
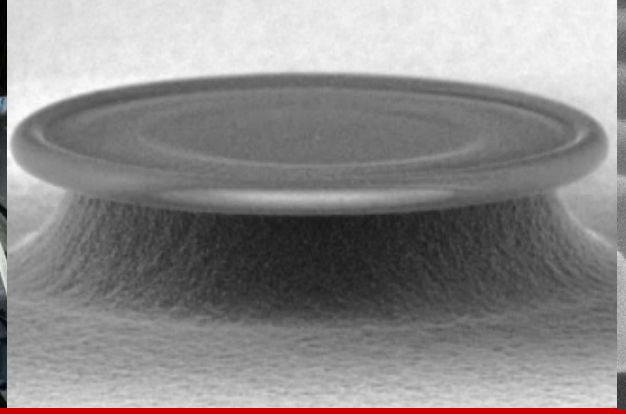
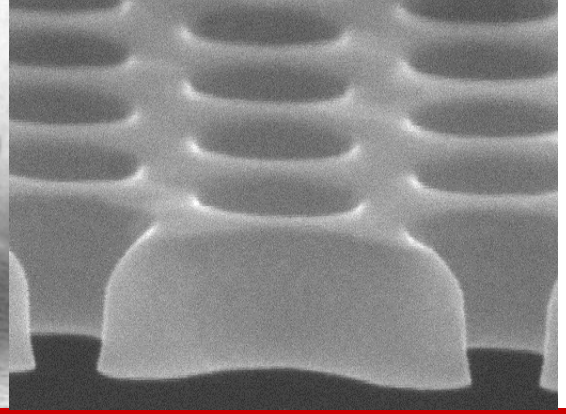
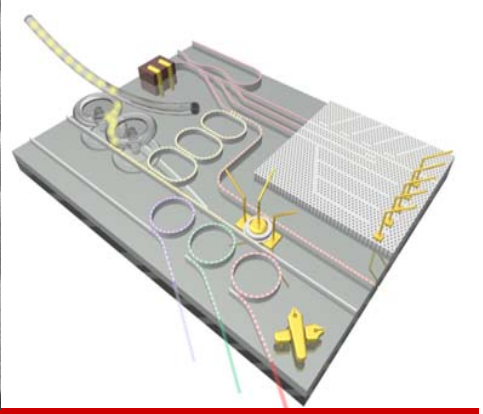

CLEO Europe 2015
CK-9.4 Photonic Micro- and Nanocavities

Nanocavity Formation with a *Q* of a Half-million using Photonic Crystal Waveguide and Nanofiber

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T. Tetsumoto, Y. Ooka, A. Fushimi, and T. Tanabe

Background

Photonic crystal (PhC) nanocavity

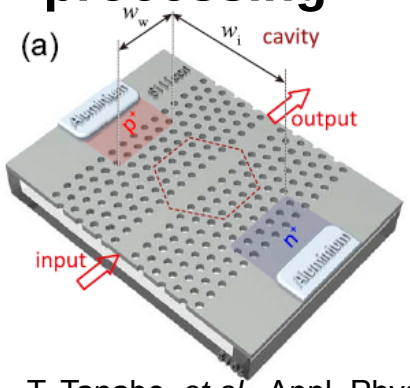
Advantages

- ✓ High *Q* & extremely small *V*
- ✓ Suitable for integration

Disadvantages

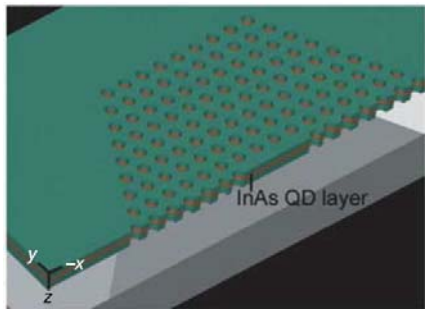
- ✓ Coupling to fiber is poor
- ✓ Collection efficiency is low

Optical signal processing



T. Tanabe, *et al*., Appl. Phys. Lett. **96**, 101103 (2010).

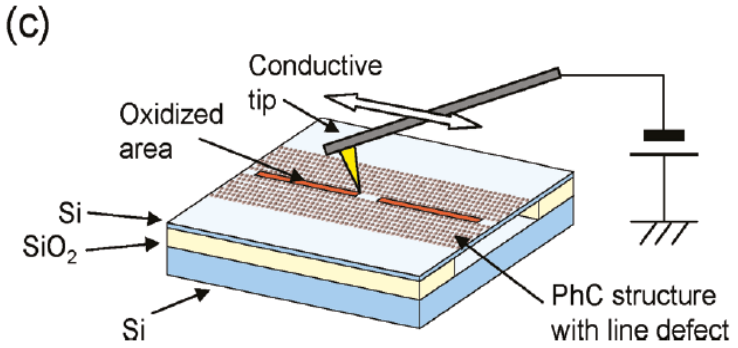
Quantum optics



T. Yoshie, *et al*., Nature **432**, 200-203 (2004).

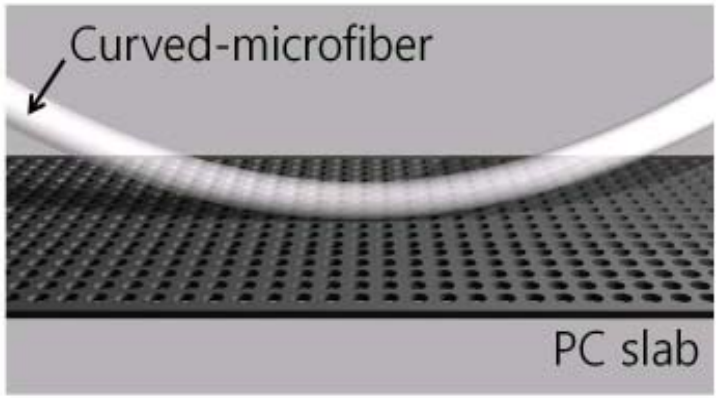
Post-formation of PhC

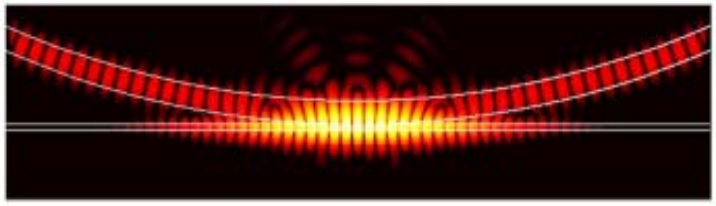
- ✓ Controlability of resonant wavelength & position
- ✓ High *Q* cavity (> 10^6)
- ✓ Relocation of the cavity not possible



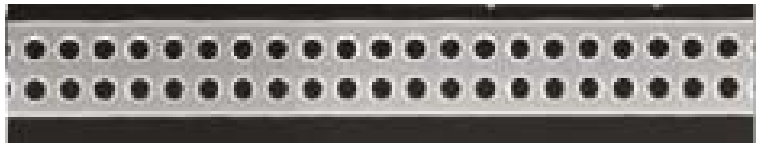
A. Yokoo, *et al*., Nano lett. **11**, 3634-42 (2011).

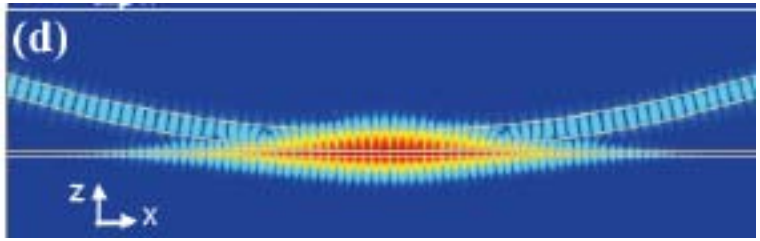
Nanofiber assisted relocatable nanocavity





Ju-Young Kim, *et al*., Optics Express **17**, 13009 (2007).





Hee-J. Lim, *et al*., Optics Express **21**, 6724 (2013).

Advantages

- ✓ Is reconfiguable
- ✓ High Q (>10^7) & high coupling efficiency (CE of nearly 100%) theoretically

Experimental values

2D photonic crystal waveguide

- ✓ $Q = 5.8 \times 10^3$, CE 2.2%

1D dual-rail photonic crystal waveguide

- ✓ $Q = 1.1 \times 10^4$, CE 30%

CE: coupling efficiency

Bottlenecks

- ✓ Absorption of quantum dots
- ✓ Fabrication imperfections

Objectives & report

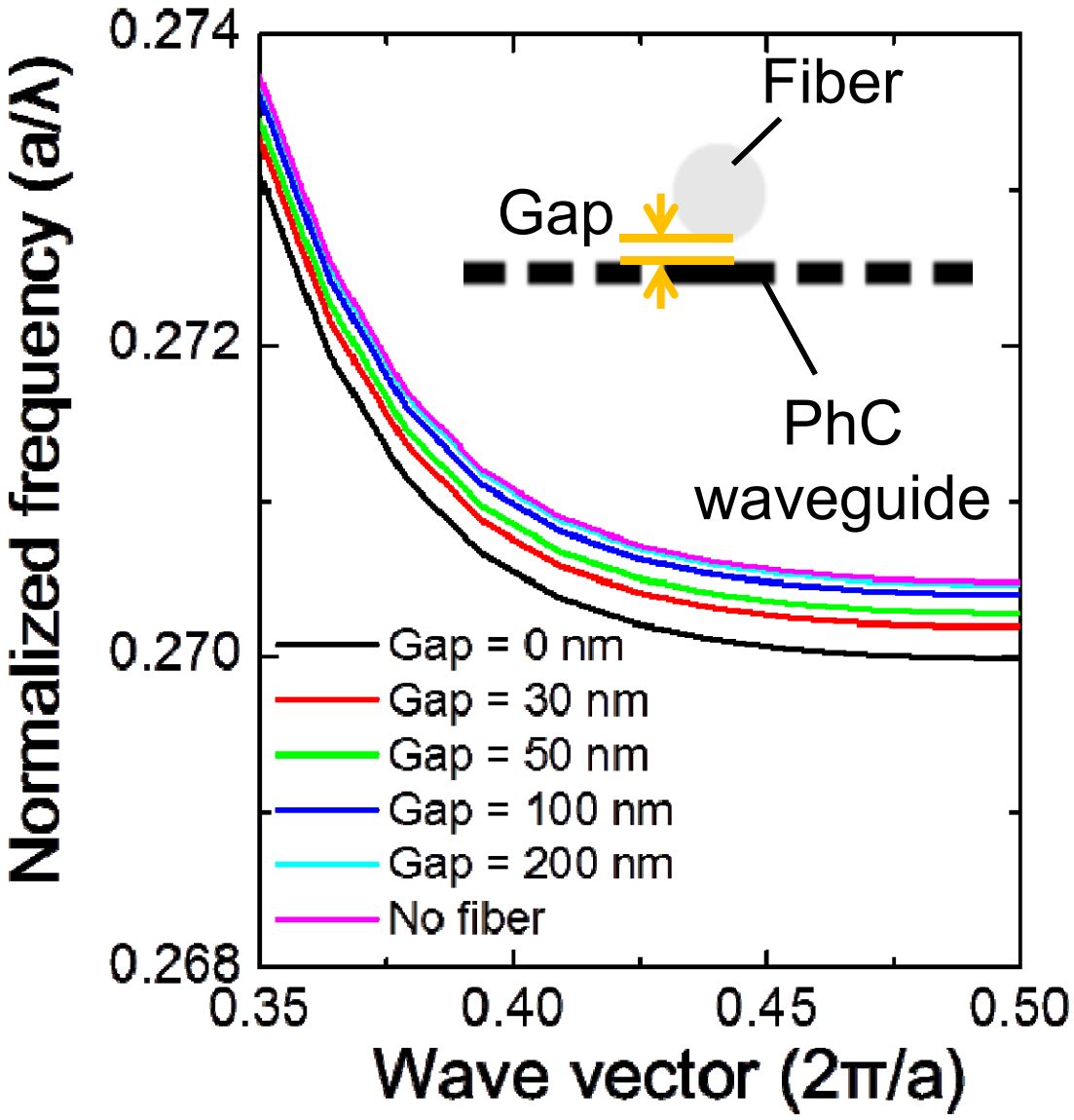
Motivations

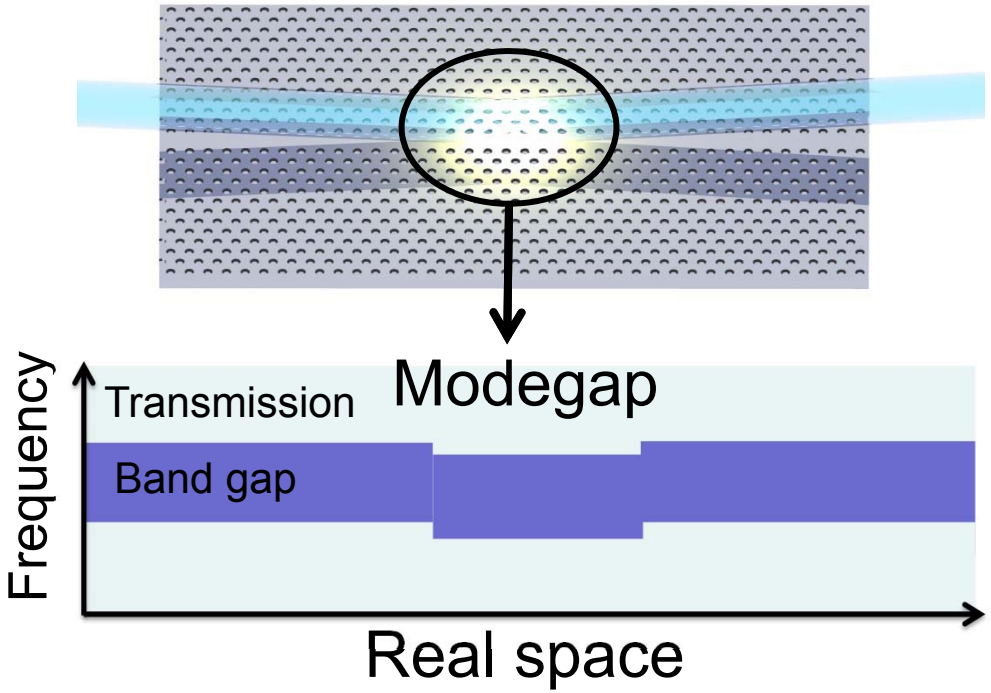
- ✓ High *Q* cavity formation on Si PhC waveguide
- ✓ Achieving high coupling efficiency
- ✓ Tuning resonant wavelength of nanocavity

In addition,
All-pass filter type coupled cavity resonance will be reported

Principle of cavity formation

Cavity formation model

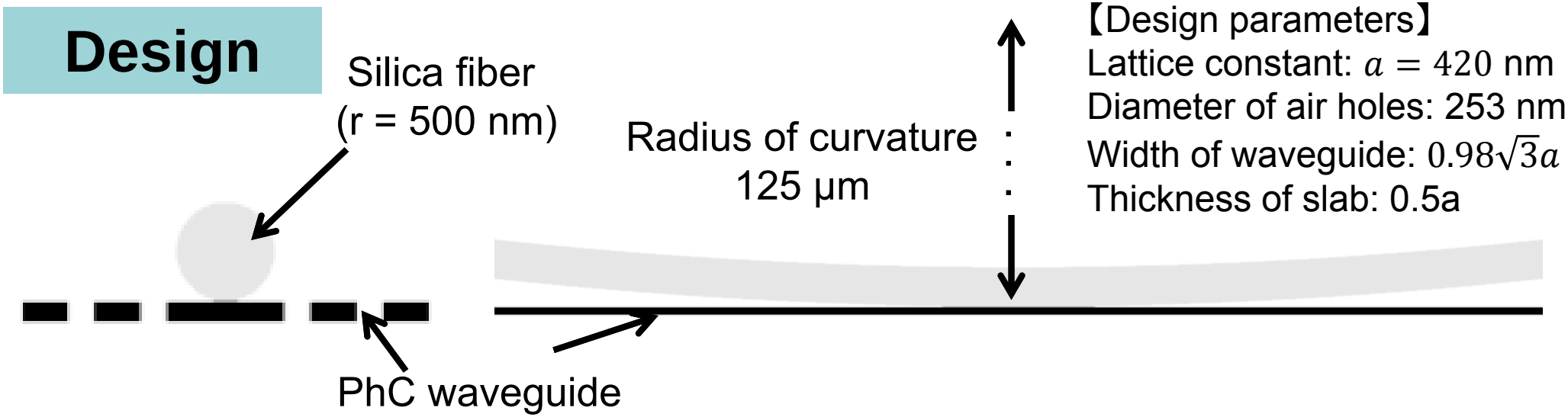




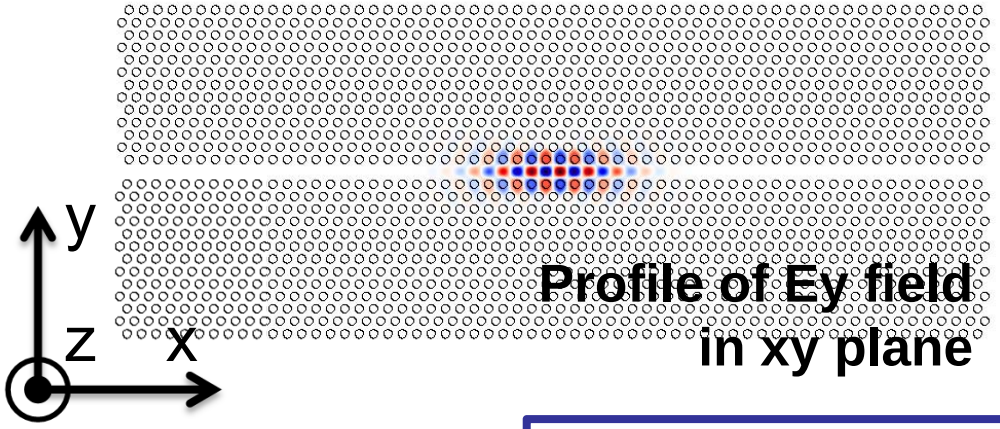
Effective refractive index change results in formation of modegap cavity

Numerical calculation

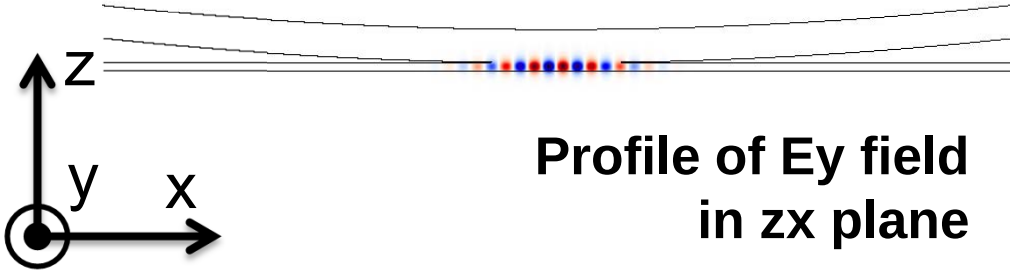
Design



Result



Profile of Ey field in xy plane



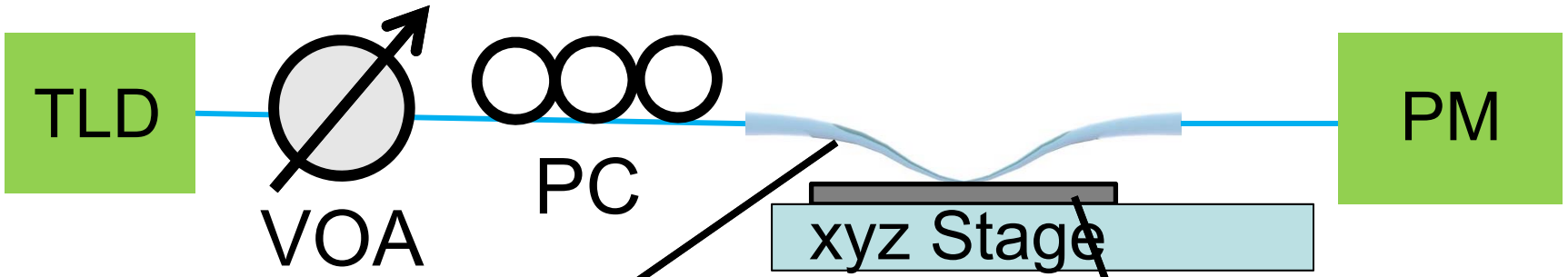
Profile of Ey field in zx plane

$Q = 1.4 \times 10^7, V = 1.9(\lambda/n)^3$ was obtained

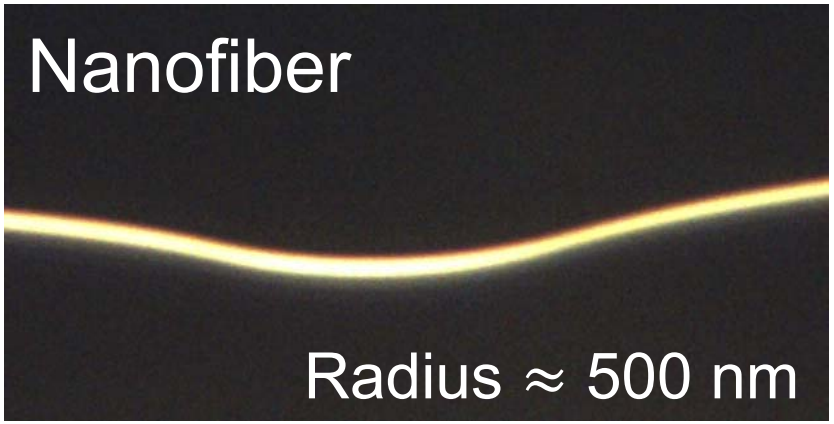
Experiment

Setup

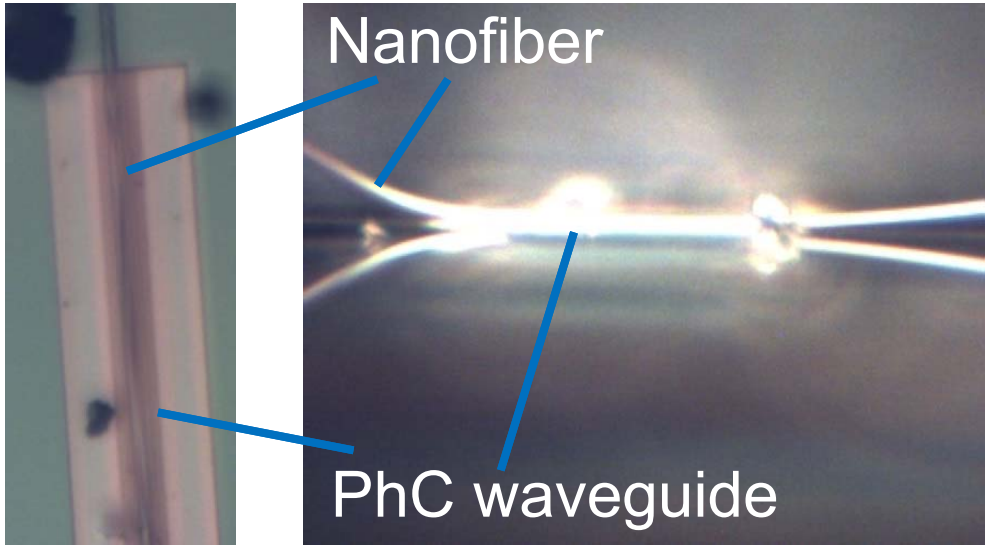
TLD: Tunable Laser Diode, VOA: Variable Optical Attenuator,
PC: Polarization Controller, PM: Power Monitor



PhC waveguide(W0.98)
Lattice constant: 420 nm,
Air hole diameter: 253 nm,
Slab thickness: 210 nm

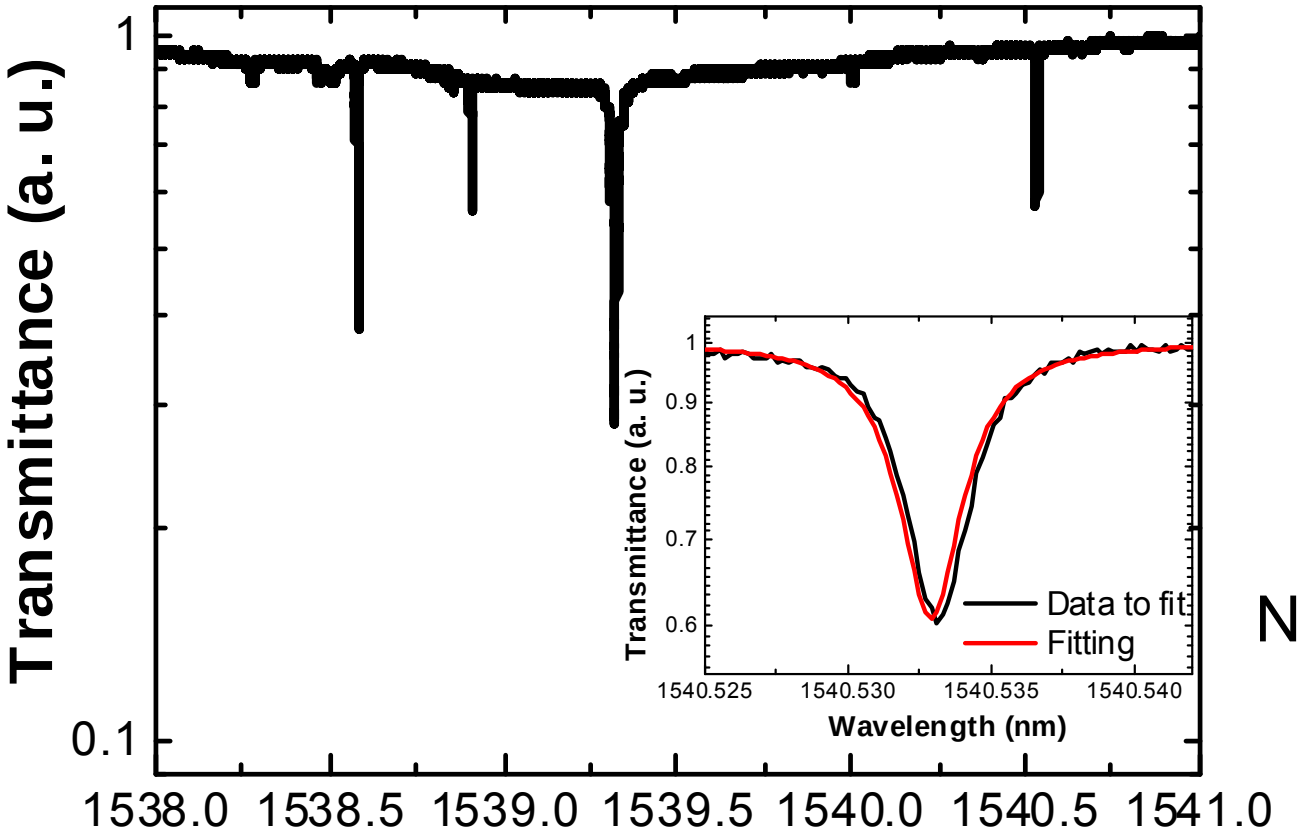


Insertion loss of nanofiber:
Typically 10 dB



Experimental results

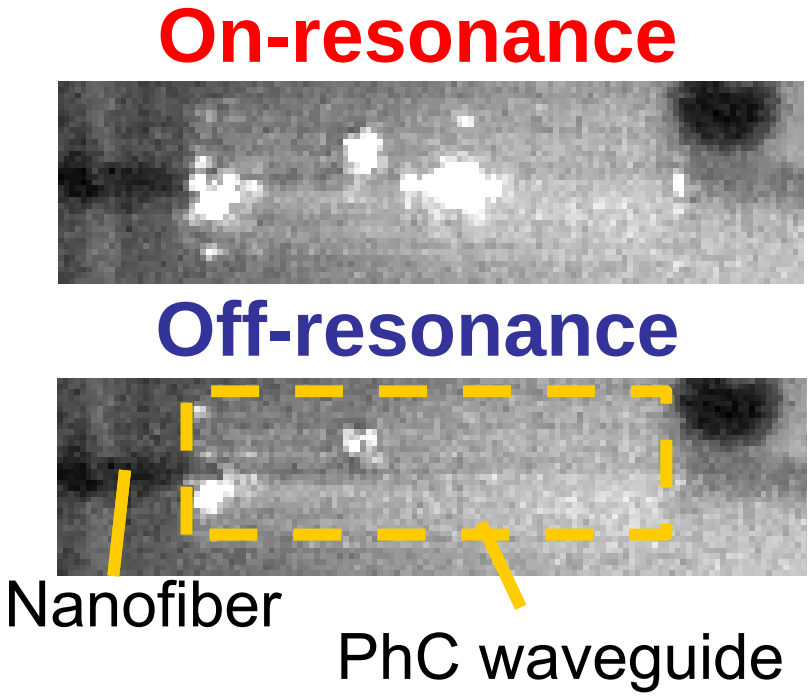
Transmission spectrum



$$Q_{load} = 5.1 \times 10^5$$

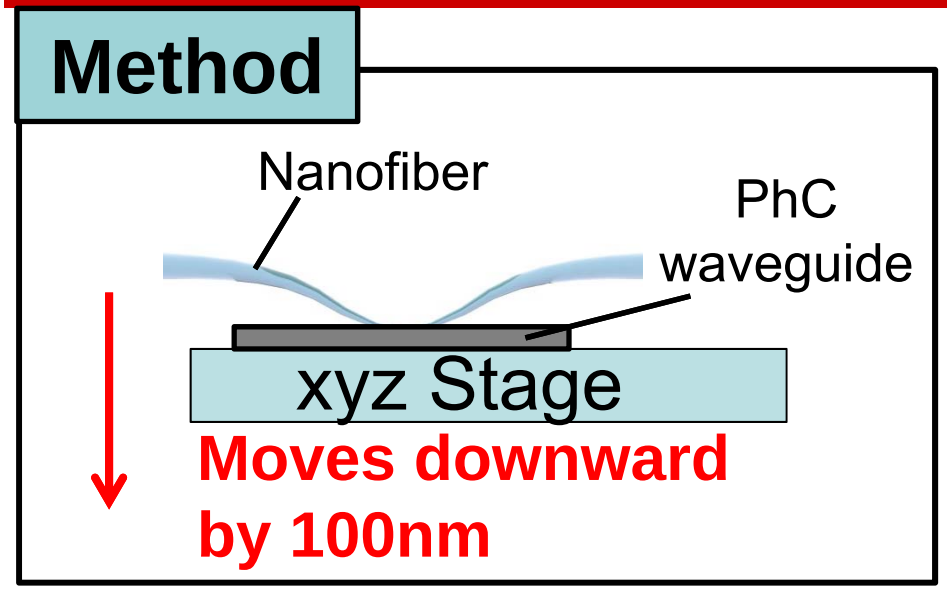
(CE 39%)

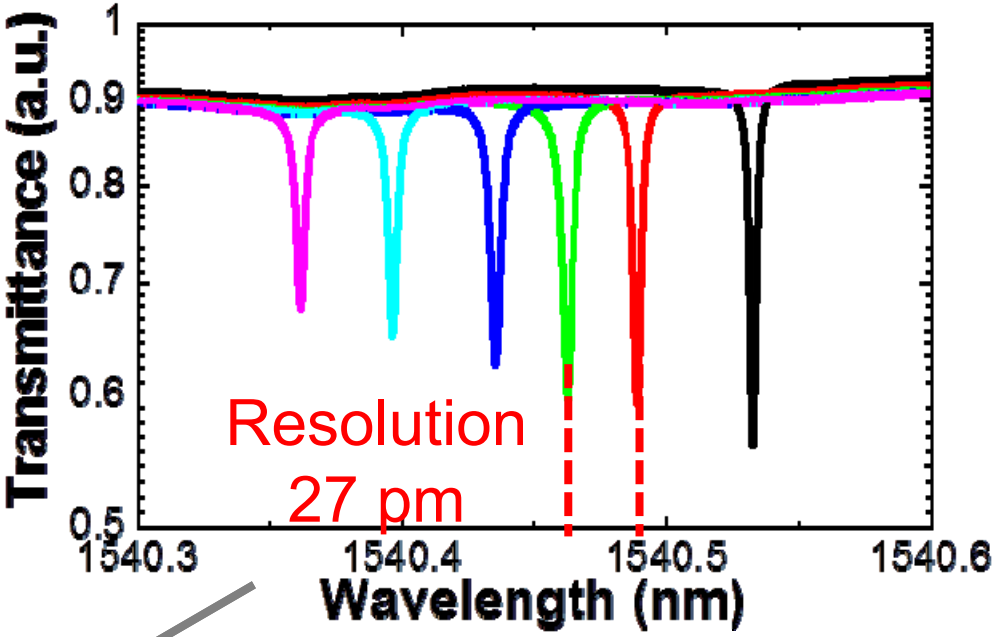
Infrared red image

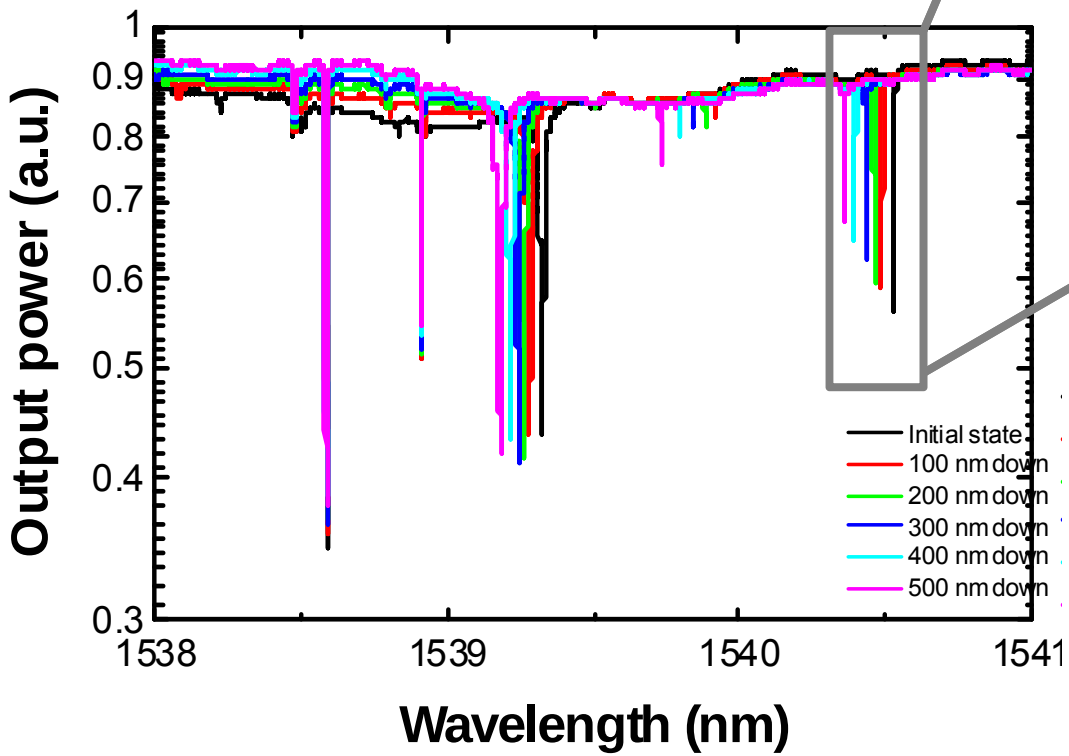


Tuning of resonant wavelength

Method



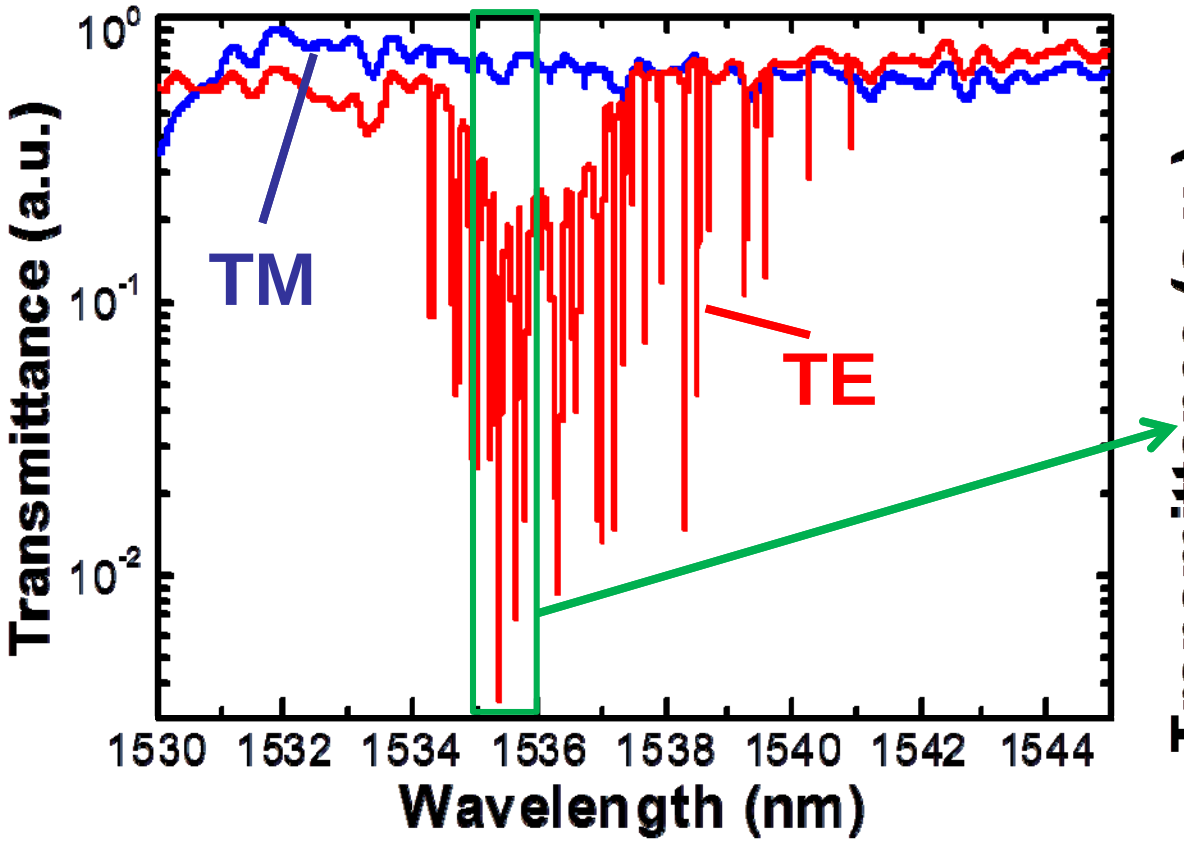


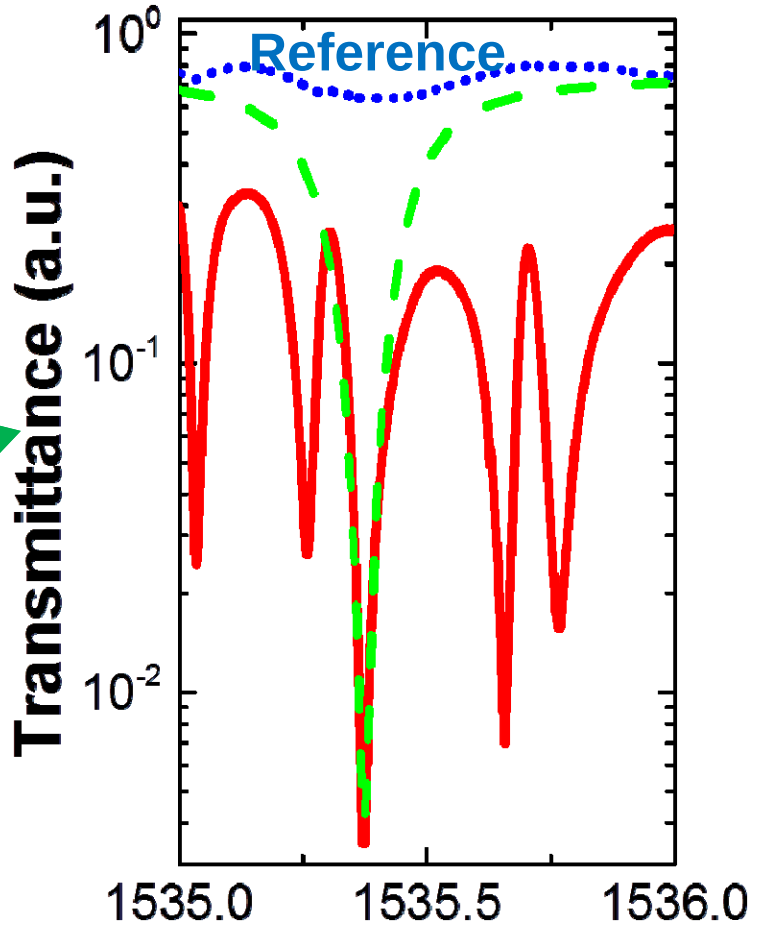


Tuning sensitivity

$$\frac{\text{Wavelength shift}}{\text{Stage shift}} = 0.27 \text{ pm/nm}$$

Polarization dependence & Coupling efficiency

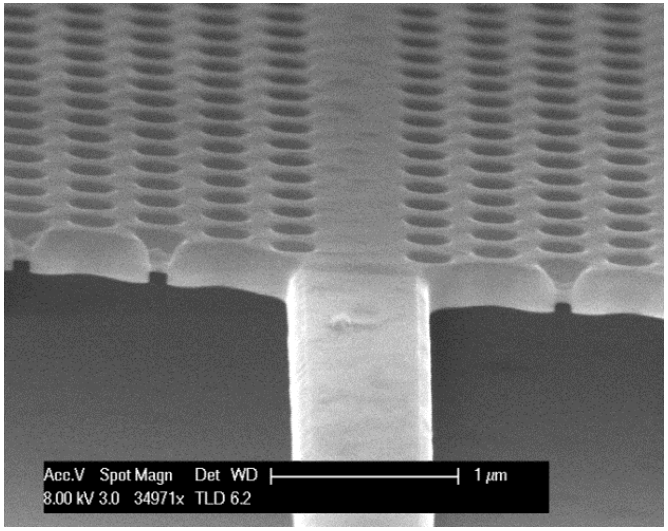


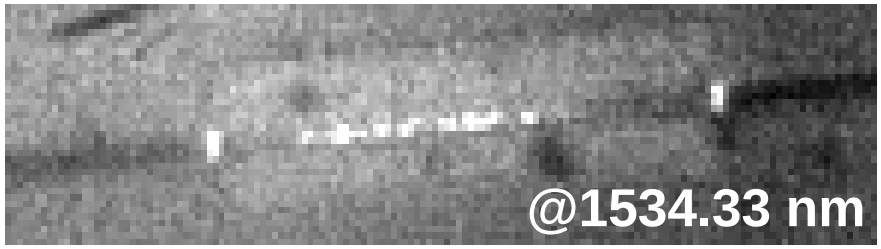


CE of 99.6% was obtained
($Q = 6.1 \times 10^3$)

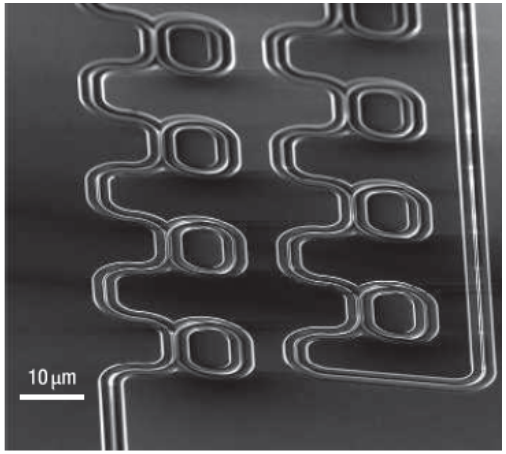
Coupled cavity resonance

Formation of coupled cavity system





All-pass filter



F. Xia, *et al*., Nat. Photonics **1**, 65-71 (2007).

- ✓ Multi-coupled cavity system formed
- ⇒ It will function as optical buffers

Summary

- **We demonstrated fiber-coupled PhC nanocavity formation on Si PhC waveguide**
  - ✓ Obtained a high ***Q* of 5.1×10^5** w/ a CE of 39%
  - ✓ Achieved a **critical coupling (CE 99.6%)** w/ a *Q* of 6.1×10^3
  - ✓ Demonstrate fine tuning of resonant wavelength (presision of 0.27 pm/nm)
- **We obtained multi-mode resonance**
  - ✓ **All-pass filter type** coupled cavity system formed
  - ✓ It will function as delay line
  - ✓ Further analysis of this type of coupling is future work

For more information,
T. Tetsumoto, *et al*., Opt. Express **23**, 16256-63 (2015).

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