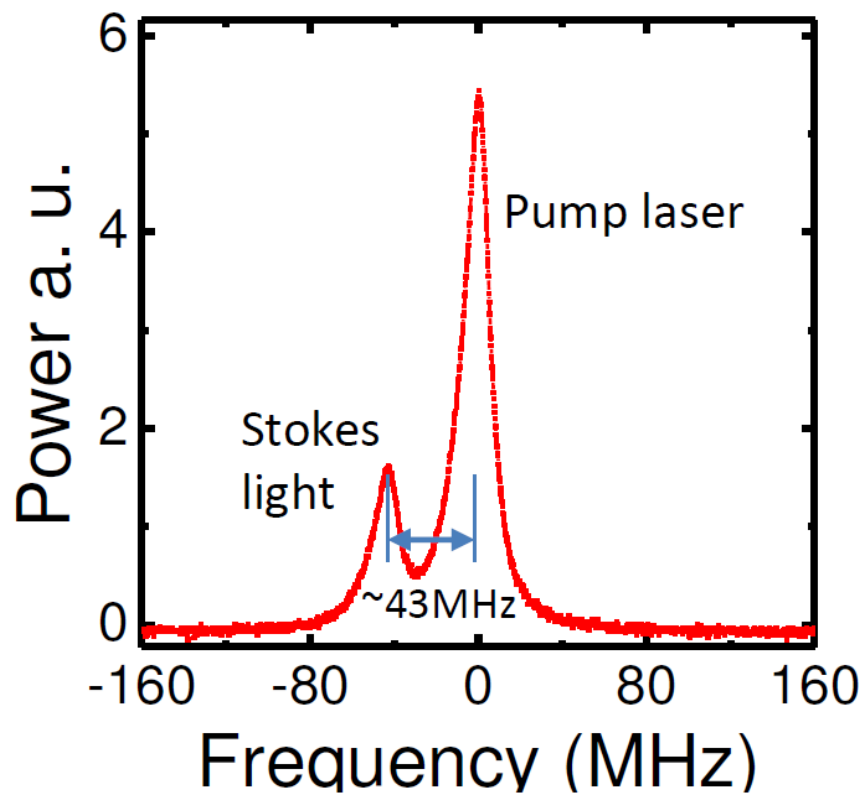
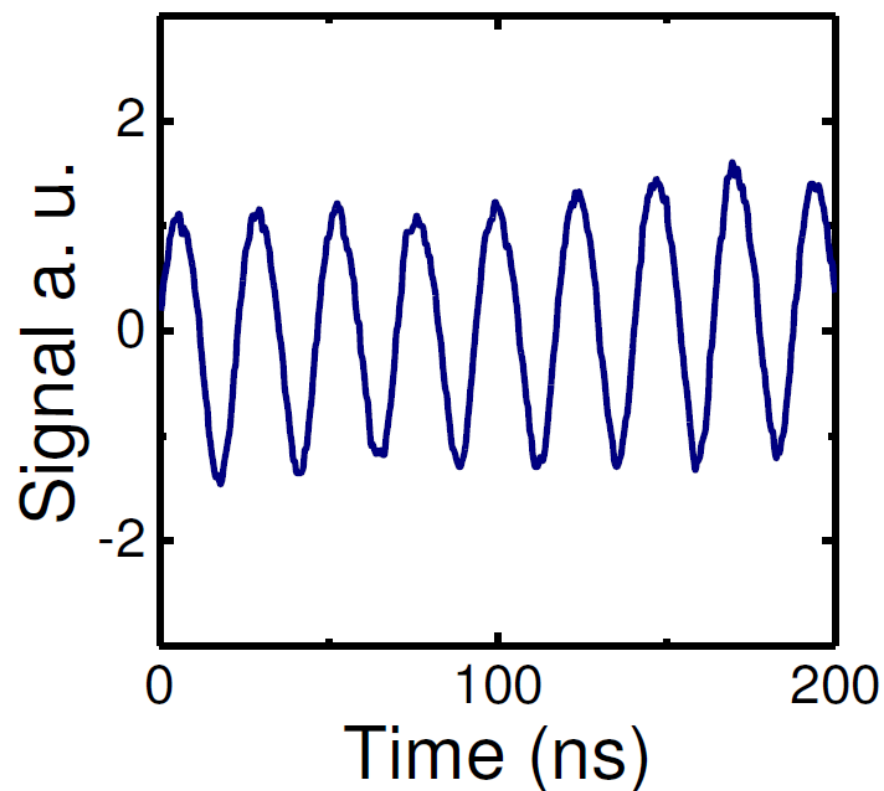$$C \equiv \frac{4g^2 N_c}{\gamma_a \kappa_d}$$

Optical circulator

EIT quantum memory

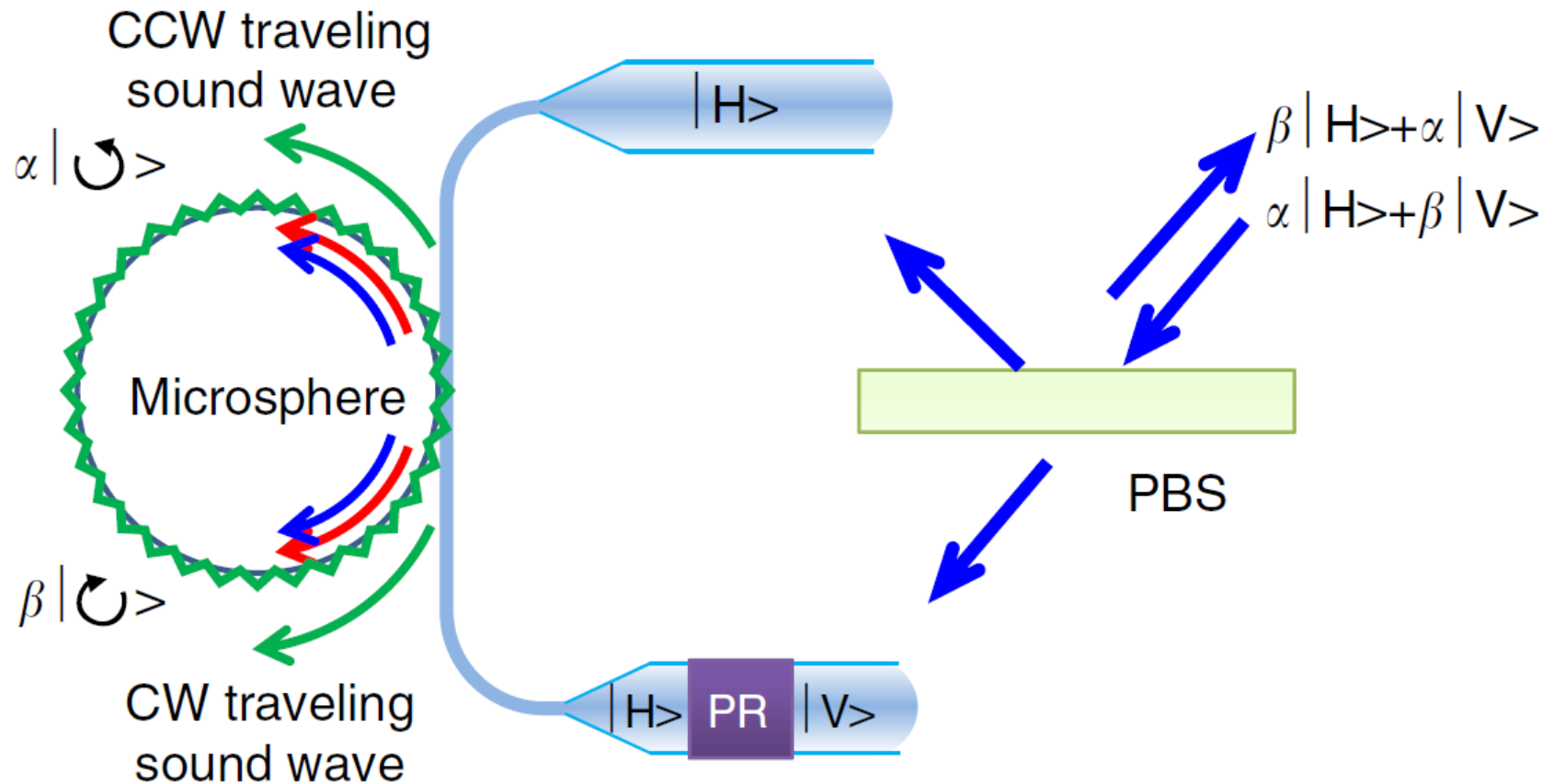A. I. Lvovsky, B. C. Sanders, and W. Tittel, Nat. Photon. 3, 706 (2009).
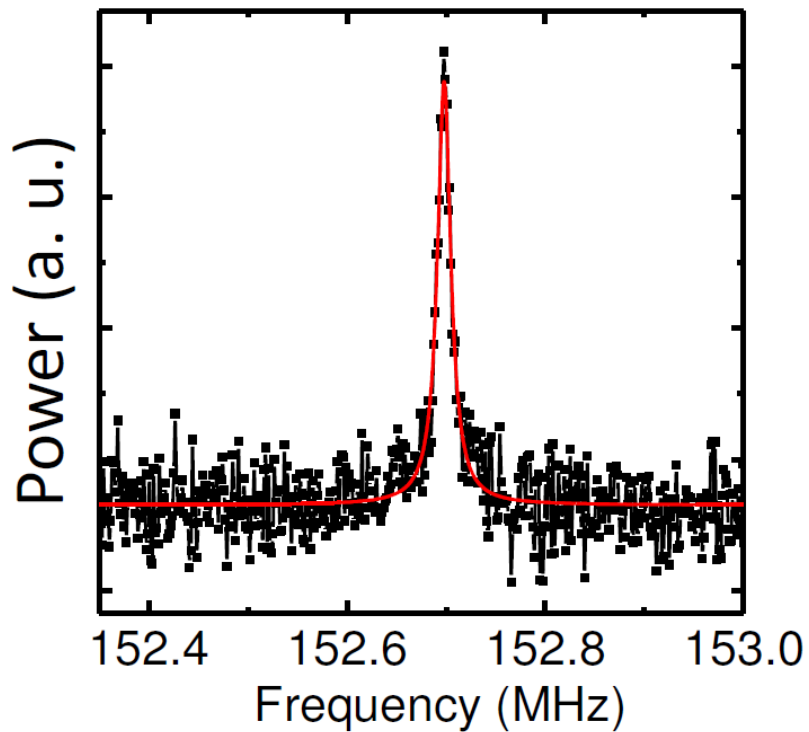
The spectrum of Stokes peak

The beating signal between the two optical signals
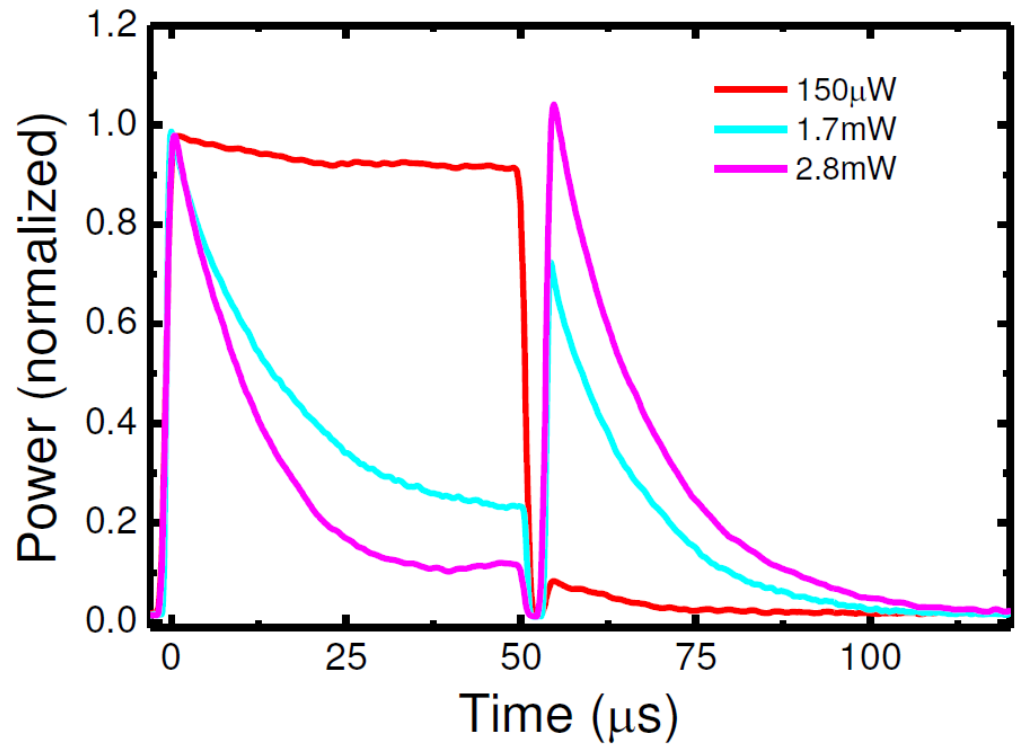
Proposed quantum memory design

Schematic diagram of single-bit quantum memory based on circulating acoustic phonons

PR : polarization rotator

The spectra of the acoustic mode
for the light storage

The storage and retrieval of signal light
with various pump power

Q & A

(slide6) What it the meaning of colors in simulated deformation of microsphere?

It is assumed as strain at each point. Every bending point is red.

(slide13) Why does the beating signal decay?

The paper mentions that curve is fitted well with exponential decay.

Decay time is around $14\mu s$. It originates from underlying dynamic BSIT process.