H1. 00113

OPTOMECHANICAL WAVEGUIDE SYSTEM FOR SWITCHING TELECOM LIGHT

Tomohiro Tetsumoto and Takasumi Tanabe

Department of Electronics and Electrical Engineering, Faculty of Science and Technology, Keio University, Japan

75th Anniversary Science & Technology Keio University

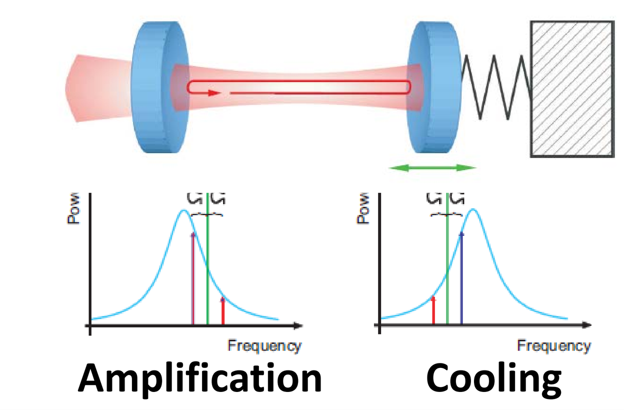
Abstract

- ✓ We numerically study an optomechanical waveguide switching system based on silica zipper cavity.
- ✓ We show the optical and mechanical properties of silica zipper cavity.
- ✓ Due to the 130-nm deformation of the cavity, over 15-dB extinction ratio is obtained.

Background : Cavity optomechanics and Optical MEMS

Cavity optomechanics

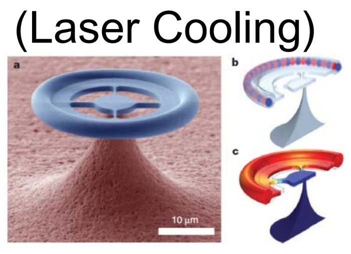
Principle



We can control the optical and mechanical energy by laser detuning.

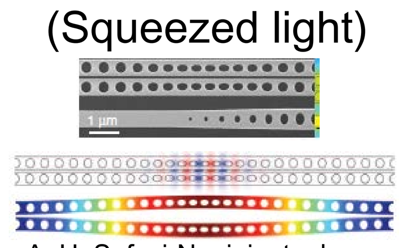
T. J. Kippenberg, K. J. Vahala, Optics Express 15, 17172-17205 (2007)

Toroid cavity (Laser Cooling)



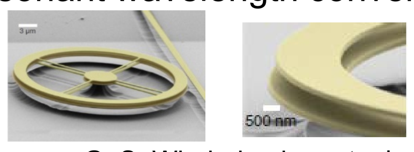
E. Verhagen, et. al., Nature 482, 63-67 (2012)

Zipper cavity (Squeezed light)



A. H. Safavi-Naeini, et. al., Nature 500, 185-189 (2013)

Double disk cavity (Resonant wavelength conversion)

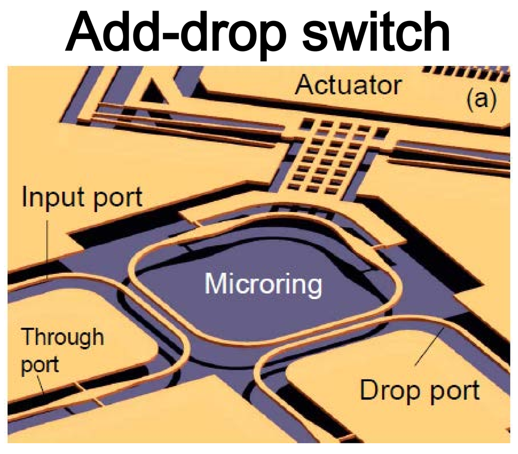


G. S. Wiederhecker, et. al., Nature 462, 633-637 (2009)

- ✓ A lot of fundamental researches are demonstrated.
- ✓ There is little industrial application.

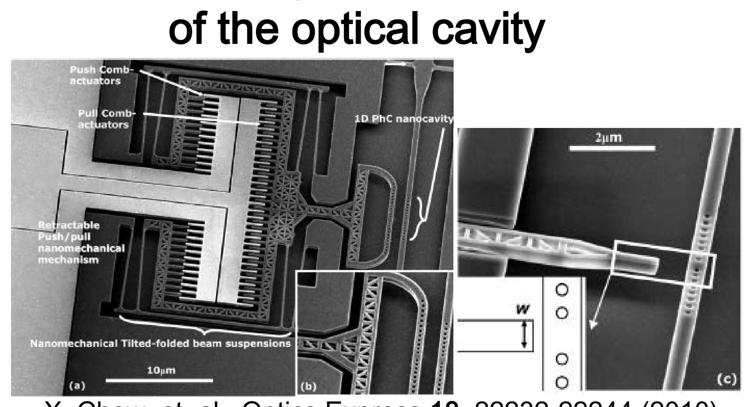
Optical MEMS switch

Add-drop switch



K. Takahashi, et. al., Optics Express 19, 14421-14428 (2008)

Controlling the resonance of the optical cavity



X. Chew, et. al., Optics Express 18, 22232-22244 (2010)

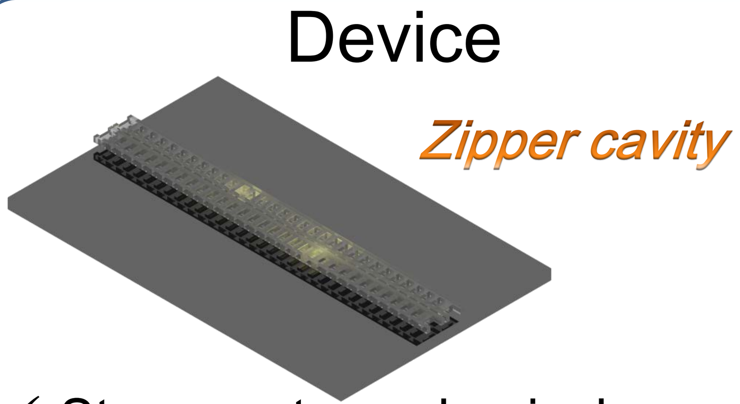
- ✓ Switching contrast is very high.
- ✓ Electrodes and complex structures are needed.

Introduction of our research

Motivation

- ✓ To make the switching system which is operated by the optical force.
- ✓ To inspect the possibility of the optomechanical switch.

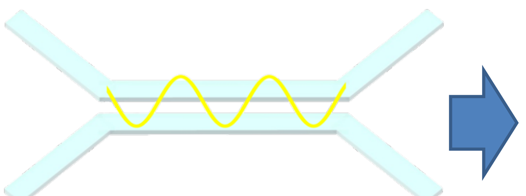
Device



- ✓ Strong optomechanical coupling
- ✓ Easy to make on-chip

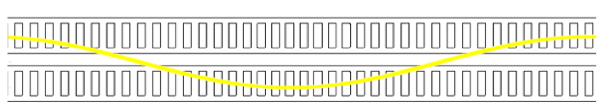
Operating principle

Directional coupler



This enables the direction change of light.

An initial state



Cavity in resonance

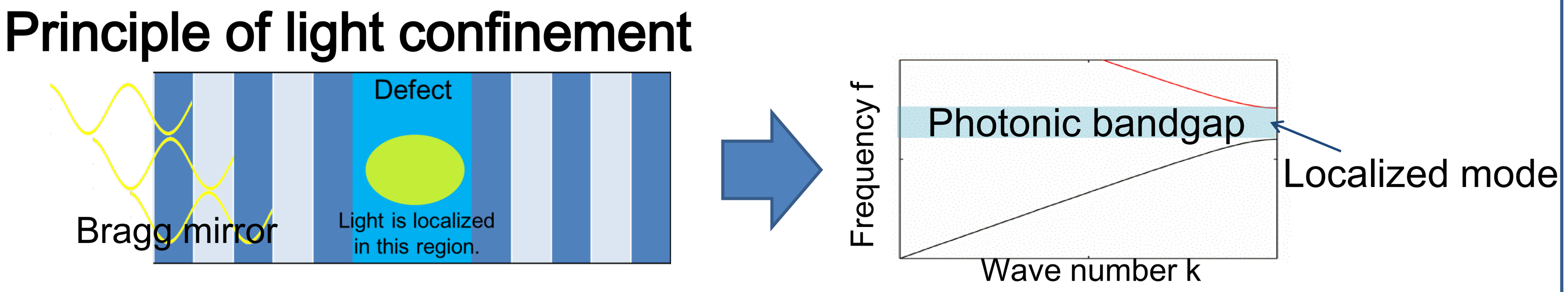
Induced optical force deform the cavity and the propagation direction of light is switched.

Light wavelength of the system

- ✓ Resonant light wavelength : 770 nm (infrared light).
- ✓ Signal light wavelength : 1550 nm (telecom light).

Problem and our solution

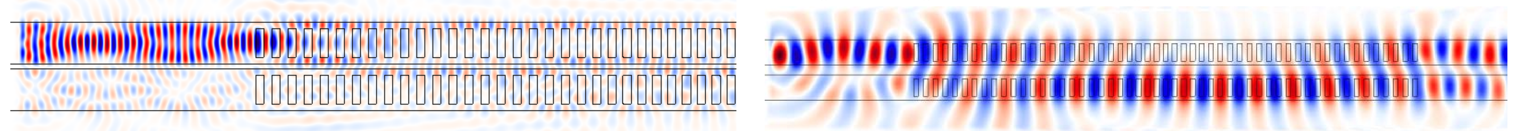
Principle of light confinement



Problem of using nanobeam cavity as a waveguide

Cavity resonant wavelength: 1550 nm
Signal light wavelength: 1580 nm

Cavity resonant wavelength: 800 nm
Signal light wavelength: 1550 nm



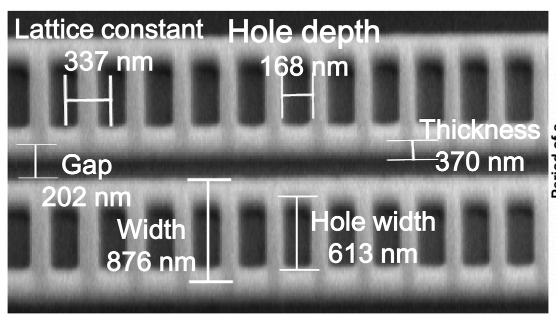
Ultra-broad wavelength range is demanded ⇒ silica

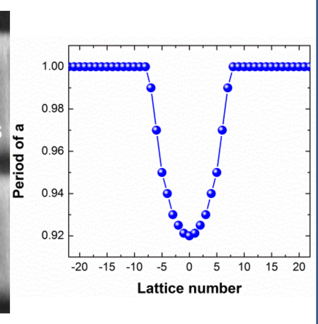
Other advantages of confining the visible light

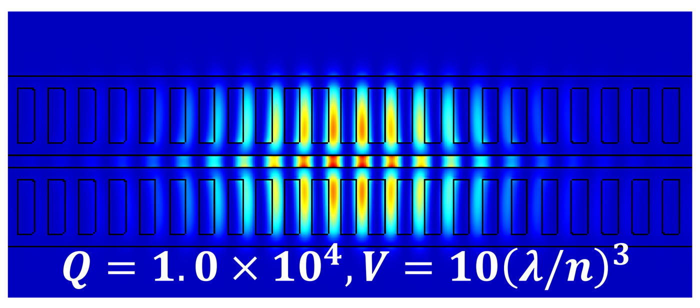
- ✓ Small size and high mechanical frequency
- ✓ High photon energy

Optical and Mechanical design of the cavity

Optical design of the cavity

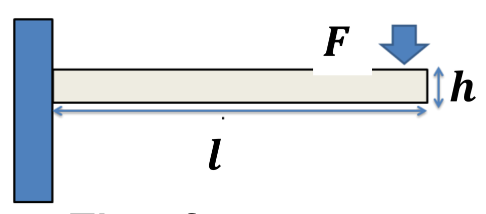






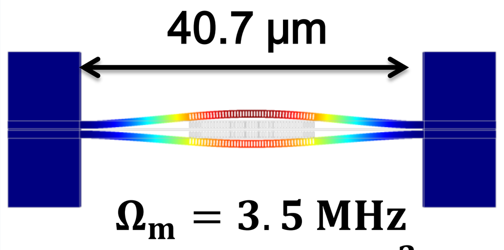
Mechanical design of the cavity

Cantilever model



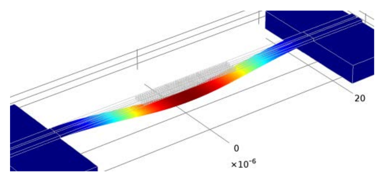
Deformation $\propto l^3/h^3$

Eigenfrequency



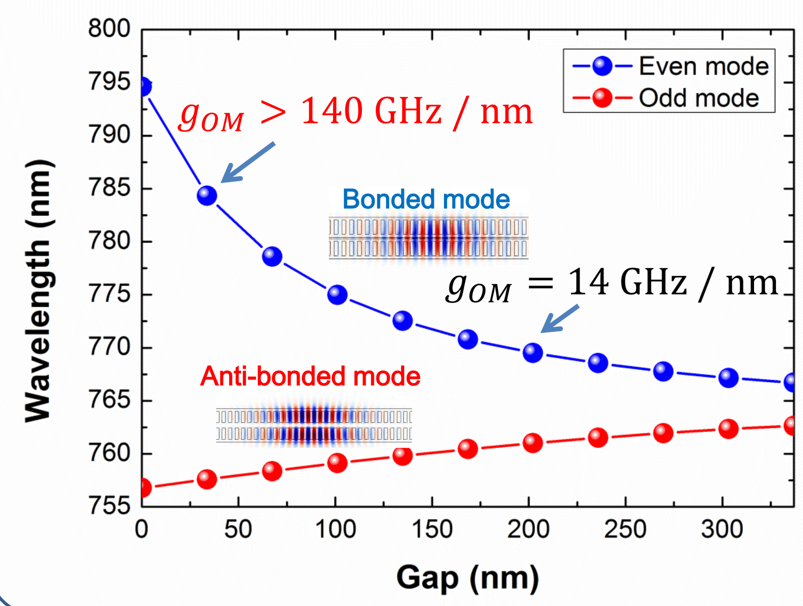
$\Omega_m = 3.5$ MHz
$Q_m = 1.5 \times 10^2$
(in a vacuum)

Distortion by the gravity

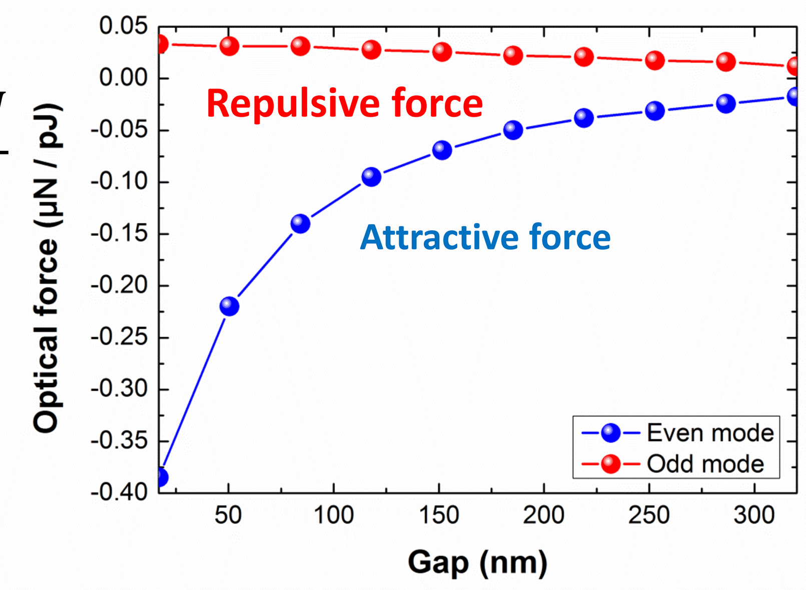


0.19 pm
(Extremely small)

The relationship between the gap change and the resonant wavelength

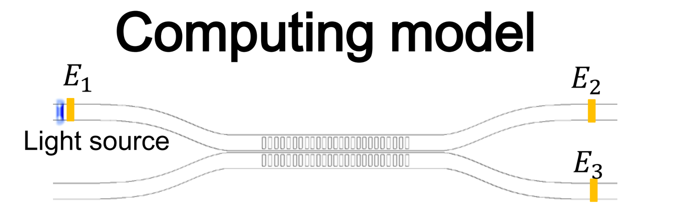


$$F = -\frac{dU}{ds}$$



Analysis of the light propagation

Computing model



E_1, E_2, E_3 are the sampling point of the energy.

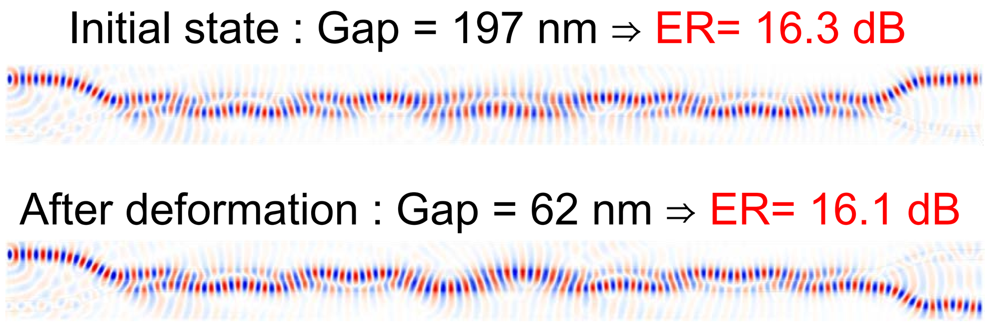
Definition of extinction ratio (ER)

$$\mathrm{ER} = \left|10\log\left(\frac{E_1}{E_2}\right) - 10\log\left(\frac{E_1}{E_3}\right)\right|$$

Result

Initial state : Gap = 197 nm ⇒ ER= 16.3 dB

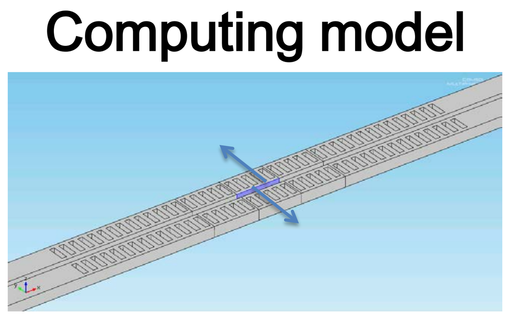
After deformation : Gap = 62 nm ⇒ ER= 16.1 dB



Over 15-dB extinction ratio is obtained due to the135-nm deformation.

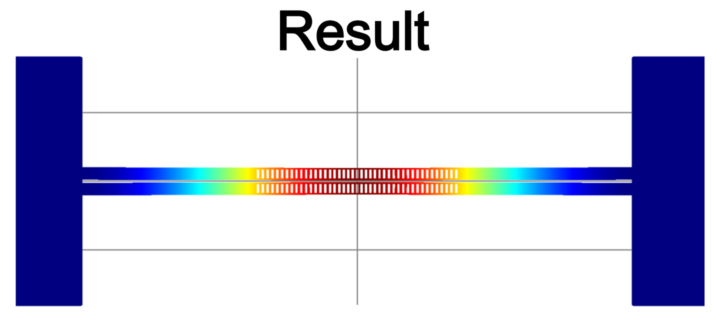
Mechanical deformation

Computing model



We apply the boundary load to the center of the cavity and compute the deformation of stationary state.

Result



About 130-nm deformation is obtained by 1.5 W input power.

Conclusion

- ✓ We shows the optical and mechanical properties of silica zipper cavity.
- ✓ The computing results show that 1.5-W input power deform the cavity 130 nm and then over 15-dB extinction ratio is obtained.
- ✓ To reduce the driving power, optimization of the structure and light propagation model is required.