

The 24th Congress of the International Commission for Optics  
(ICO-24)

F1E-06 10:40 am – 10:55 am Aug. 25. 2017

# Experimental investigation of the feasibility of a hybrid system consisting of a photonic crystal waveguide and a toroidal microcavity

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Keio Univ



# Background: Coupled optical cavity system

## Optical nano-microcavities

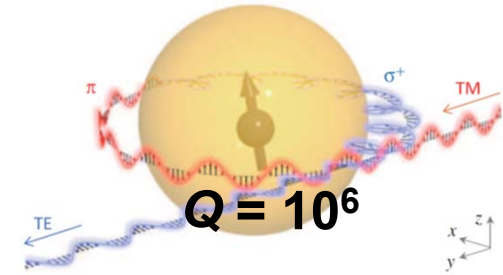
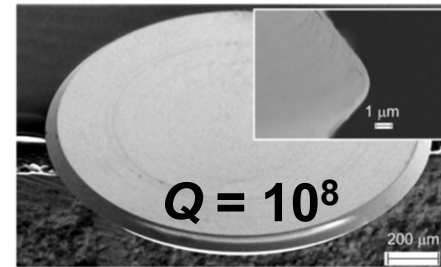
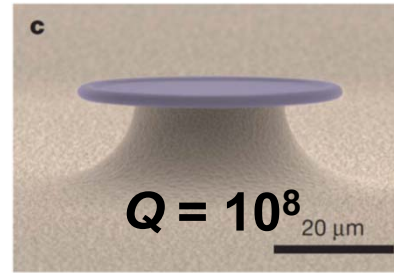
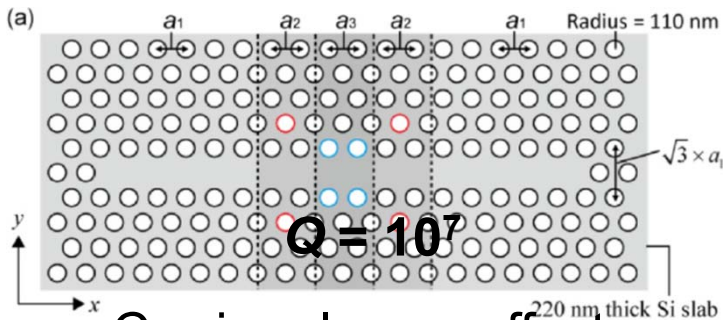
Si PhC nanocavity [1]

Silica toroid microcavity [2]

LN WGM cavity [3]

YIG micro sphere cavity [4]

[1] Opt. Express **25**, 1769-77 (2017) [2] Nature **450**, 1214-7 (2007)  
 [3] Phys. Rev. B **74**, 245119 (2006) [4] Phys. Rev. Lett. **117**, 123605 (2016)



Carrier plasma effect  
(EO effect)

Kerr effect

Piezo-electric effect

MO effect

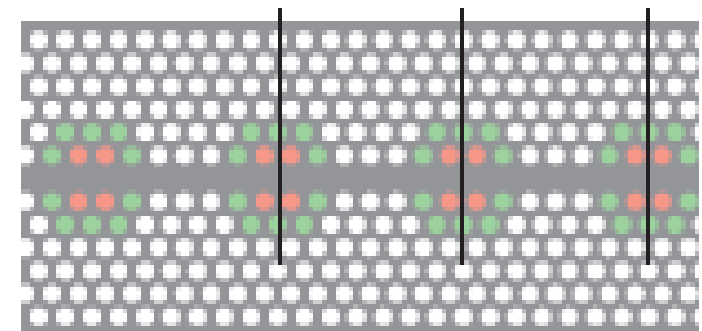
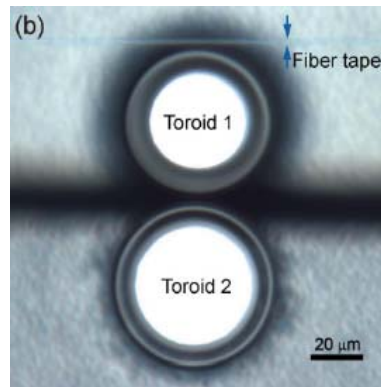
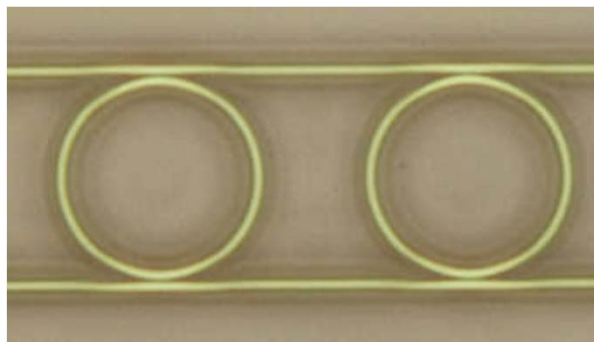
## Coupled optical cavities

Si rings [5]

Silica toroids [6]

Si PhCs [7]

[5] Nat. Phys. **3**, 406 - 410 (2007) [6] Opt. Express **20**, 18319-18325 (2012)  
 [7] Nat. Photon. **2**, 1741 - 747 (2008)



Bandwidth tuning

Optical isolation

Optical buffering



# Hybrid system consisting of two different cavities

## Silica toroid microcavity

Ultra-high Q (Long storage time)

Operating principal: **Optical Kerr effect**

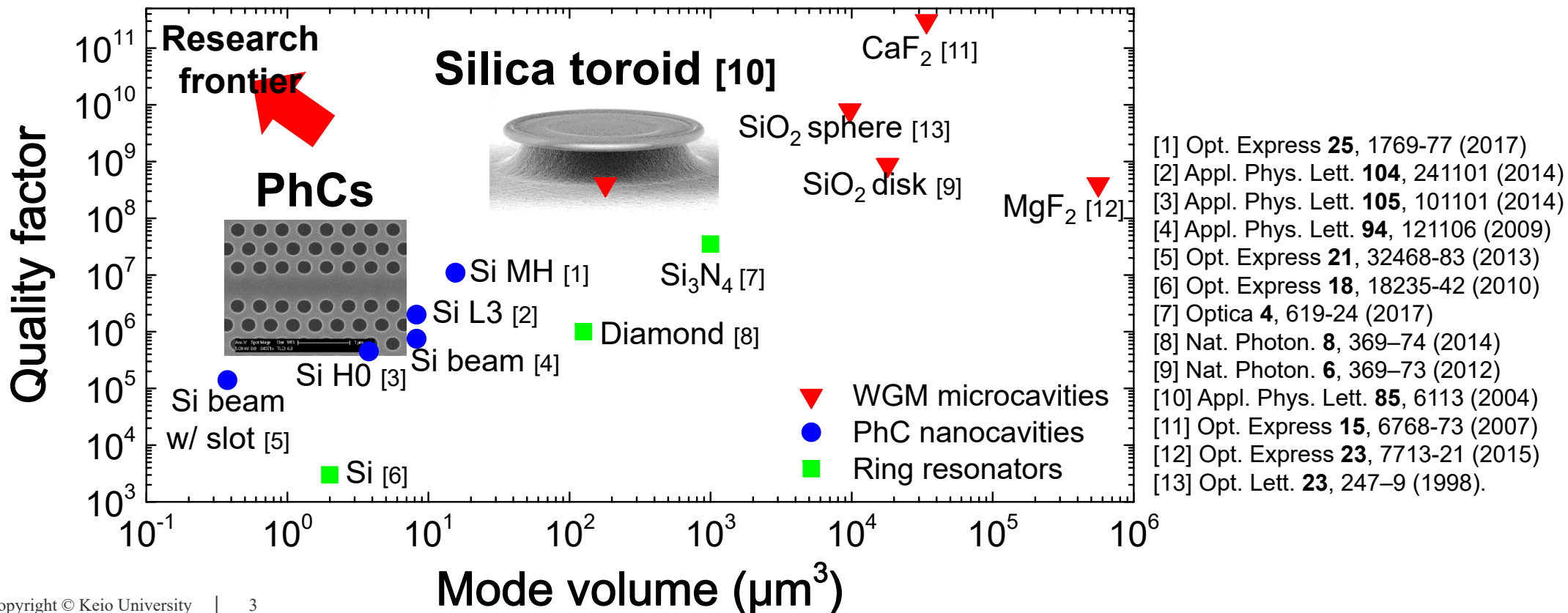
- Frequency Kerr comb
- Low power optical switch
- Optical buffer

## Si Photonic crystal nanocavity

Ultra-small V (Quick response)

Operating principal: **Carrier plasma effect**

- Fast optical switching
- Photodetection
- EO modulation







# Hybrid system consisting of two different cavities

## Silica toroid microcavity

Ultra-high  $Q$  (Long storage time)

Operating principal: **Optical Kerr effect**

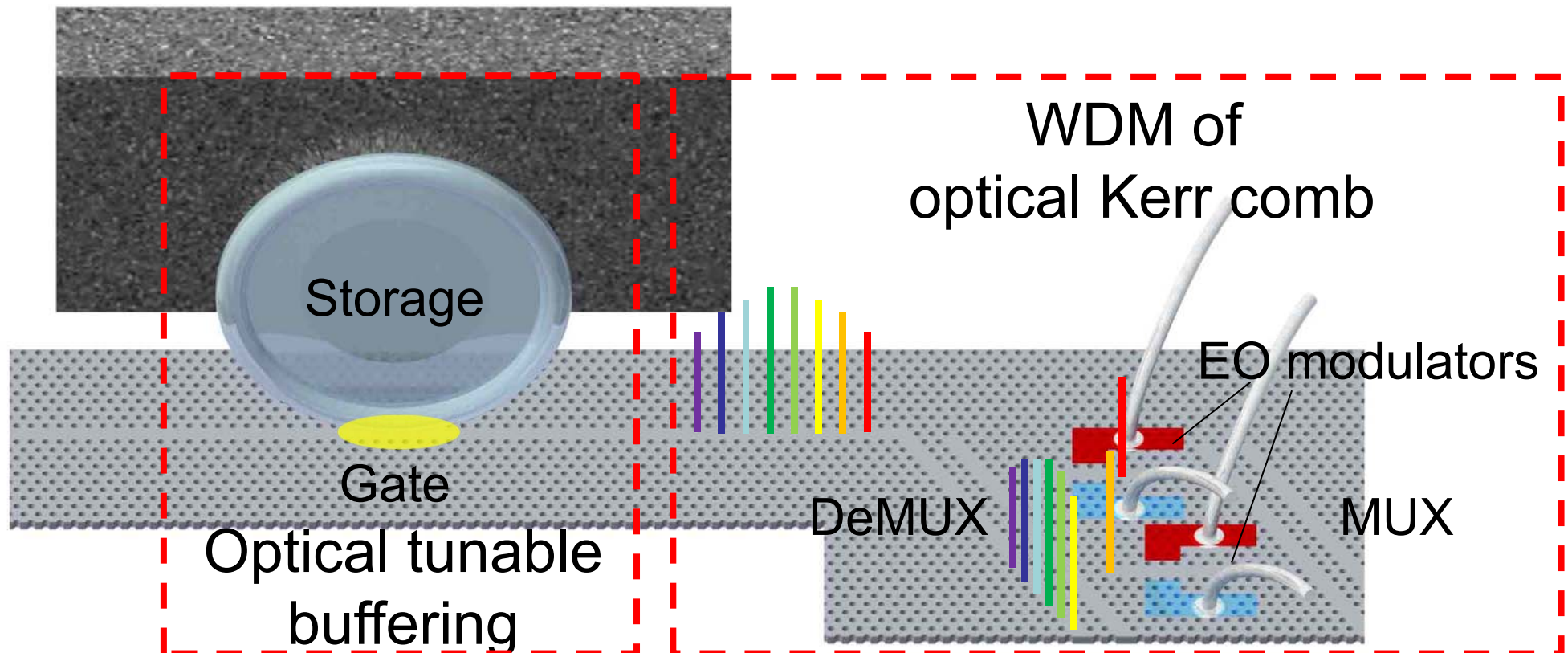
- Frequency Kerr comb
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## Si Photonic crystal nanocavity

Ultra-small  $V$  (Quick response)

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- Fast optical switching
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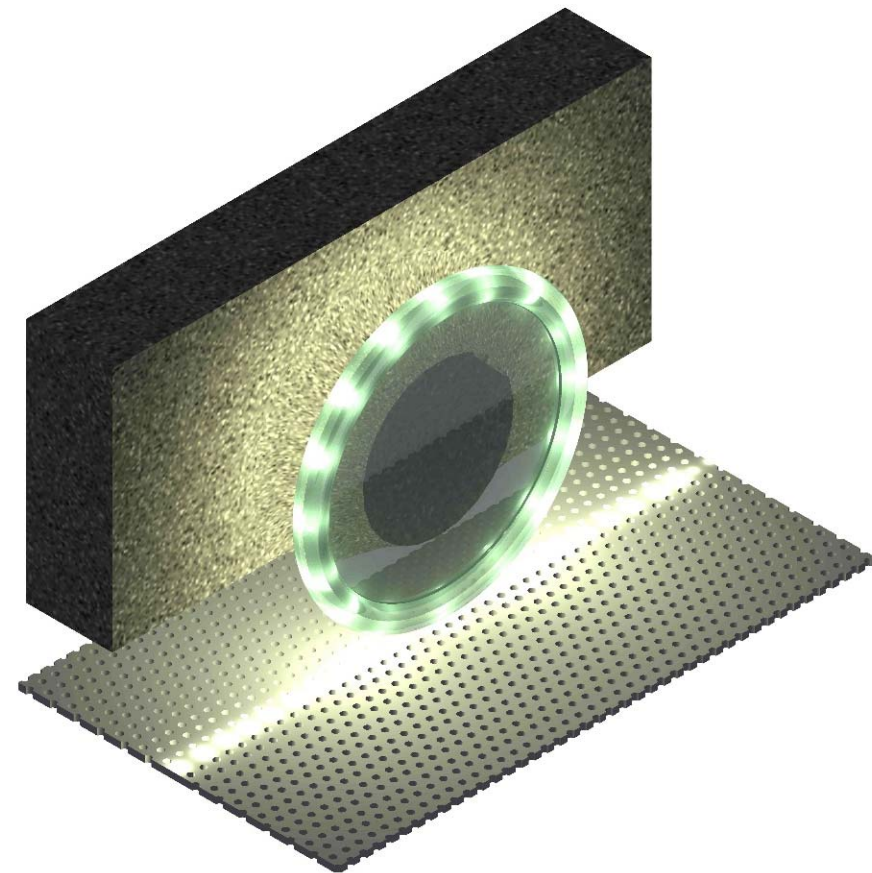
# Motivation

## Goal

Hybrid coupled cavity system of silicon photonic crystal nanocavities & silica microcavities

## Agendas

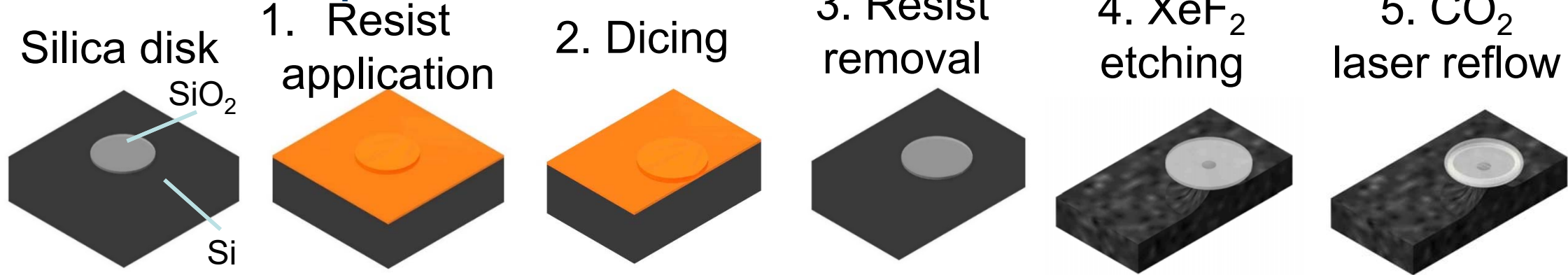
- ✓ Demonstration of direct coupling between a toroid microcavity & a PhC waveguide experimentally
- ✓ Quantification of a possible coupling quality factor





# Sample preparation

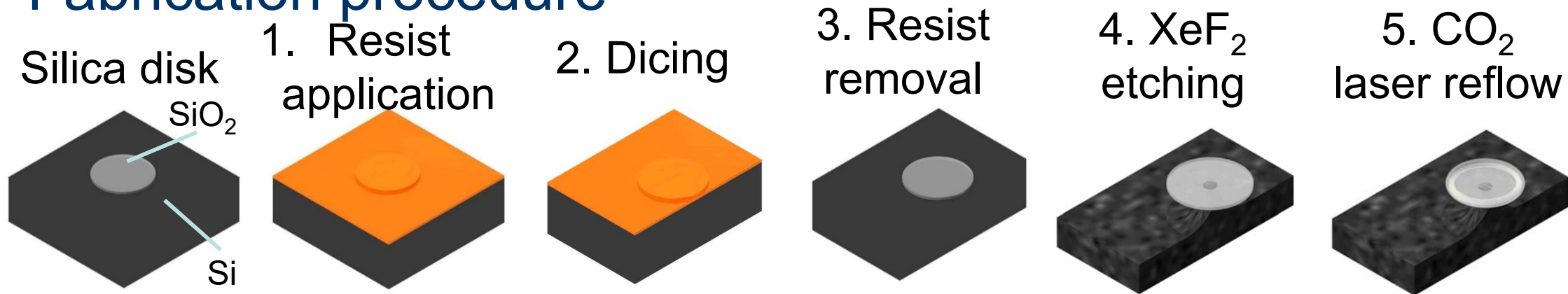
## Fabrication procedure



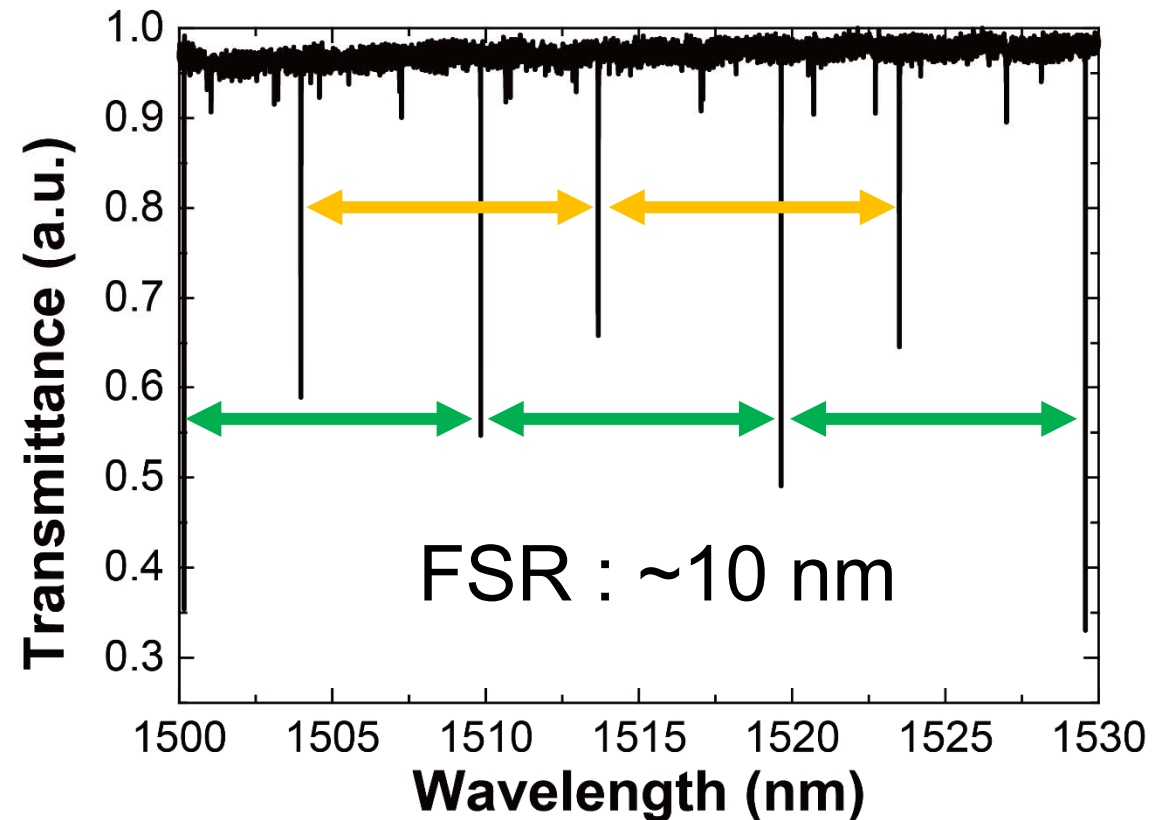
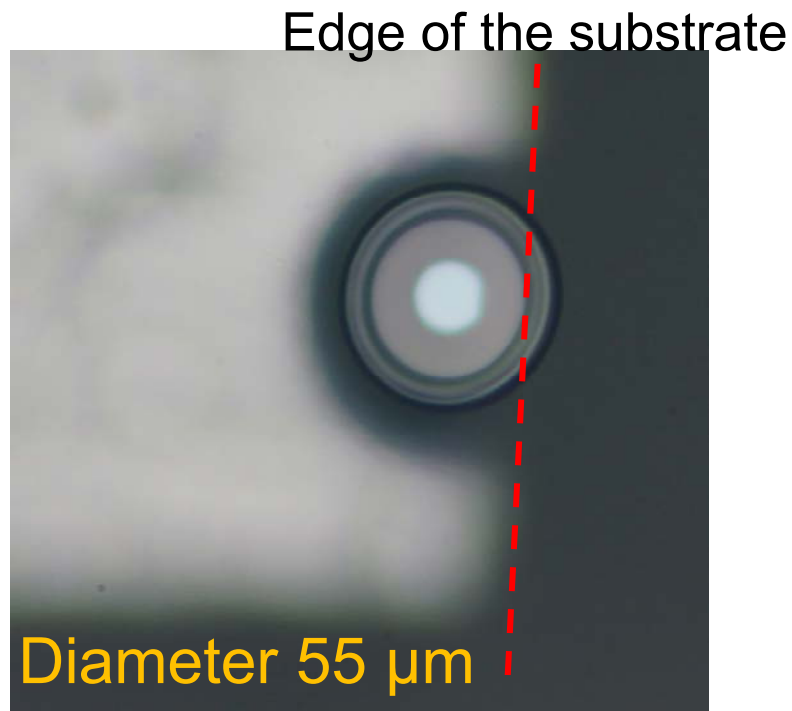


# Sample preparation

## Fabrication procedure



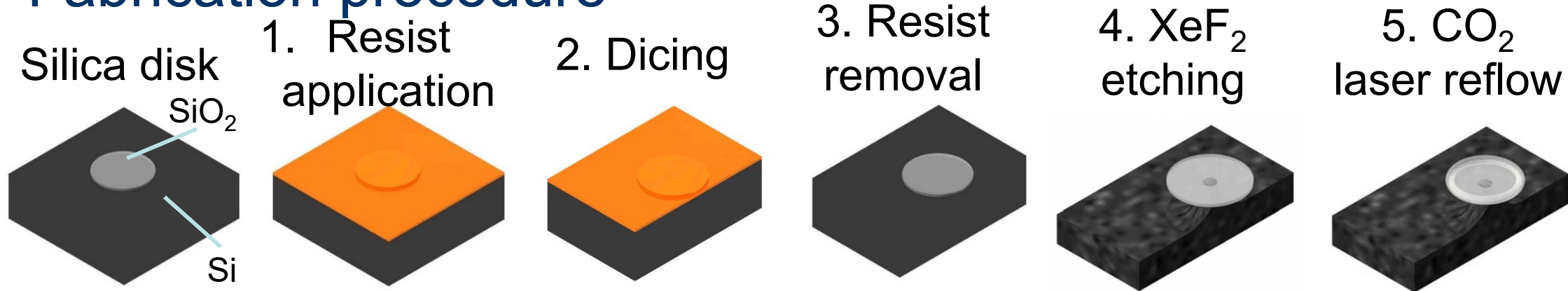
## Fabricated structure



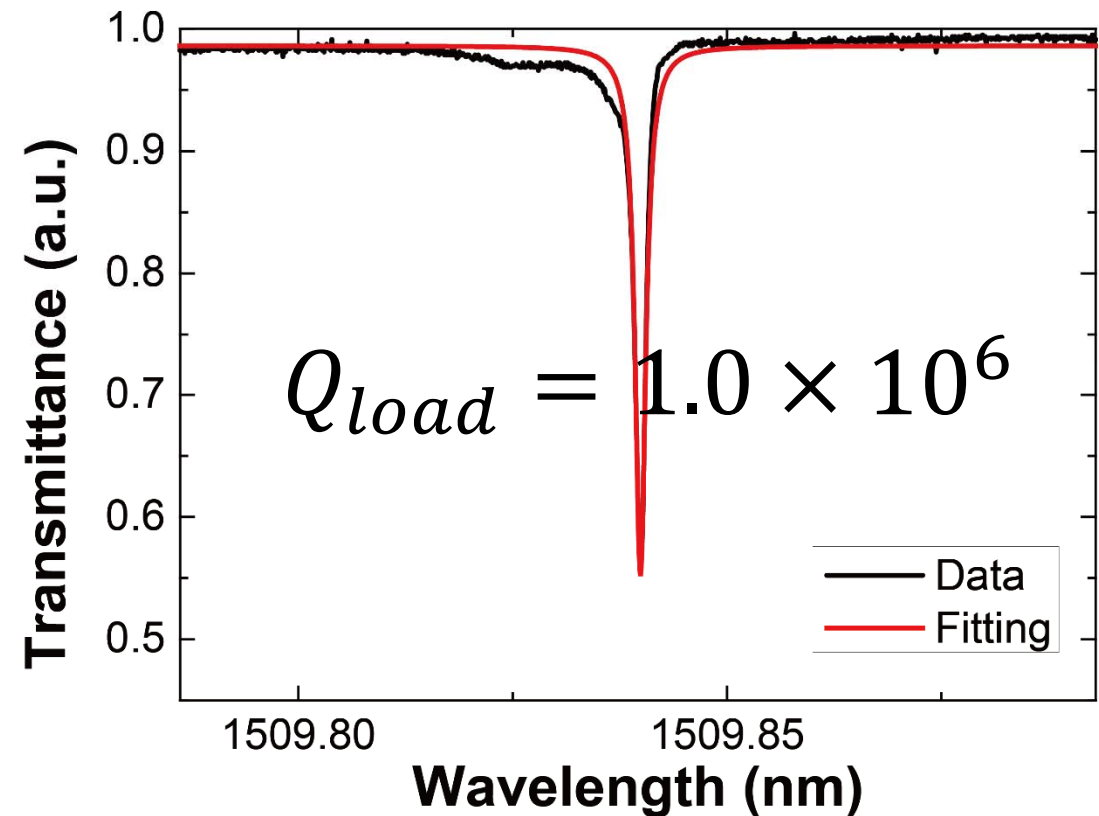
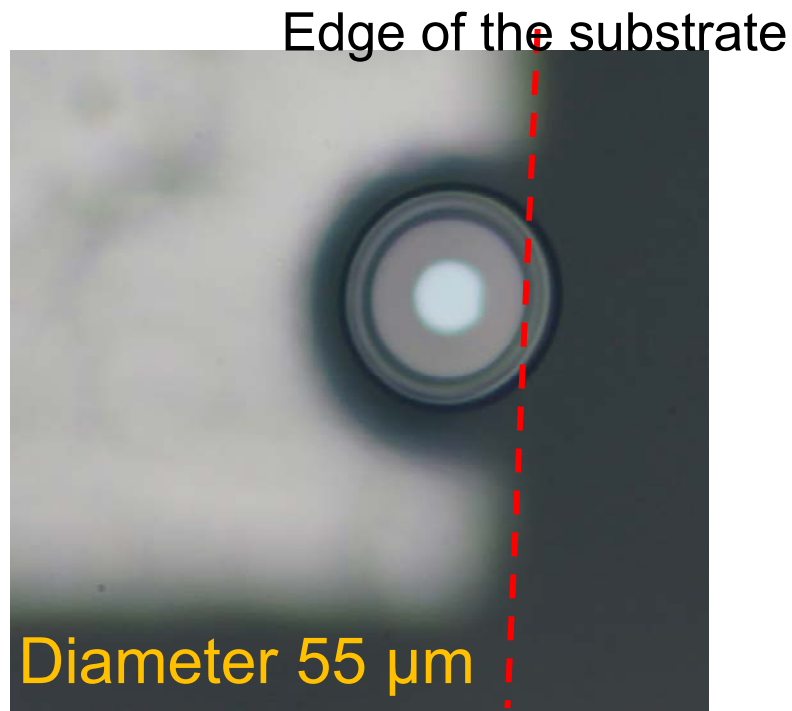


# Sample preparation

## Fabrication procedure



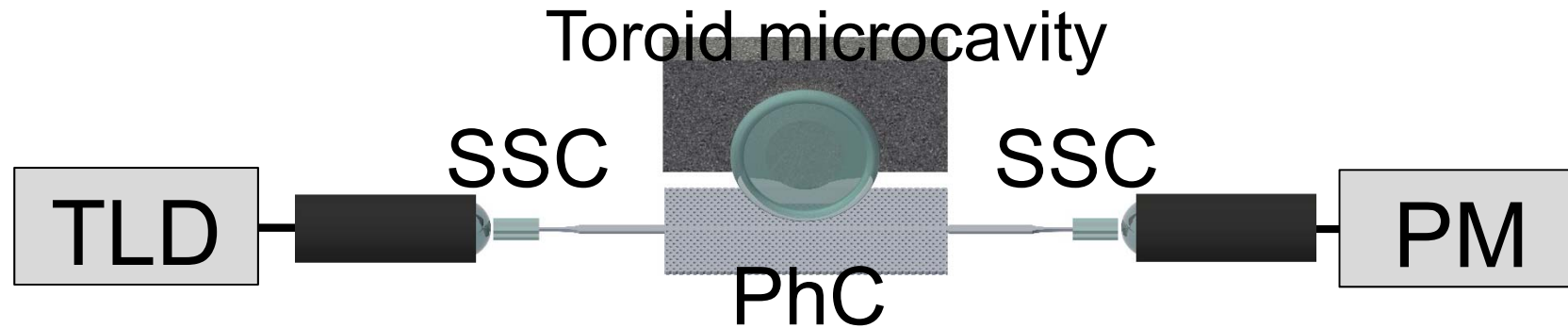
## Fabricated structure



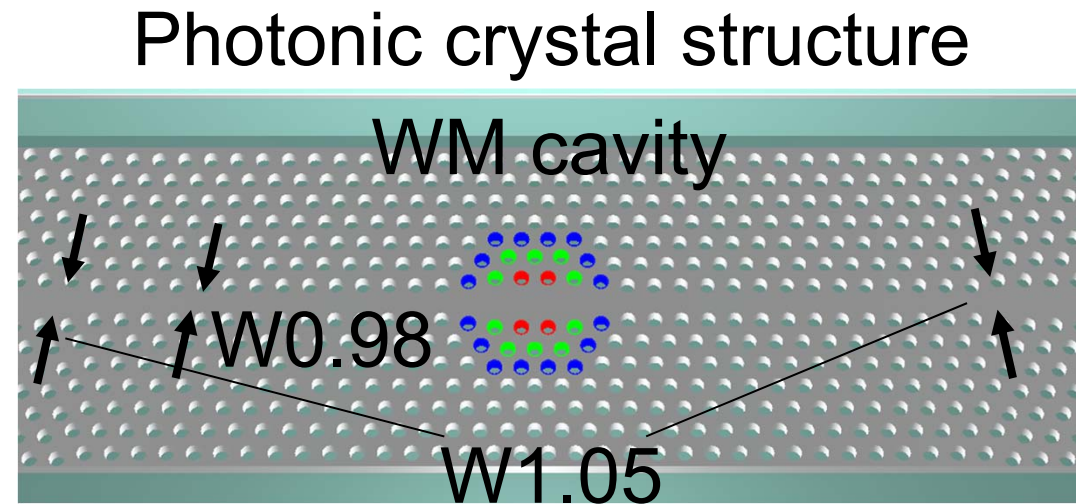
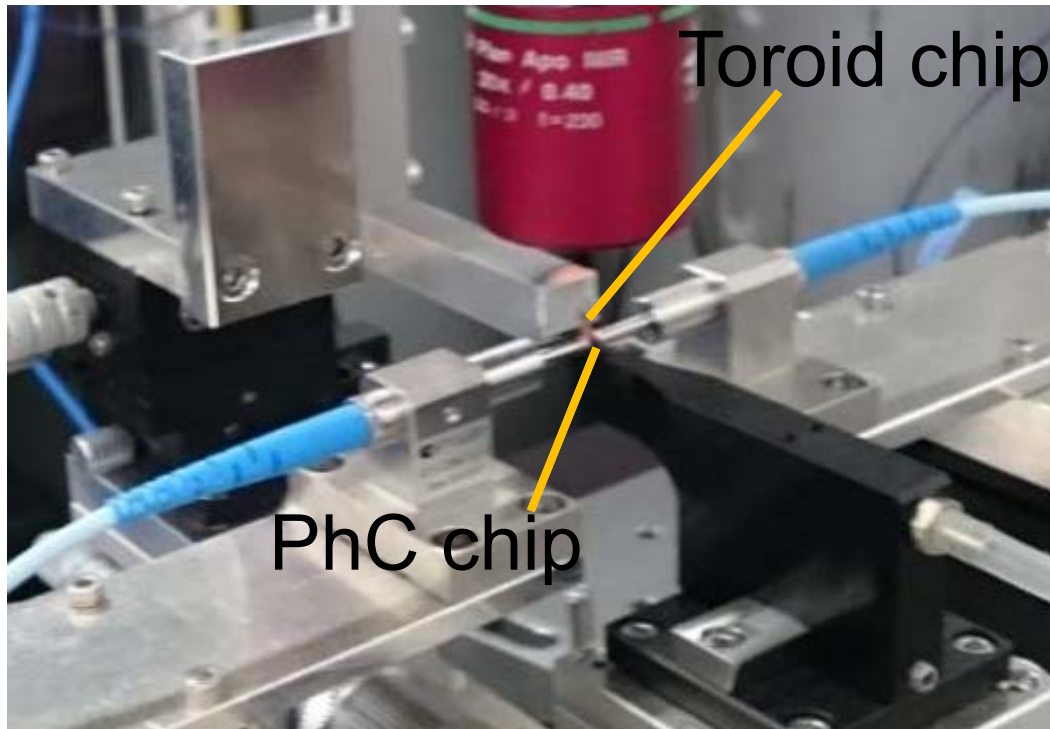




# Experimental setup



TLD: Tunable laser diode. SSC; Spot size converter. PM: Power monitor



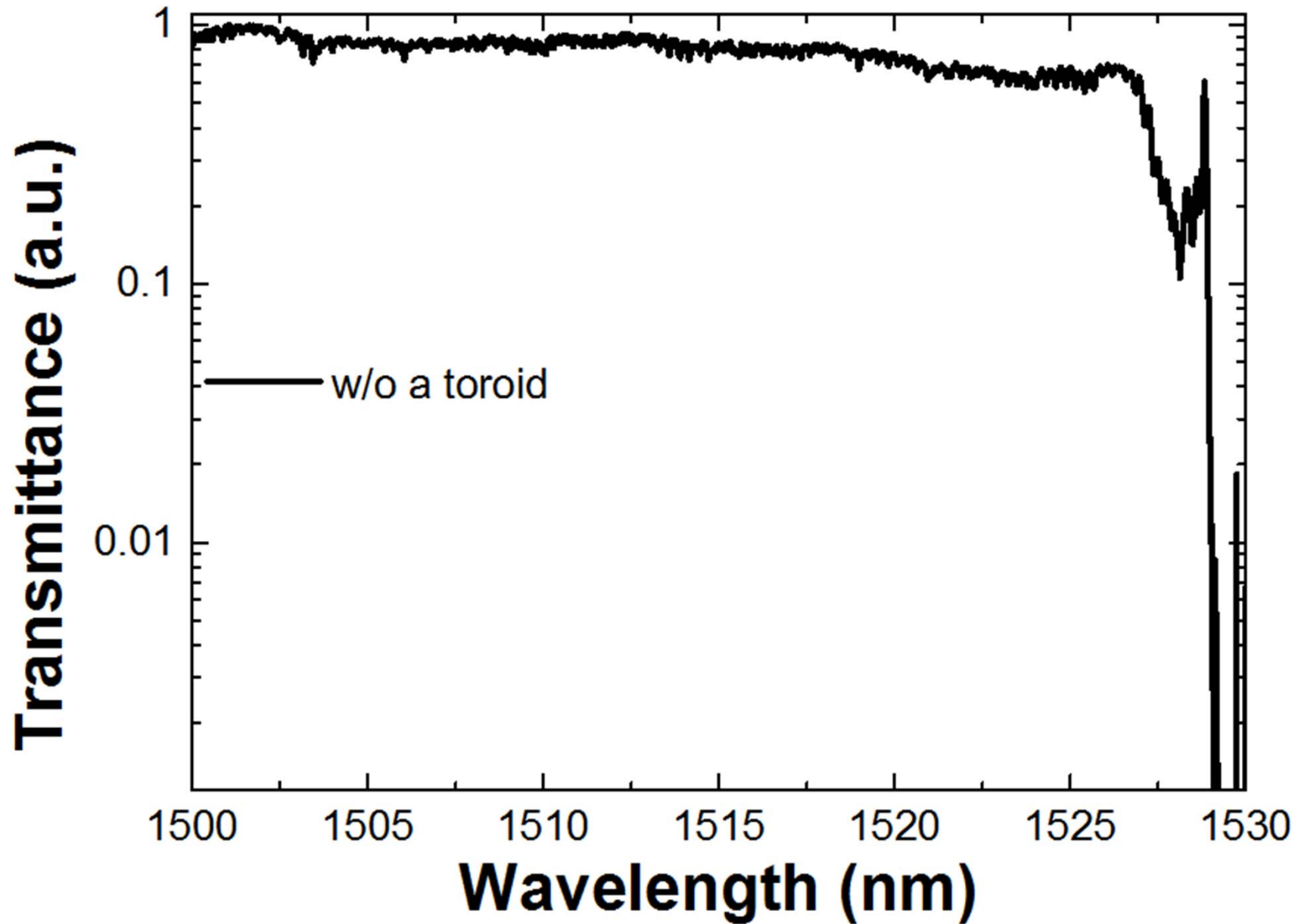
Lattice constant 420 nm Radius 123 nm,  
Thickness 210 nm

Length of W0.98 waveguide : about 13  $\mu\text{m}$

Length of each W1.05 waveguide : about 44  $\mu\text{m}$

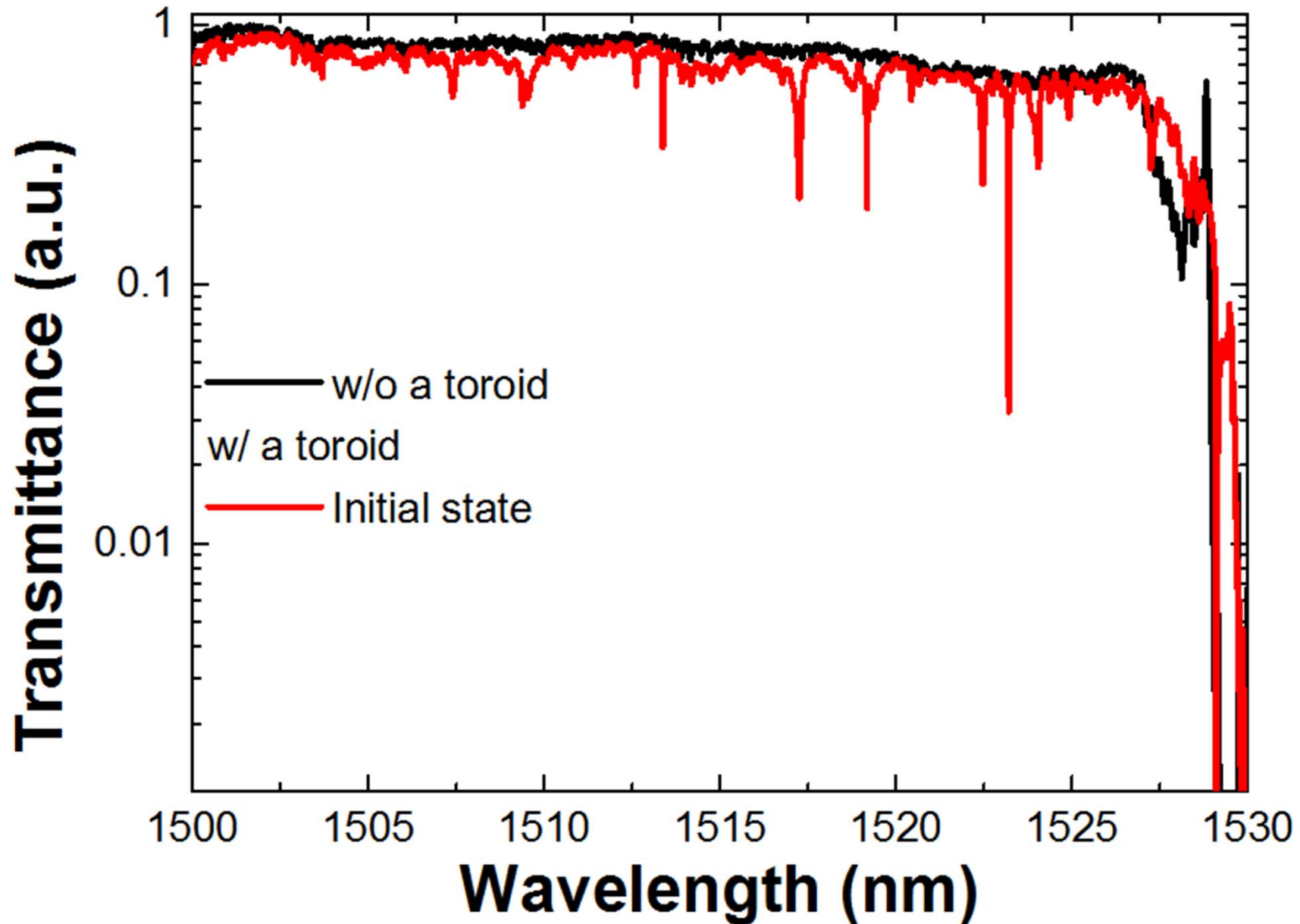


# Result: Transmission spectrum



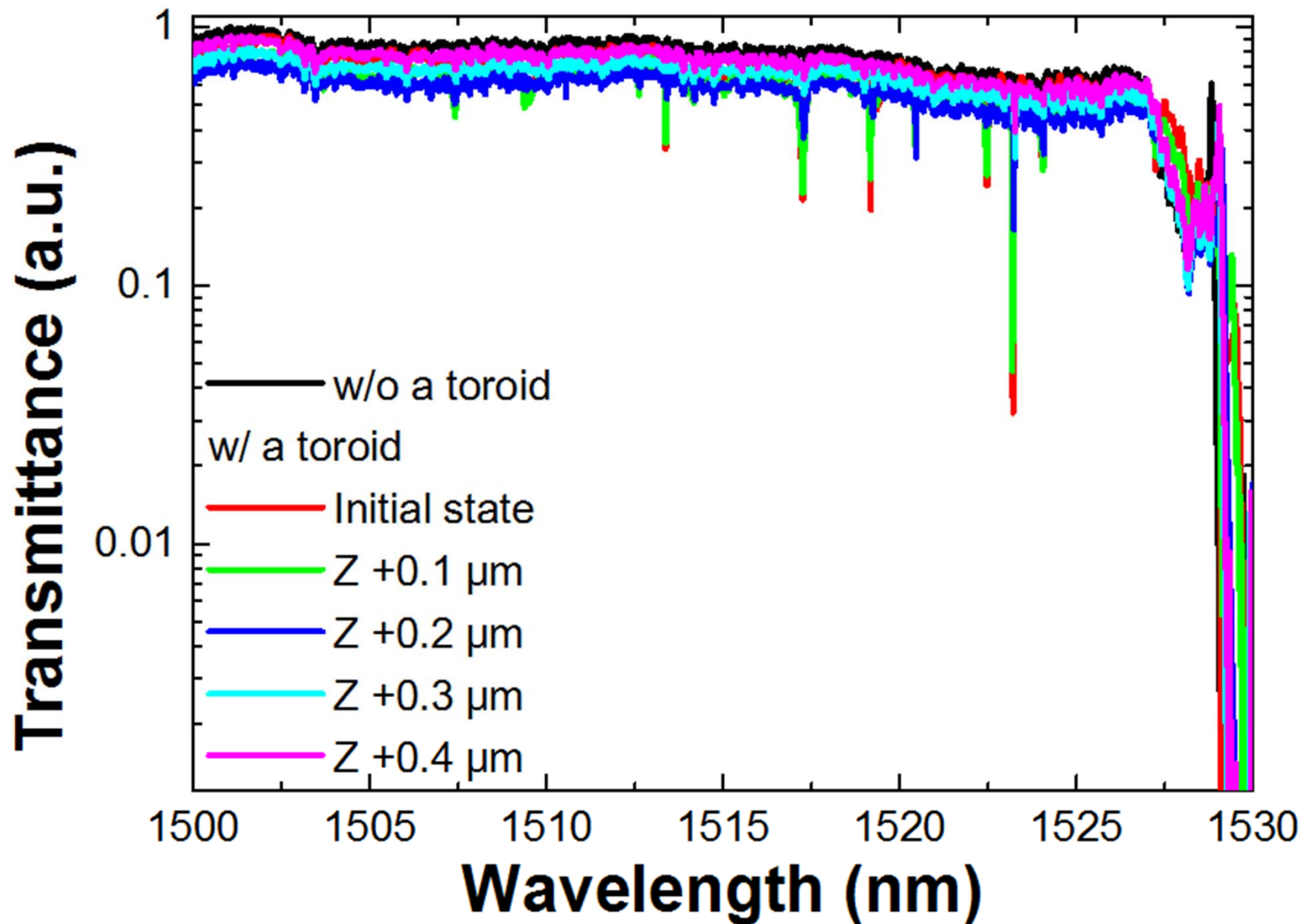


# Result: Transmission spectrum





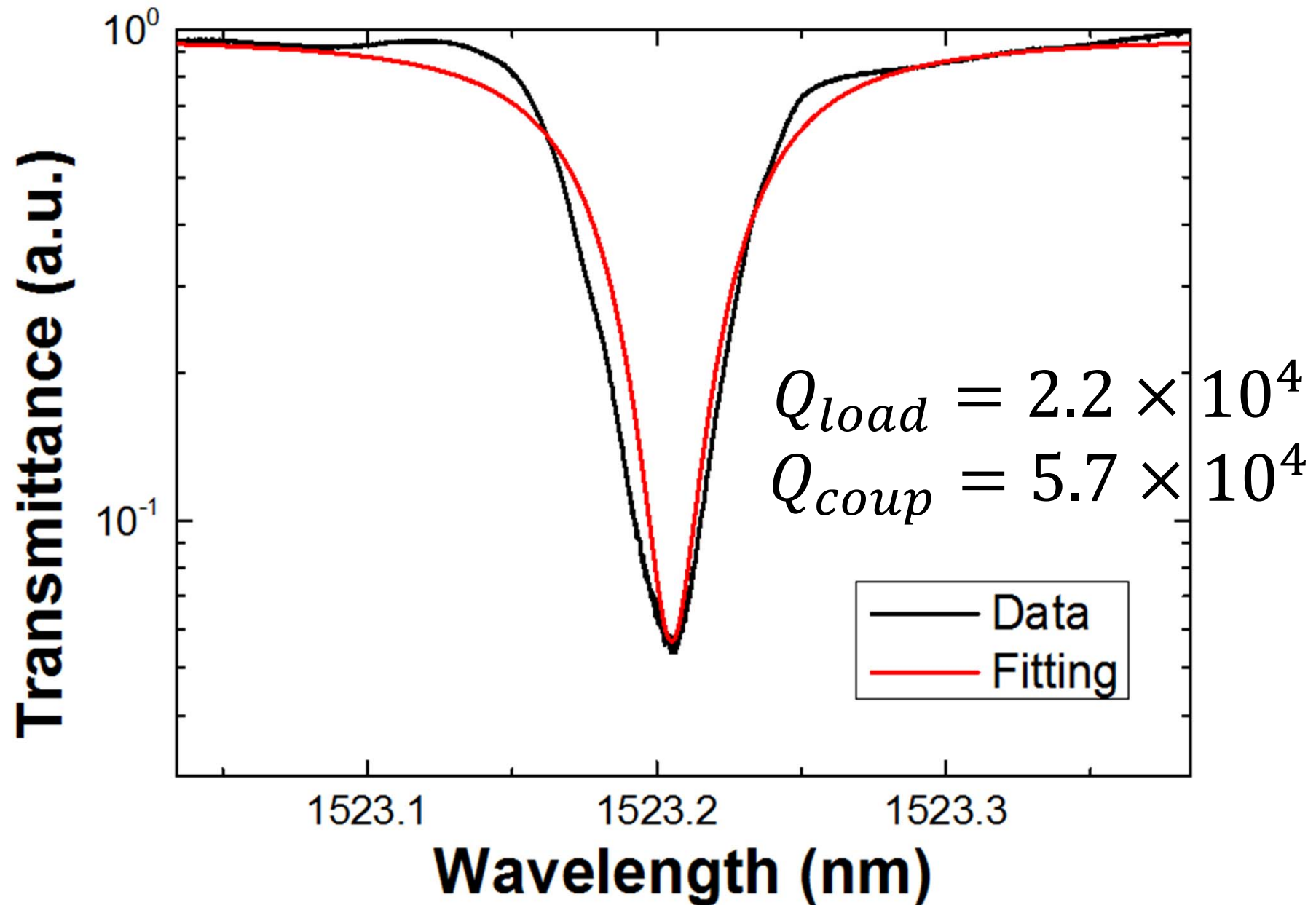
# Result: Transmission spectrum



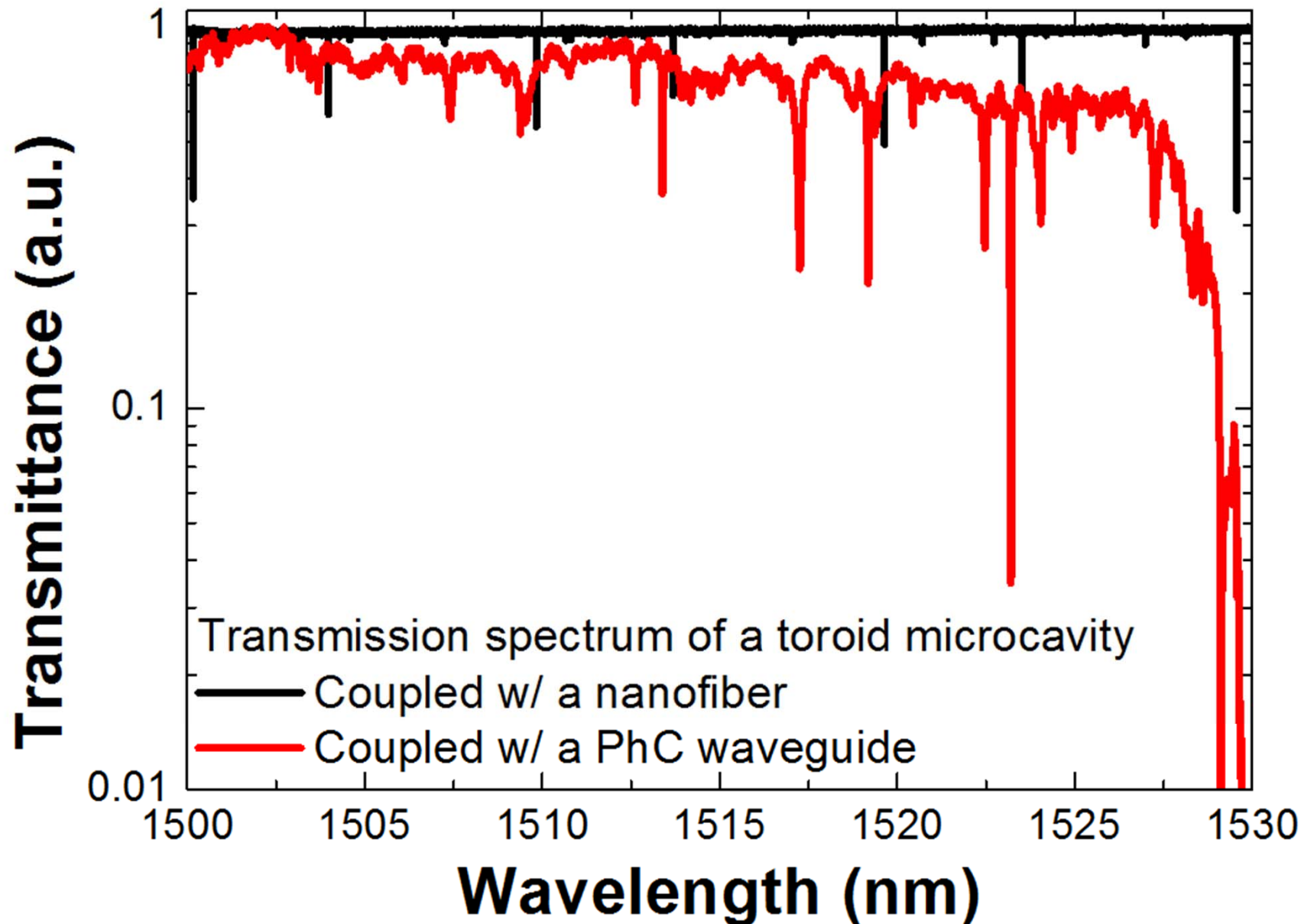




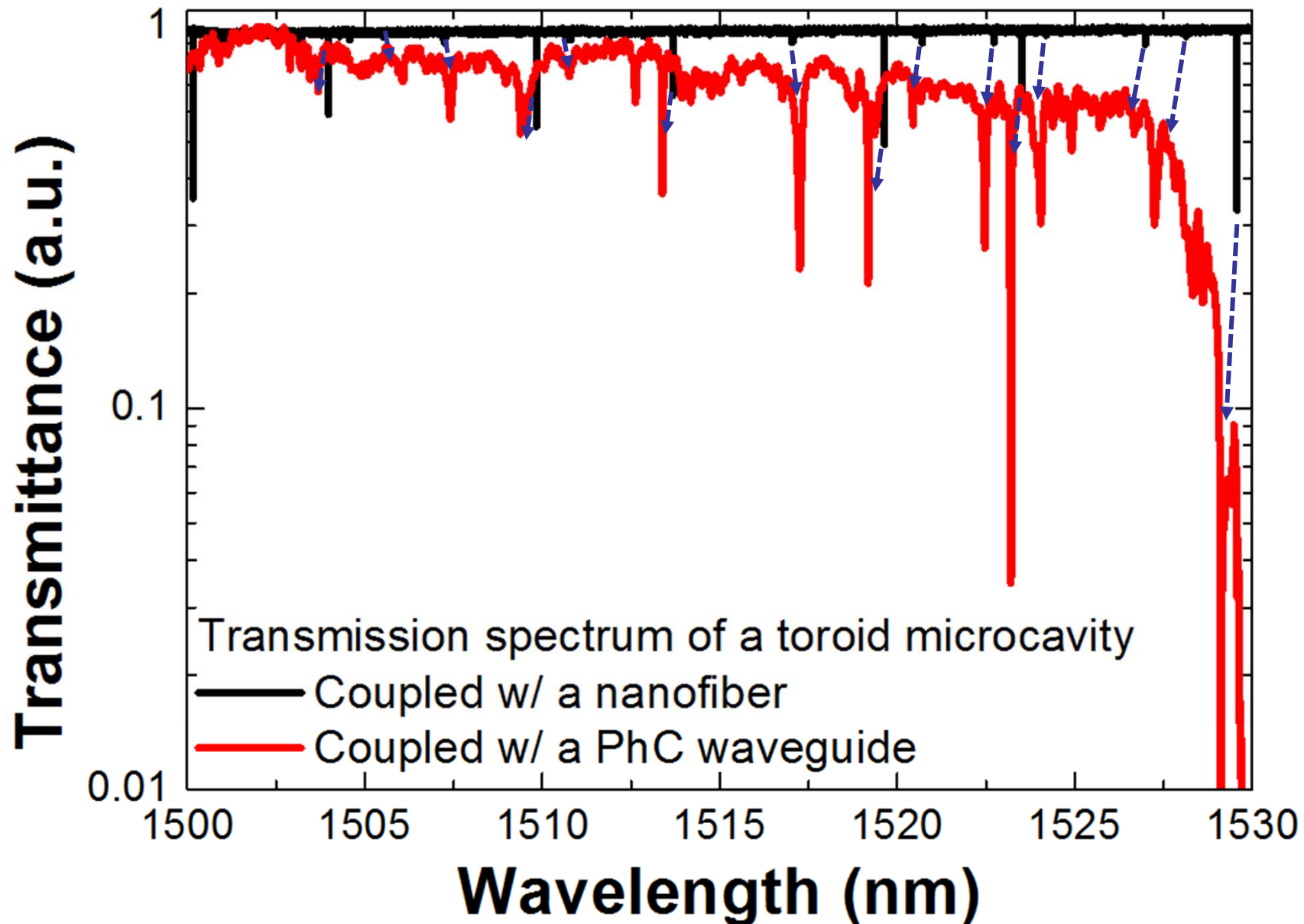
# Result: Smallest coupling $Q$



## Result: Comparison of the transmission spectrums

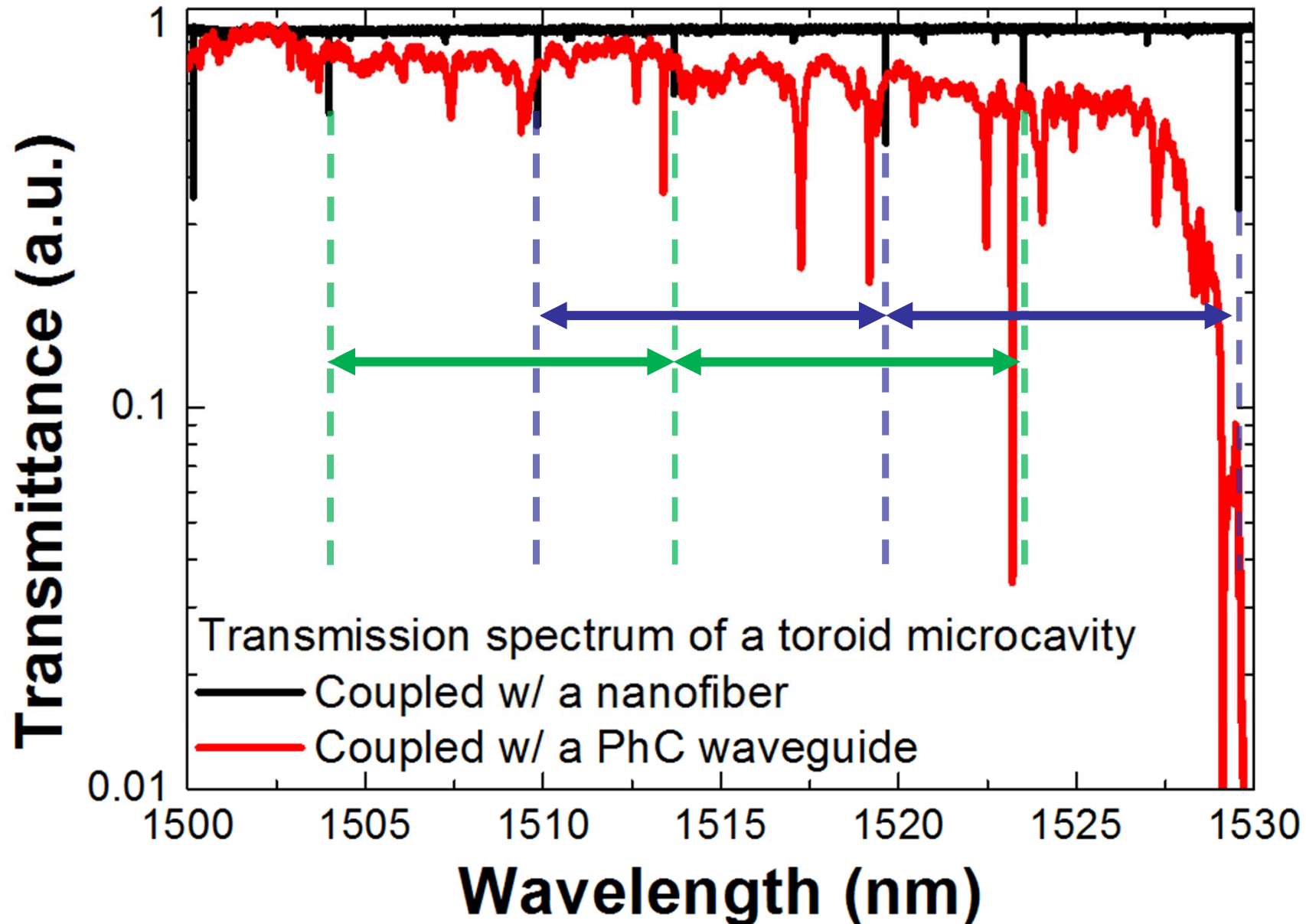


## Result: Comparison of the transmission spectrums





# Result: Comparison of the transmission spectrums







# Summary

## Achievements

- ✓ Demonstrated direct coupling between a toroid microcavity & a PhC waveguide
- ✓ Obtained a coupling  $Q$  of  $5.7 \times 10^4$

## Acknowledgements

This work is supported by

- ✓ Strategic Information and Communications R&D Promotion Programme (SCOPE) (#152103015)
- ✓ JSPS KAKENHI Grant Number 16J05171