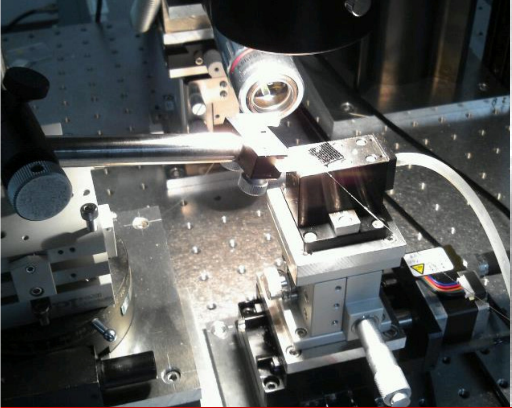
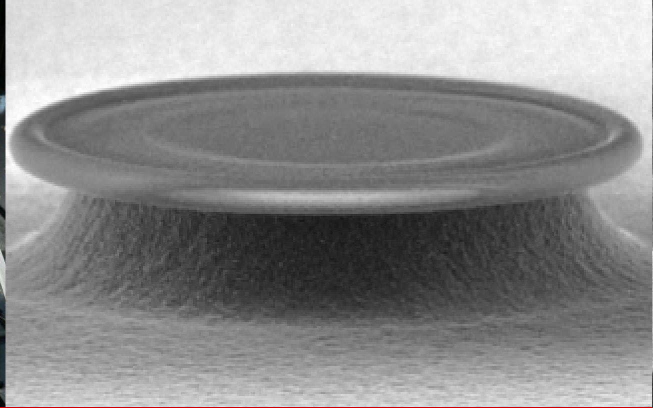
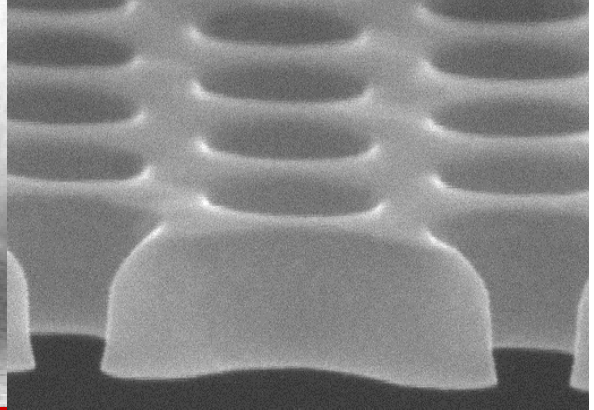
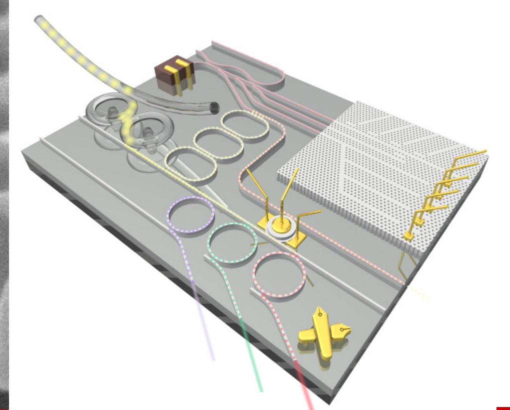

PIERS2016
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Recent progress on high-*Q* photonic crystal nanocavities: Photolithographic fabrication and reconfigurable system

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Tomohiro Tetsumoto, Yuta Ooka and Nurul Ashikin Binti Daud

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Keio University, Japan

Outline

1. Background & Motivation

2. Ultrahigh *Q* nanocavity w/ photolithographic Si PhC
3. Controlling the randomness: EO modulator
4. 8-ch in-plane DWDM DEMUX

5. Reconfigurable high-*Q* PhC nanocavity

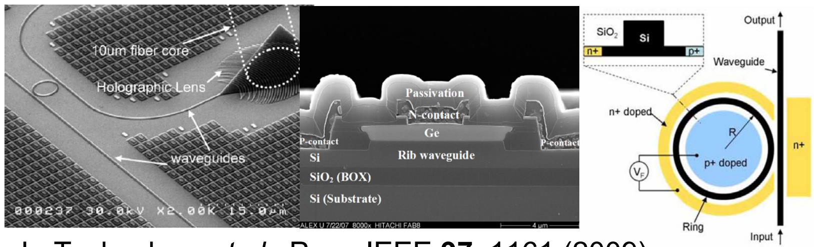
6. Summary

Motivation: Si-photonics vs. PhC

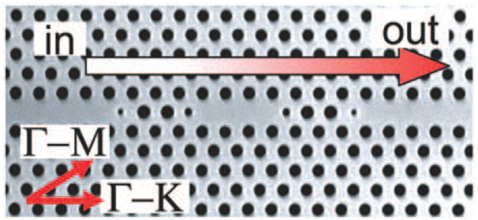
Si-photonics

Photonic crystals

1. Photolithography ⇔ EB-lithography
2. SiO_2-cladding ⇔ Air-bridge



L. Tsybeskov, *et al*., Proc. IEEE **97**, 1161 (2009)
Q. Xu, *et al*., Opt. Express **15**, 430 (2007)
T. Yin, *et al*., Optics Exp. **15**, 13965 (2007)



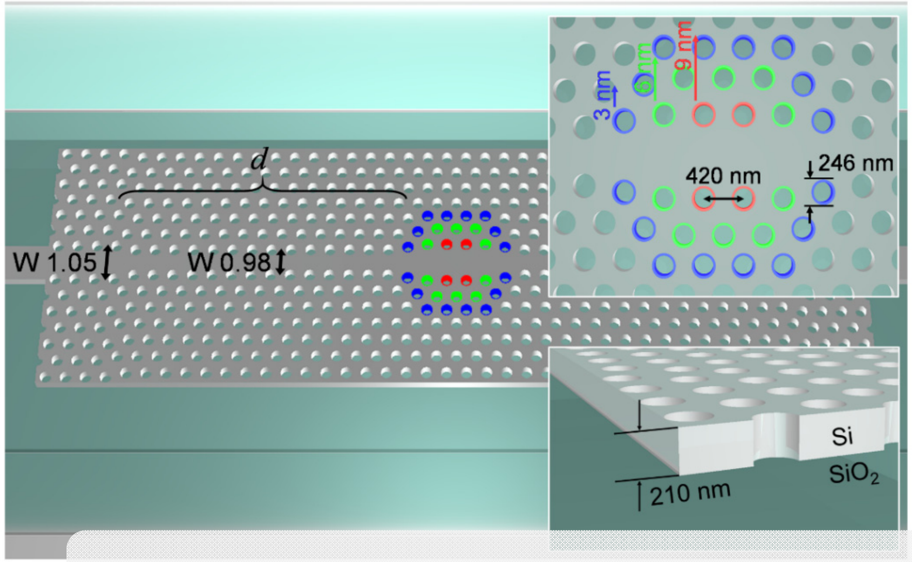
T. Tanabe, *et al*., Appl. Phys. Lett. **87**, 151112 (2005).
T. Tanabe *et al*., Nature Photon. 1, 49 (2007).

Fusion of
Si-photonics & Photonics crystals

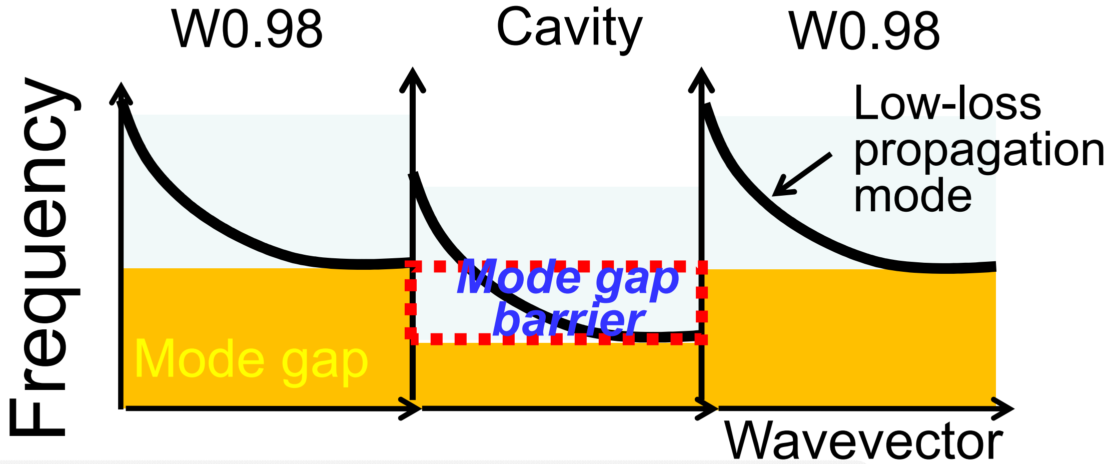
Design & Simulation

▶Width-modulated line defect cavity

T. Tanabe, *et al.*, Nature Photon. 1, 47 (2007).



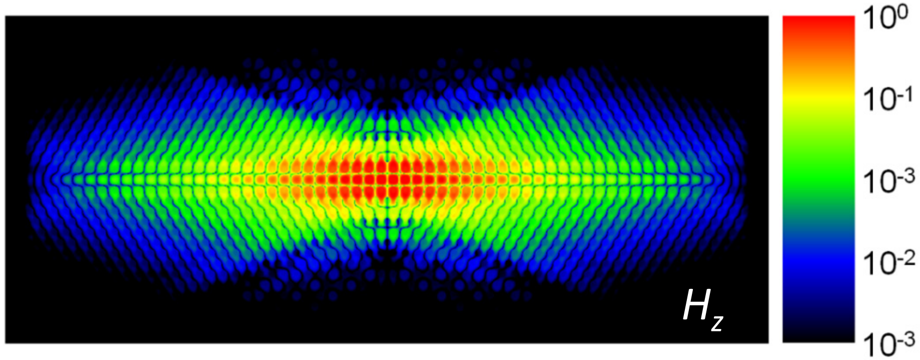
Principle of confinement



Photolithographic fabrication? & Dielectric cladding?

▶FDTD – w/ SiO_2 cladding

Y Ooka, *et al.*, *Sci. Rep.* **5,** 11312 (2015).



Optimized structure

$Q = 7.1\times10^6$ $V = 2.4\ (\lambda/n)^3$

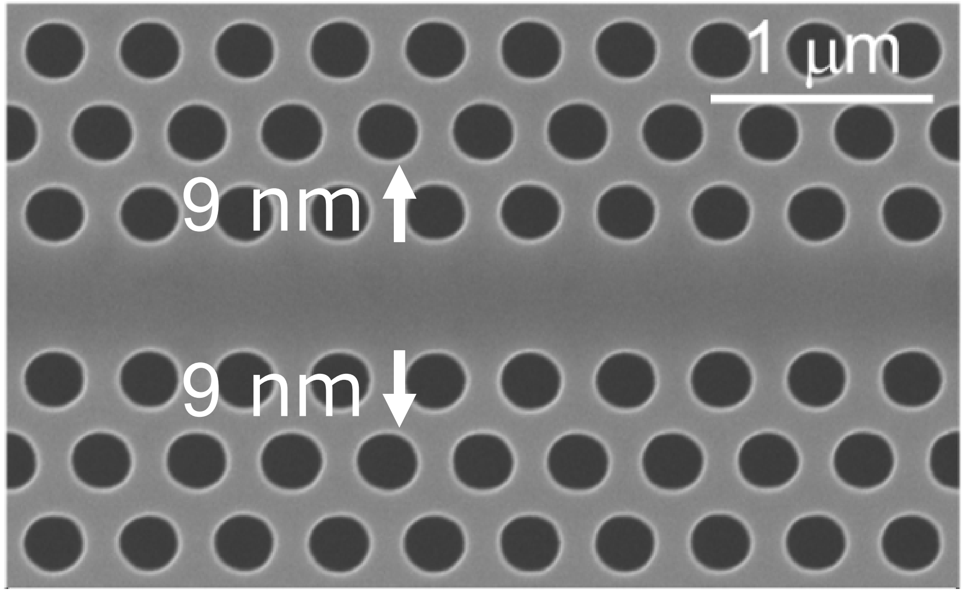
Fabricated parameter

$Q = 8.1\times10^5$ $V = 1.7\ (\lambda/n)^3$

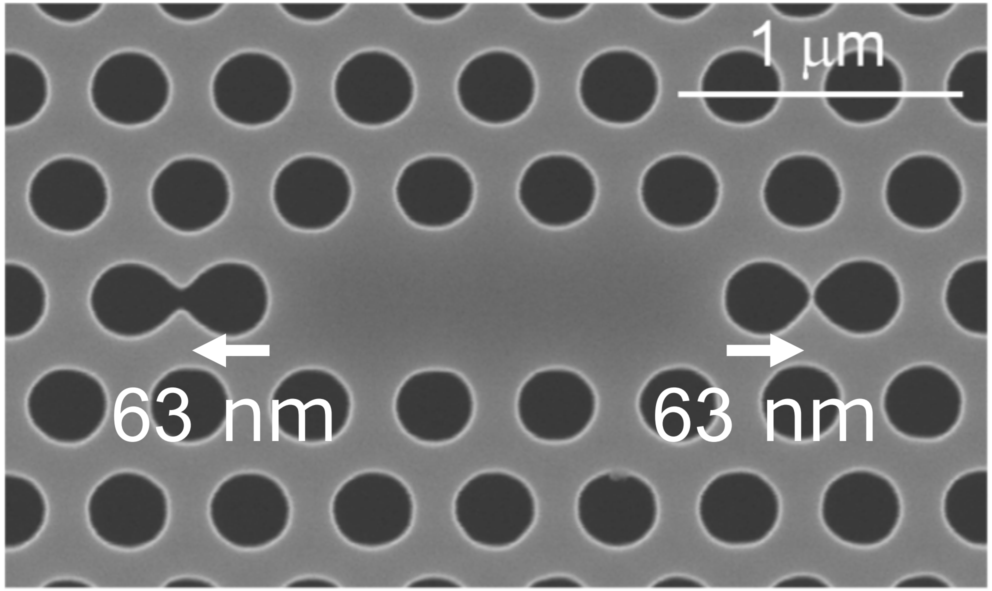
Photolithographic fabrication & proximity effect

Y Ooka, *et al*., *Sci. Rep.* **5,** 11312 (2015).

SEM images (effect of fabrication error)



Width-modulated line defect cavity



L3 cavity

Max amount of shift : 9 nm

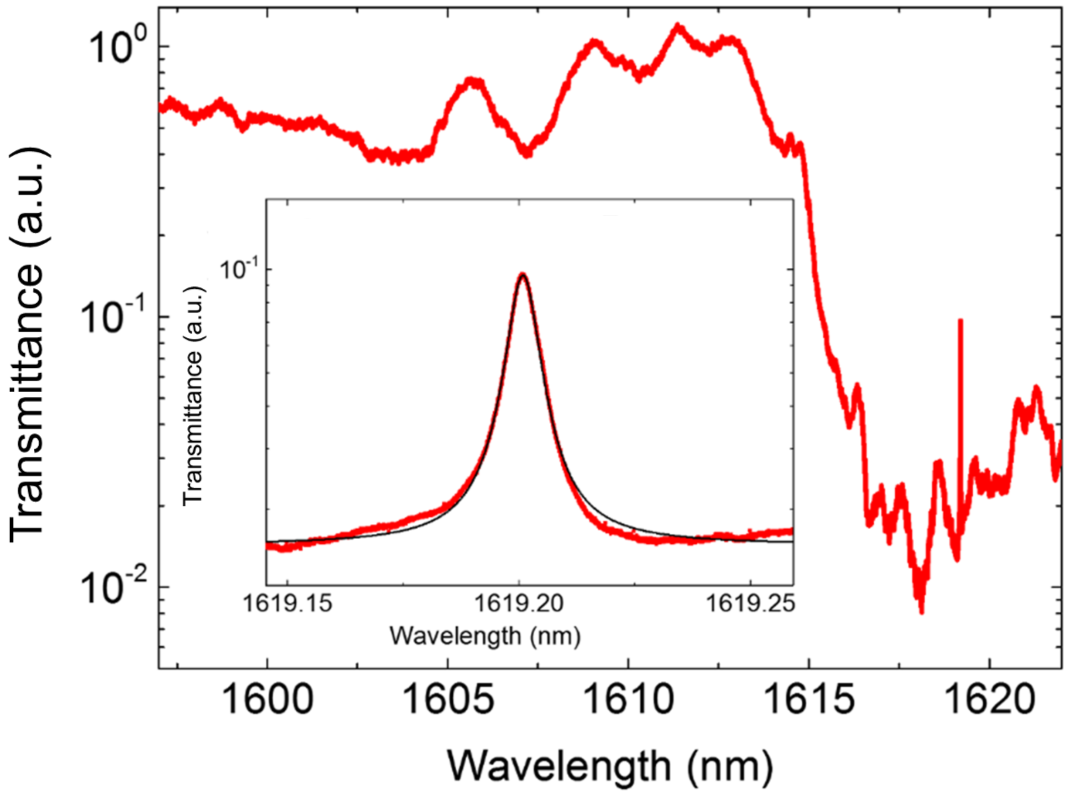
Max amount of shift : 63 nm

Width-modulated line defect cavity is
robust against the proximity effect

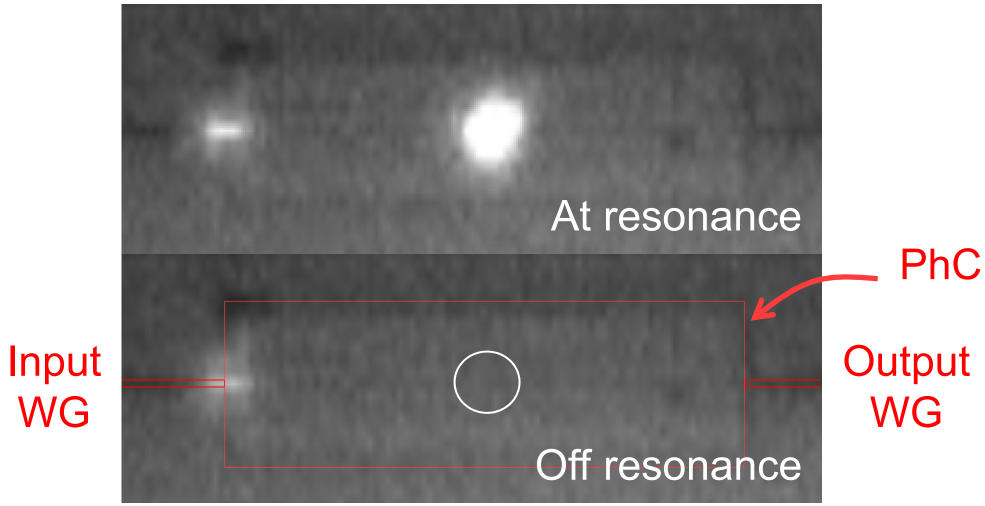
Experiment: High-Q demonstration

Y Ooka, *et al.*, *Sci. Rep.* **5,** 11312 (2015).

Transmission spectrum



Top view



and w/ SiO_2-cladding!!

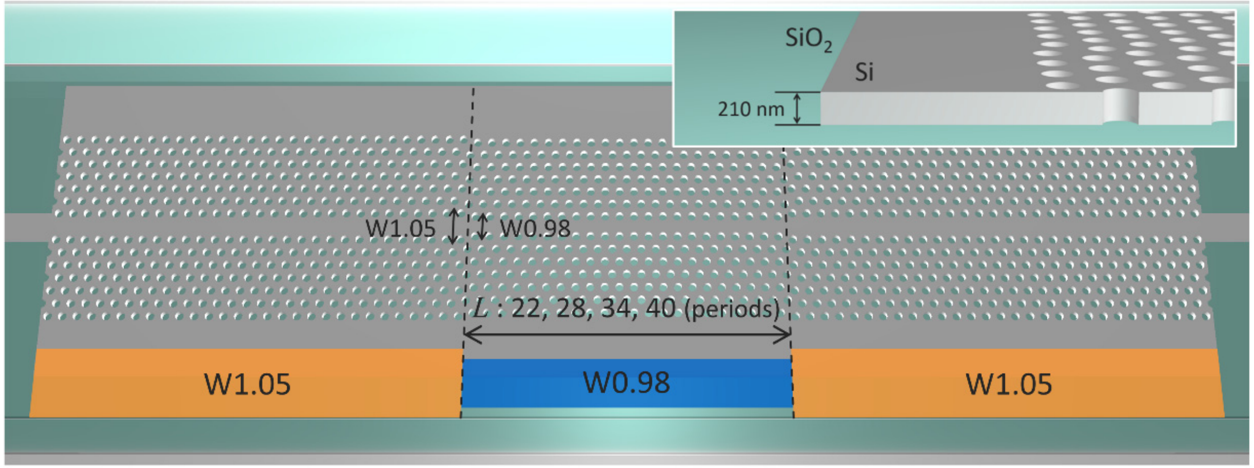
The highest Q w/ photolithography

$Q = 2.2\times10^5$

Managing the randomness

Y. Ooka, *et al*. Opt. Express **24**, 11199 (2016).

Design of our device

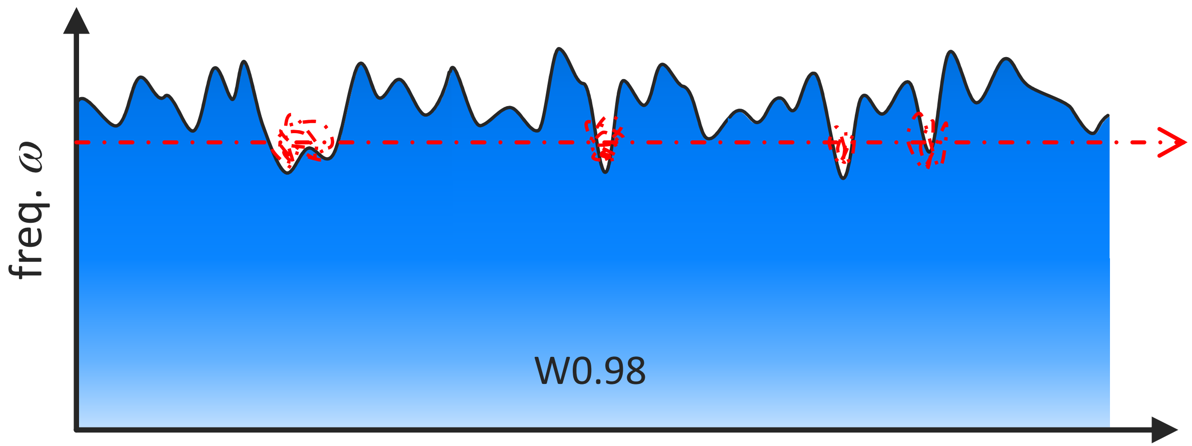


Waveguide width

W1.05 → wide

W0.98 → narrow

Cutoff frequency (mode gap)

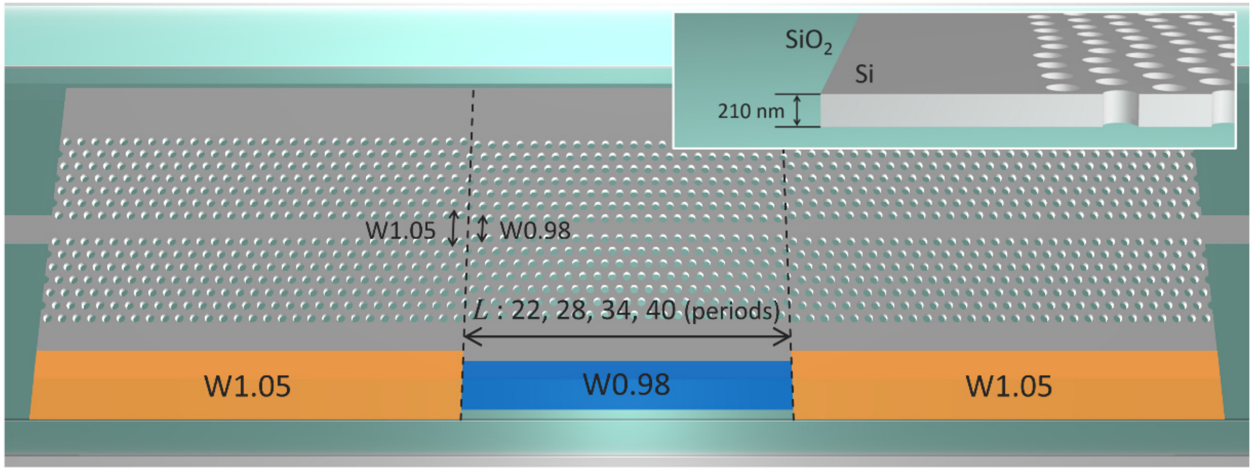


Position of light localization occurs randomly in W0.98

Managing the randomness

Y. Ooka, *et al*. Opt. Express **24**, 11199 (2016).

Design of our device

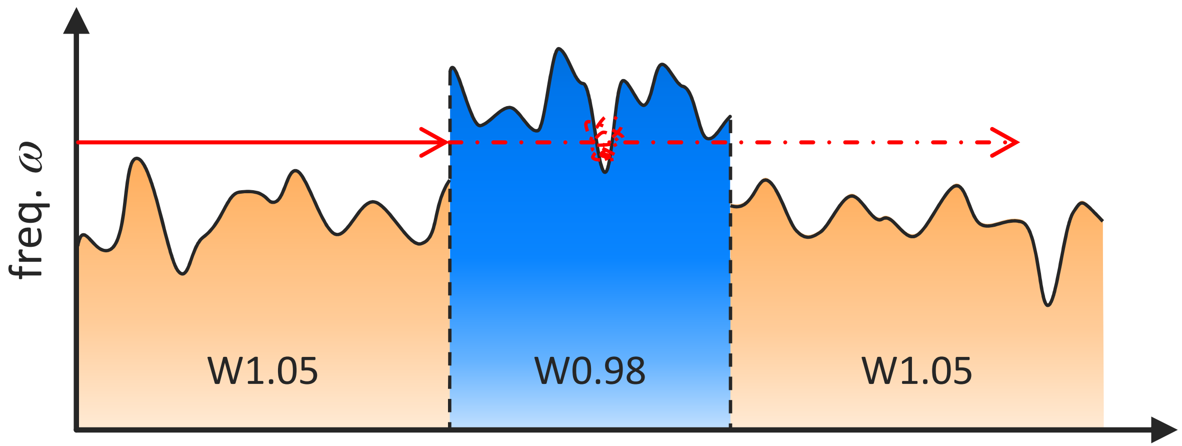


Waveguide width

W1.05 → wide

W0.98 → narrow

Cutoff frequency (mode gap)



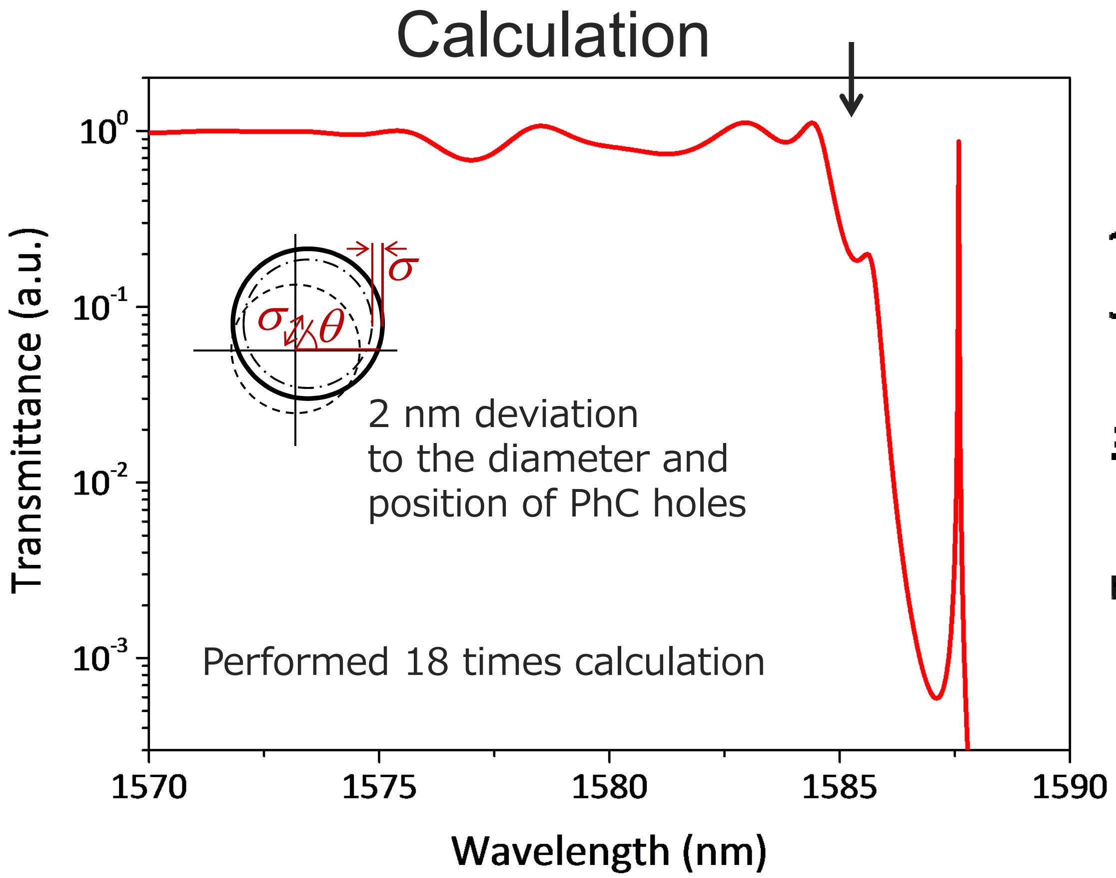
Position of light localization occurs only in W0.98

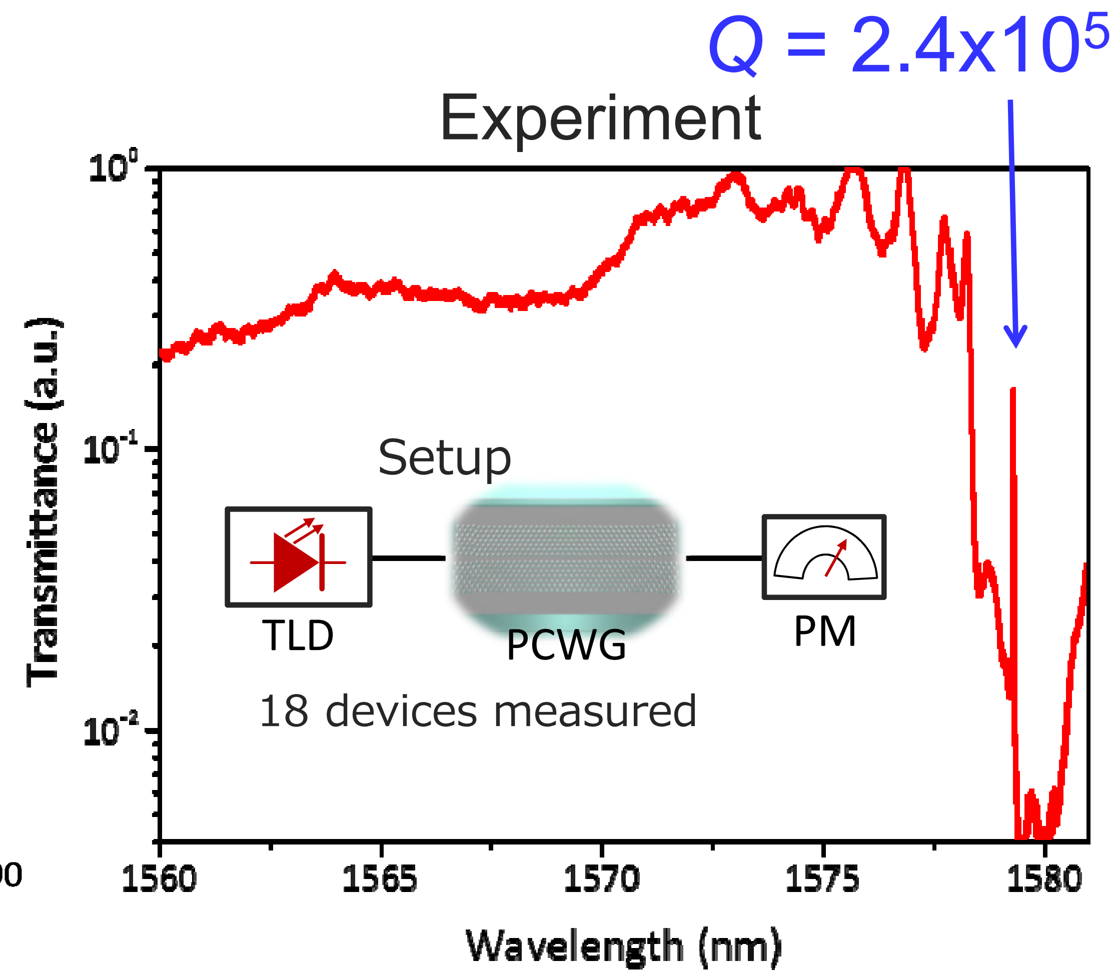
⇩

The effect of randomness occurs in a limited area (controlled way)

Theory & experimental result

Y. Ooka, *et al*. Opt. Express **24**, 11199 (2016).



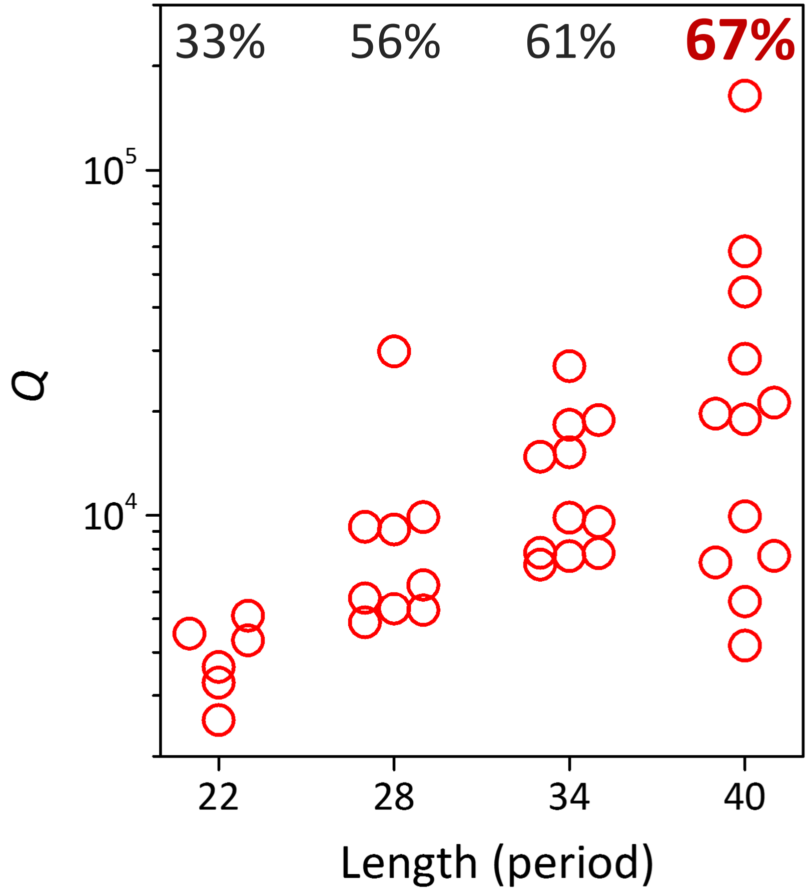


Localization observed at desired position

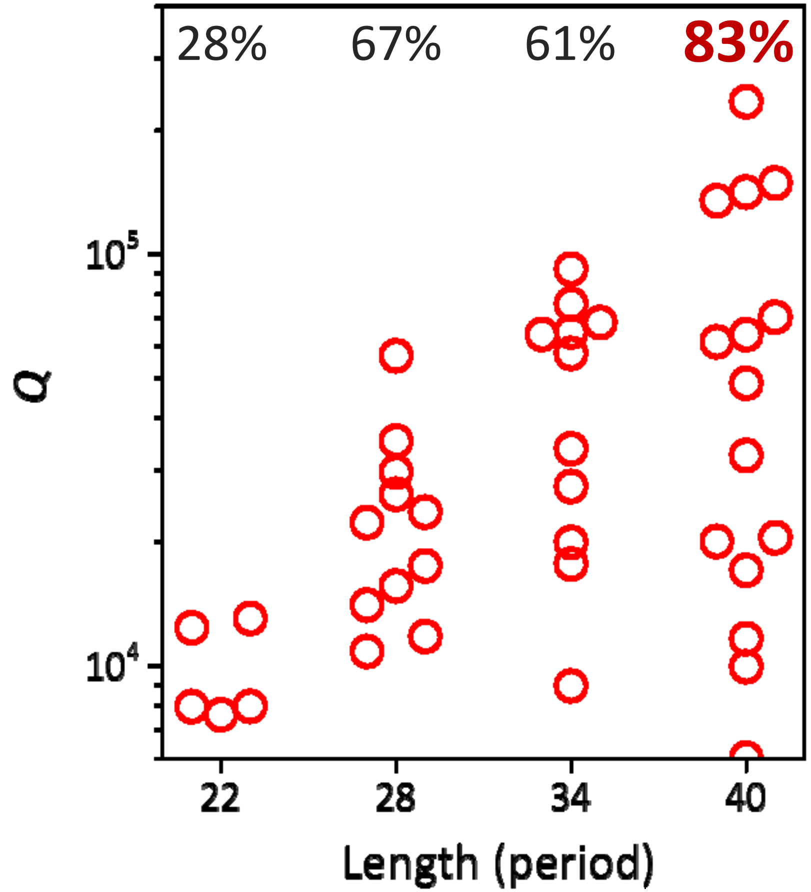
Yield rate of obtaining localization

Y. Ooka, *et al*. Opt. Express **24**, 11199 (2016).

Calculation



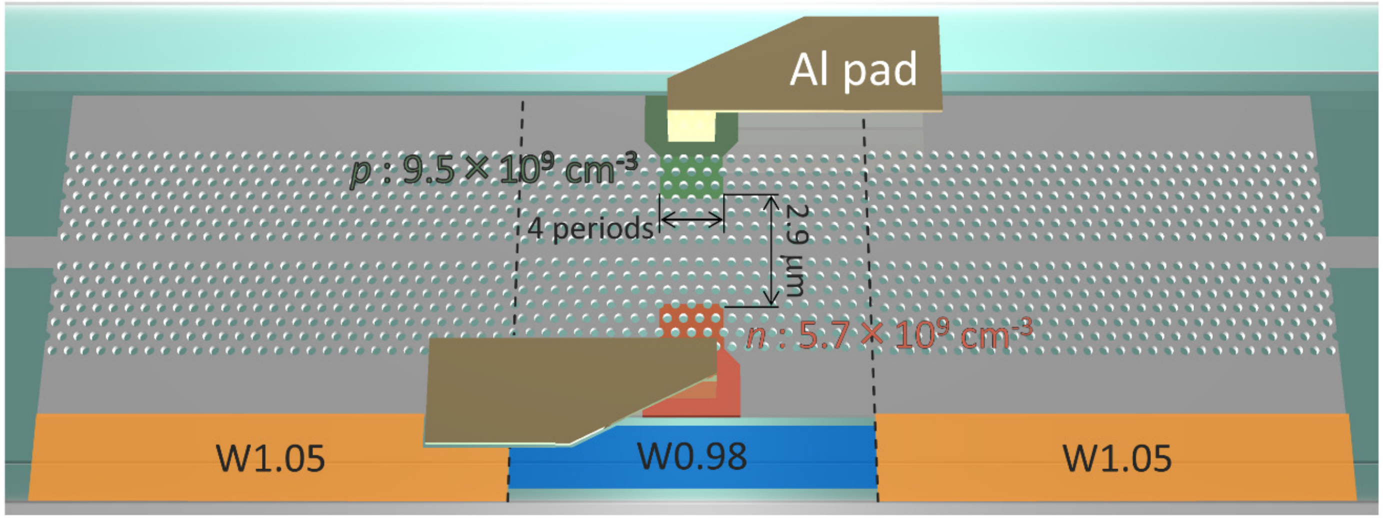
Experiment

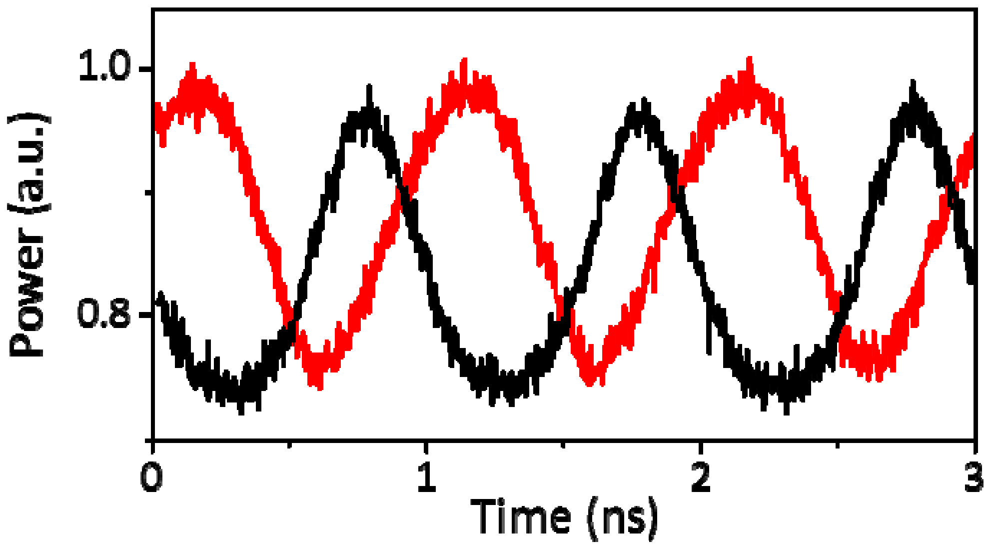


> 80% yield obtained

Using random PhC for controlled experiment

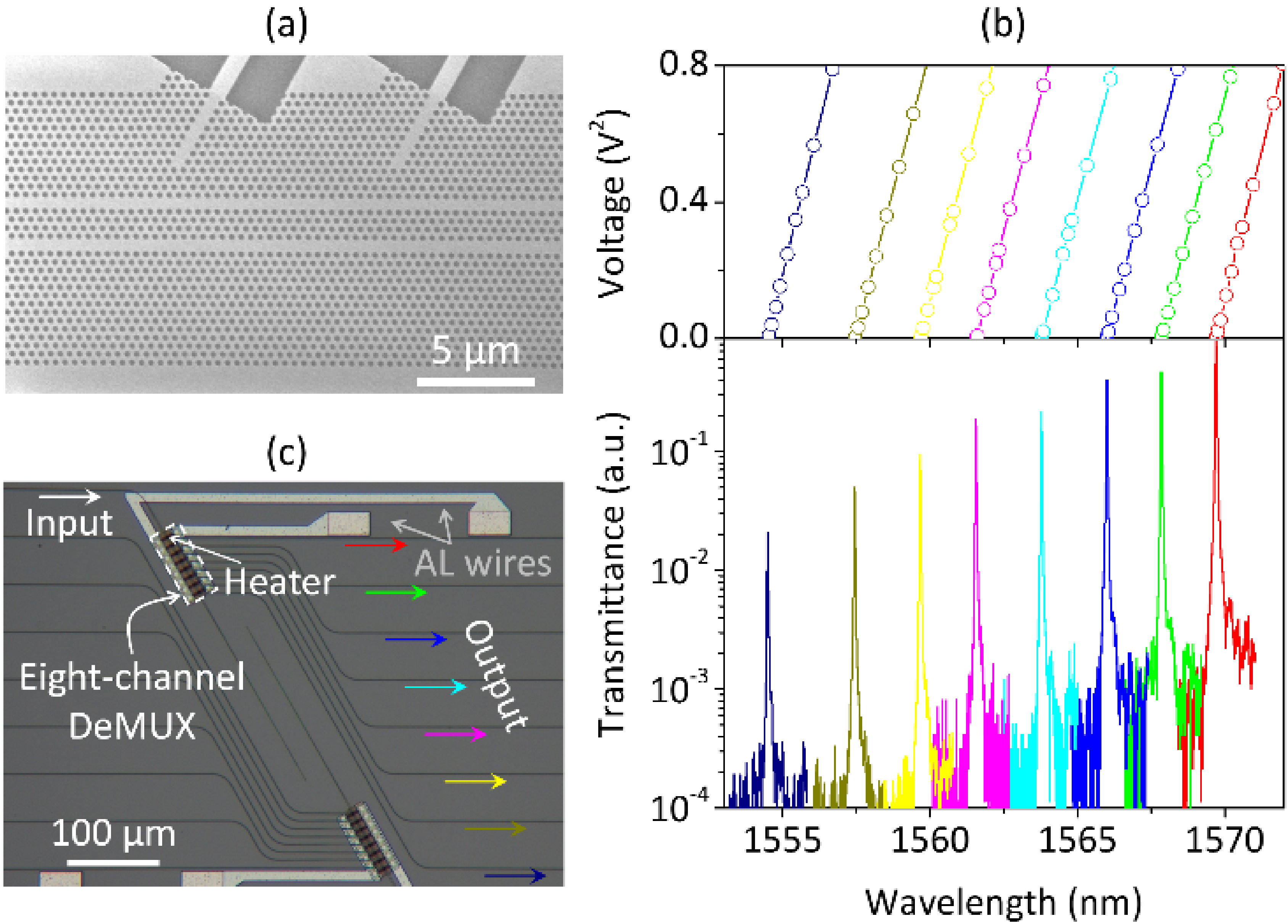
Y. Ooka, *et al*. Opt. Express **24**, 11199 (2016).





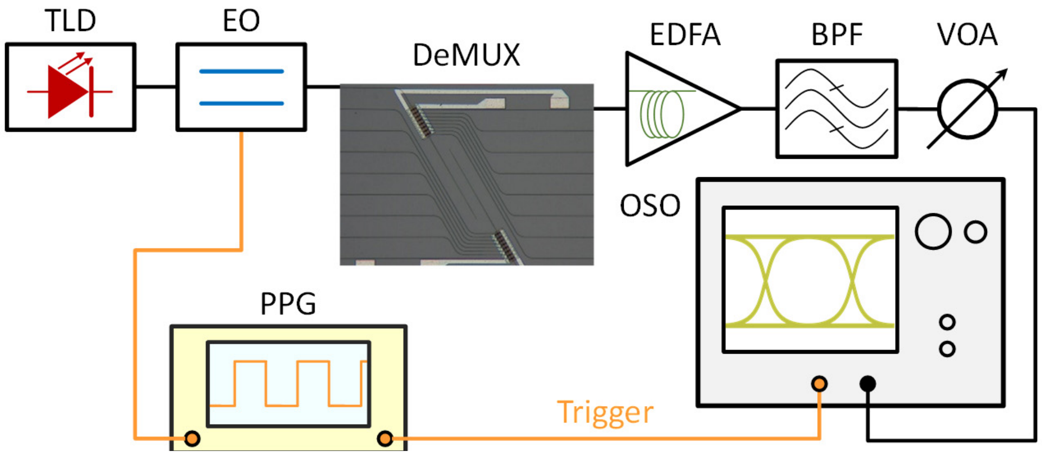
EO modulation achieved w/ pin structure integrated at W0.98 regime

In-plane 8ch DWDM demonstration

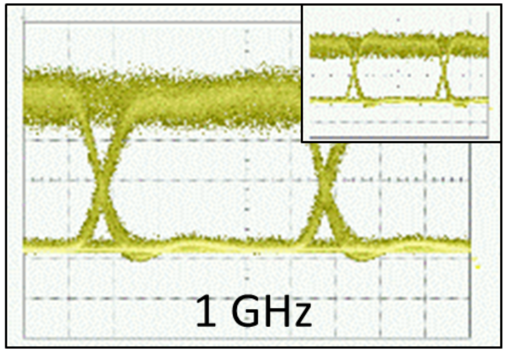


In-plane 8ch DWDM demonstration

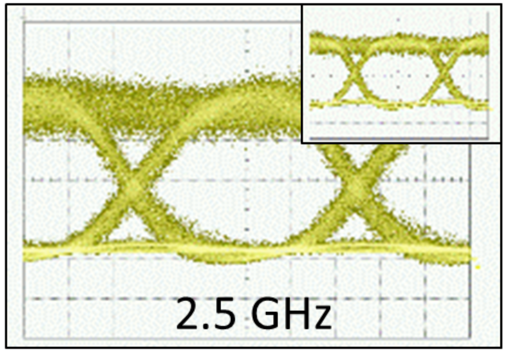
Setup

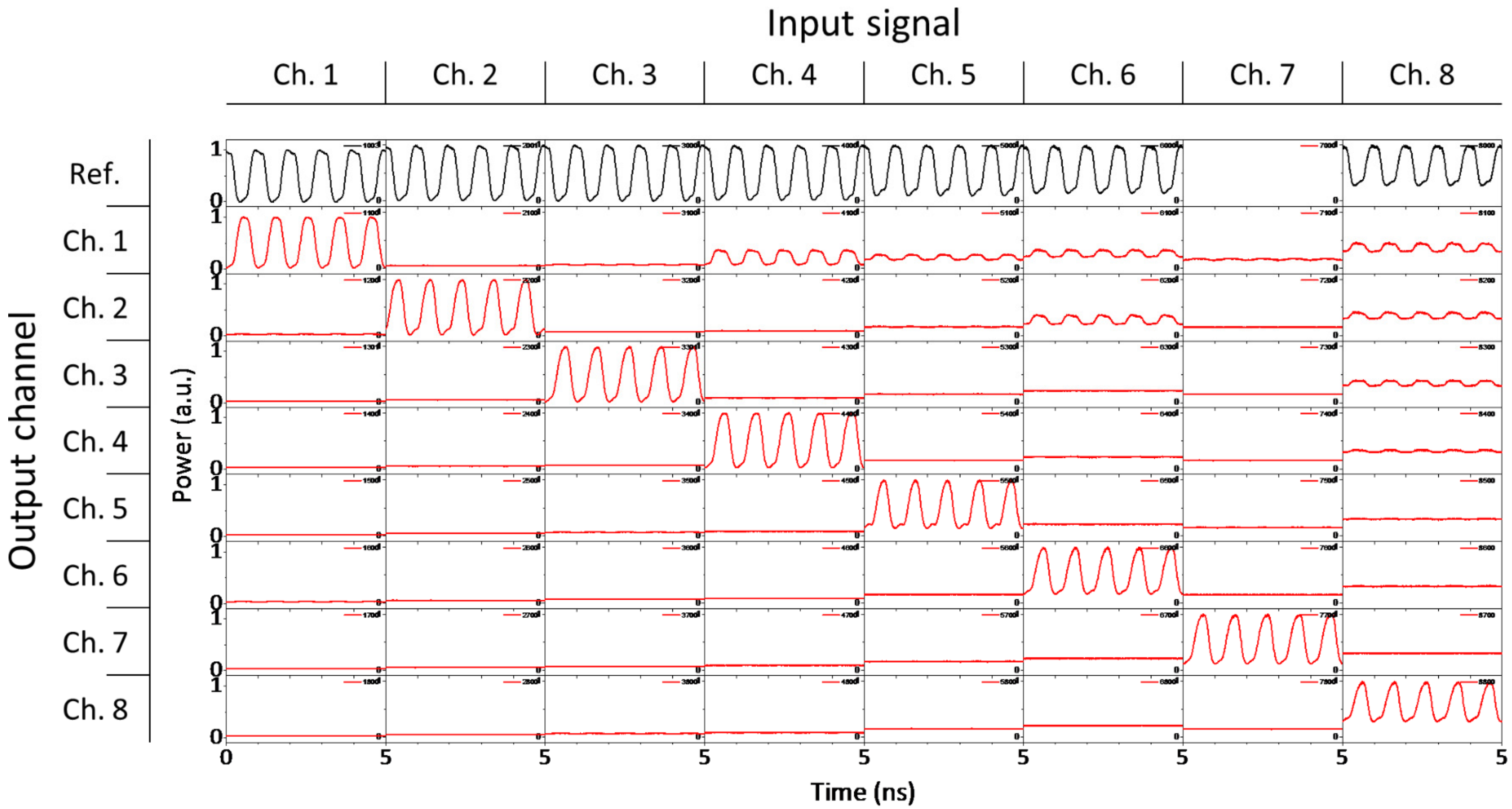


Eye pattern



(c)





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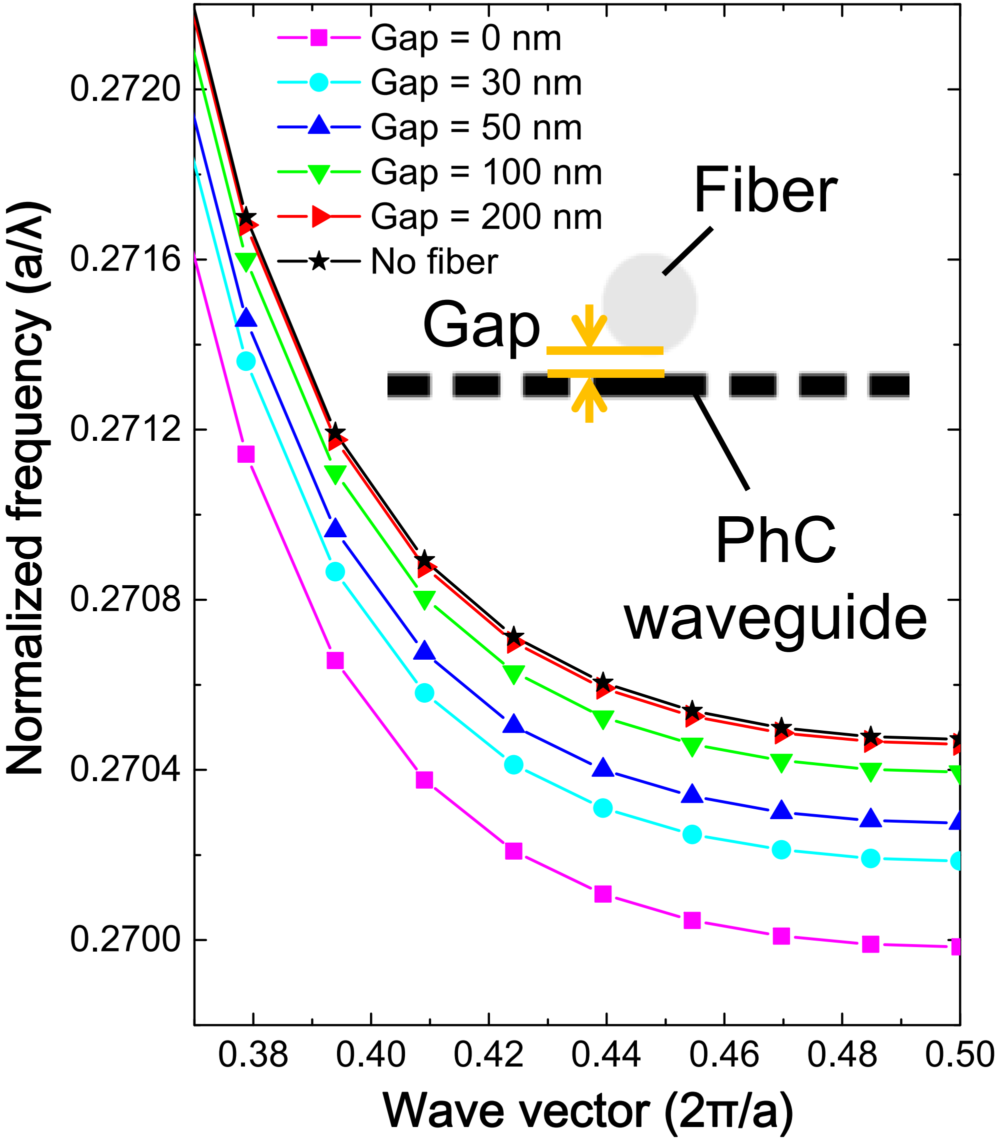
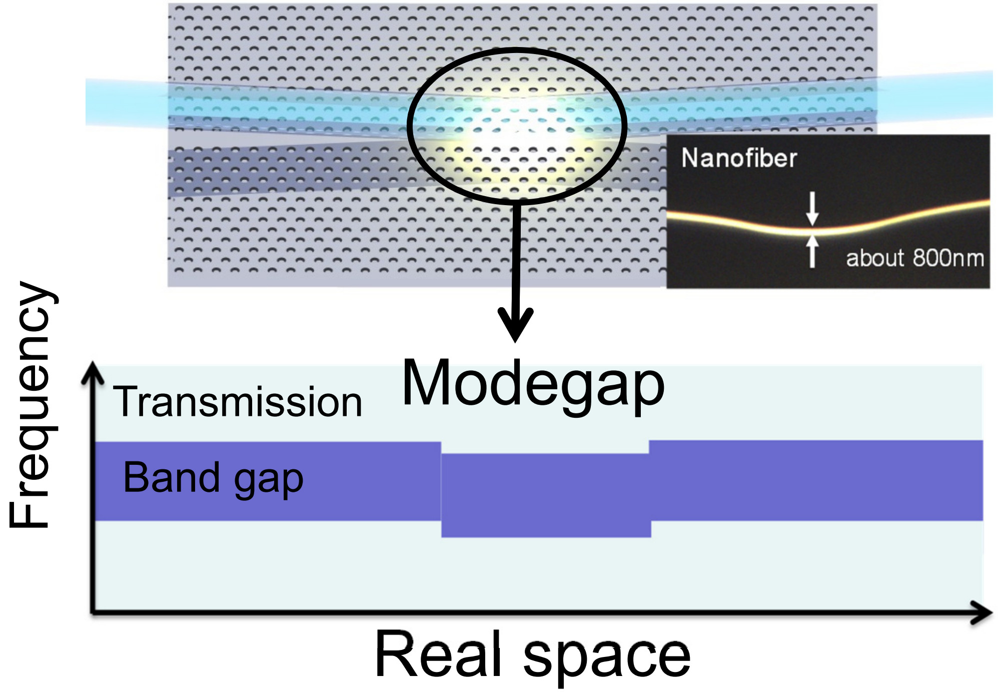
5. Reconfigurable high-*Q* PhC nanocavity

6. Summary

Principle of cavity formation

T. Tetsumoto, *et al*., Opt. Express **23**, 16256 (2015).



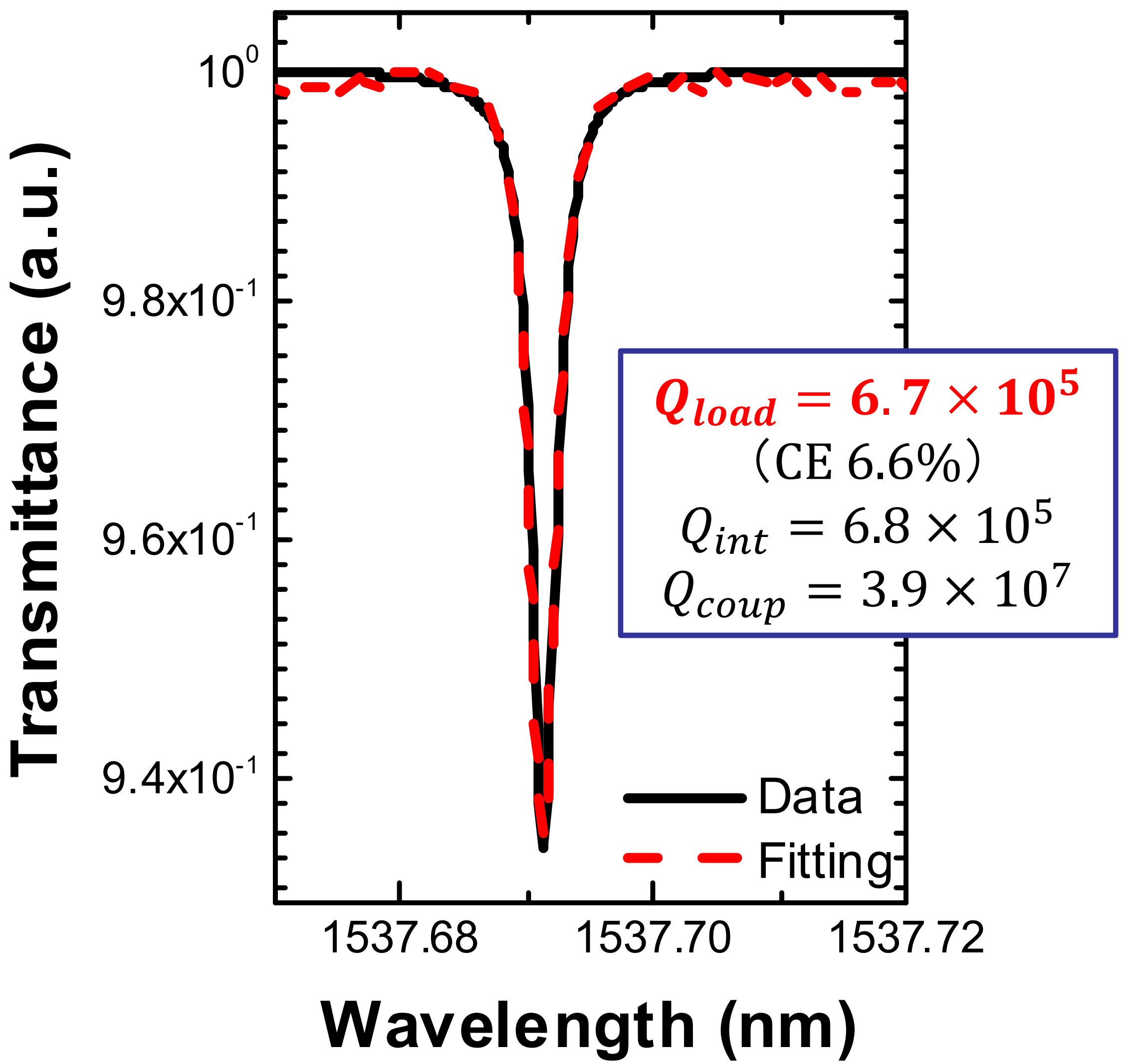


Effective refractive index change results in formation of modegap cavity

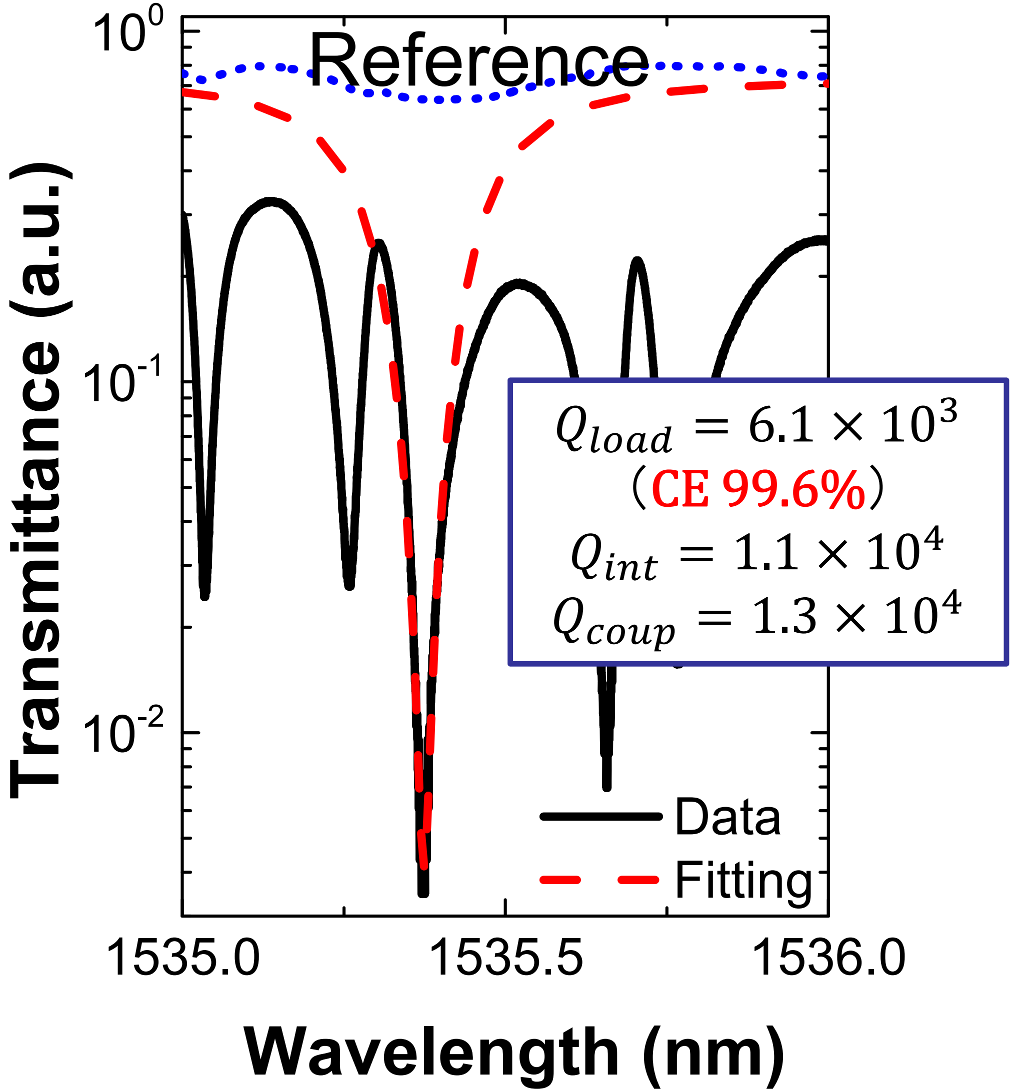
Measurement of *Q* and CE of FCPC

T. Tetsumoto, *et al.*, Opt. Express **23**, 16256 (2015).

Highest Q

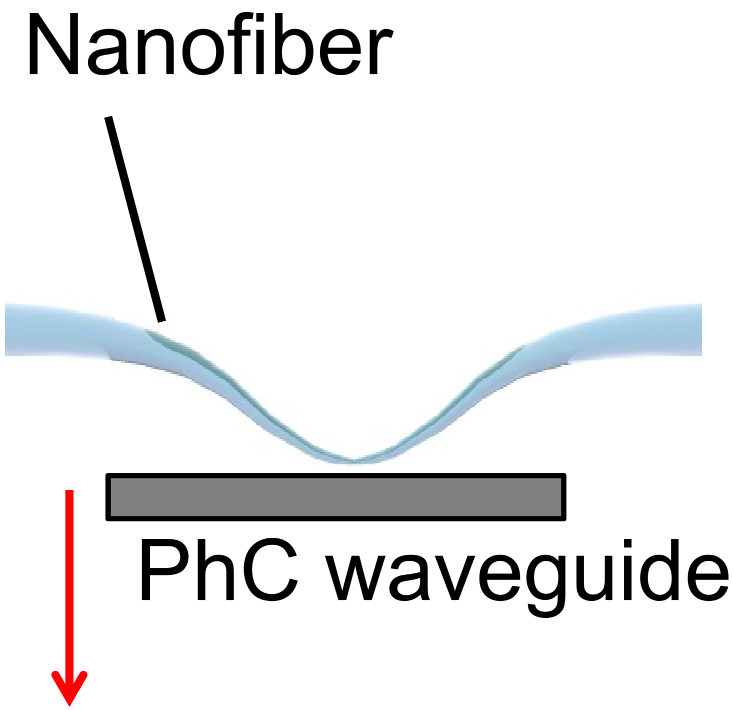


Highest coupling

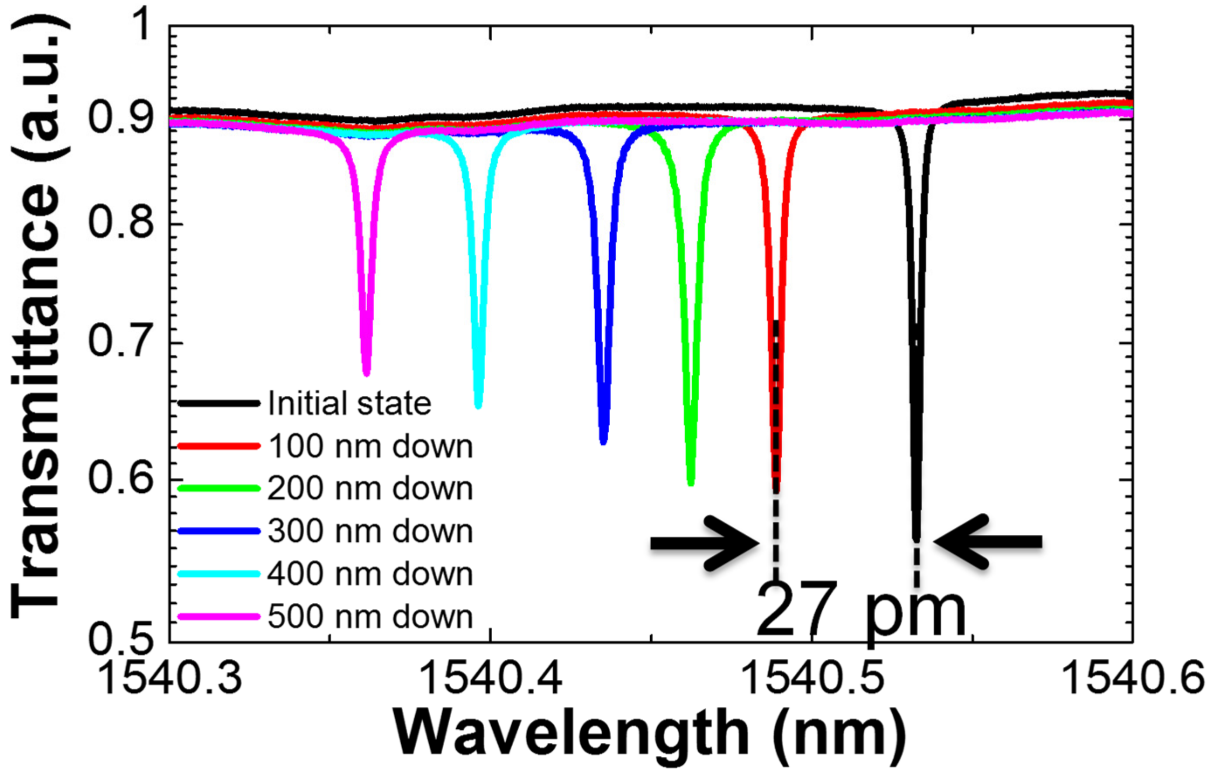


Resonant wavelength tuning

T. Tetsumoto, *et al.*, Opt. Express **23**, 16256 (2015).



Change the position at 100-nm step



Tuning sensitivity

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

Summary

1. Very high-Q is achieved w/ SiO_2 clad photolithographic Si PhC ($Q = 2.4\times10^5$)

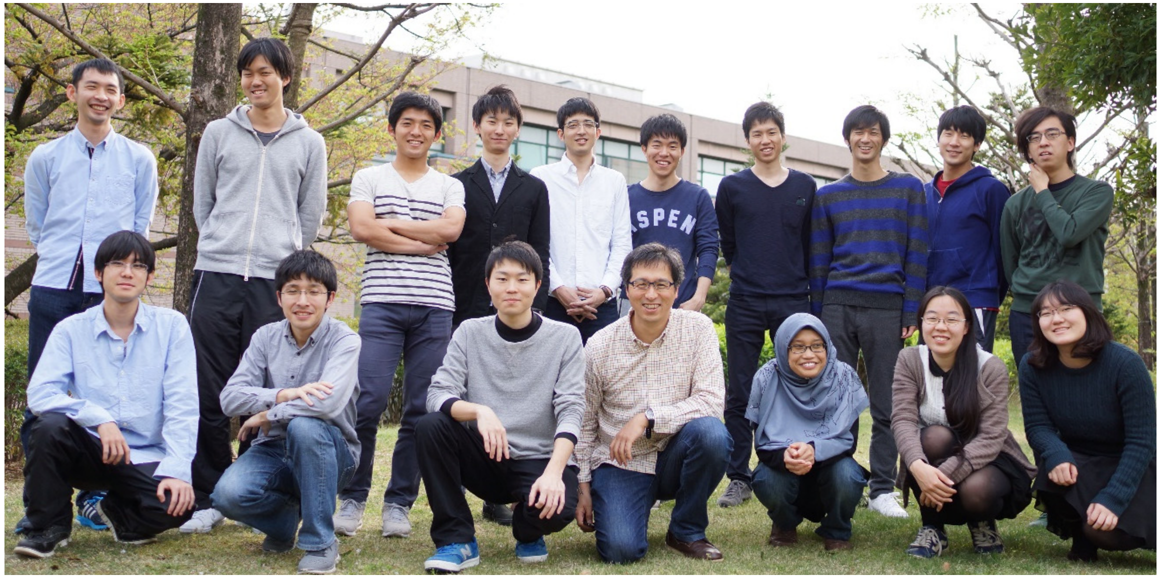
2. Practical EO modulation is demonstrated w/ controlled random PhC device

3. 8-ch in-plane DWDM demonstrated

4. Reconfigurable (position & wavelength) high-Q PhC nanocavity ($Q = 6.7\times10^5$) w/ high-transmittance ($T > 99\%$) demonstrated using nanotapered optical fiber

Acknowledgement

The team



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Mr. Yuta Ooka (M2)
Mr. Naotaka Kamioka (B4)

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