
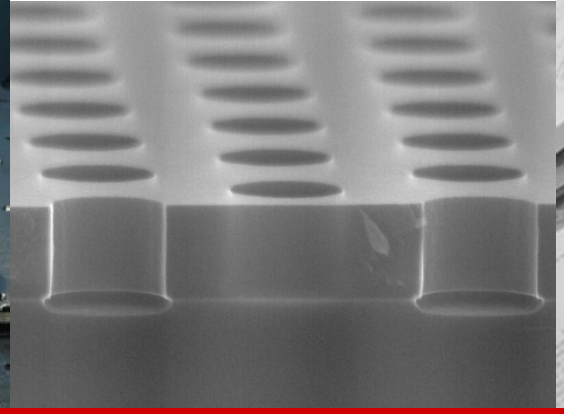


CH-3.3

Study on detection of contamination of pure water using silica microsphere and silica toroid microcavity

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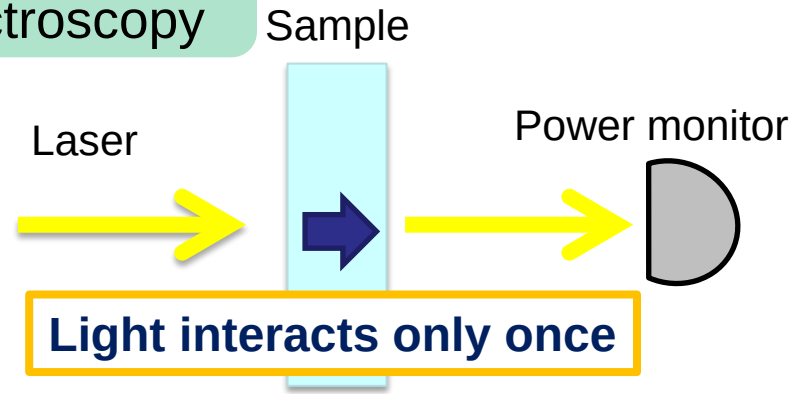
Outline

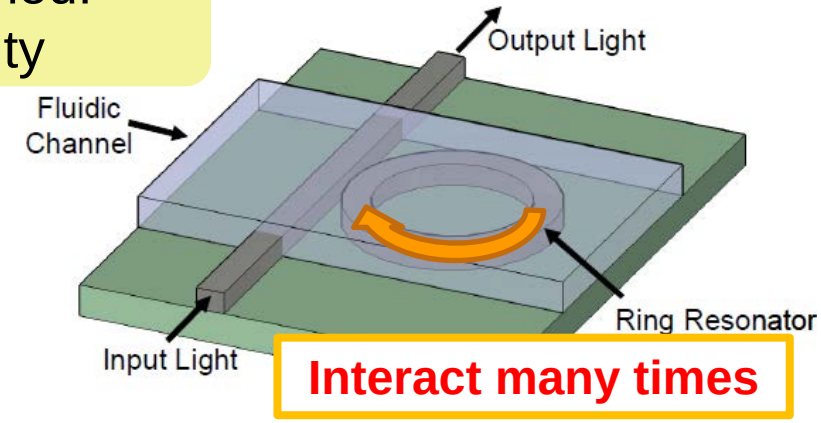
1. Introduction: Conventional optical sensors
    - ✓Tradeoffs device size vs. sensitivity
2. Objective
3. Sensor w/ silica toroid microcavity
    - ✓Detection limit
4. Sensor w/ silica microsphere
    - ✓Comparison of two types of cavities
5. Summary

Advantage of microcavity sensor

Conventional:
IT spectroscopy



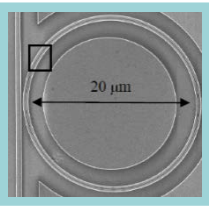
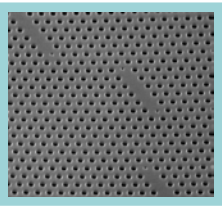
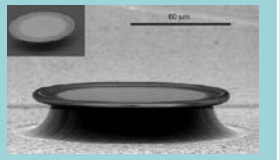
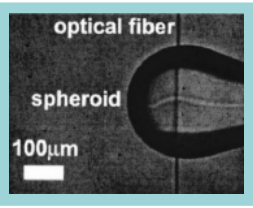
New method:
Microcavity



A. Nitkowski, *et al.*, Opt. Express, **16**, 11930 (2008).

Small size & sensitivity **CANNOT** coexisist

Small size & sensitivity **CAN** coexisist

	Silicon microring resonator	Photonic crystal	Silica toroid cavity	Silica microsphere
				
V	2.5 μm^3	**1.7 μm^3**	110 μm^3	5,000 μm^3
Q	5,000	10^6	**10^8**	**8×10^9**
Coupling w/ fiber	difficult	difficult	easy	easy
	J. Robinson *et al.*, Opt. Express **16**, 4296 (2008).	E. Kuramochi *et al.*, APL **88**, 041112 (2006).	D. Armani *et al.*, Nature **421**, 925 (2003).	F. Vollmer *et al.*, APL **80**, 4057 (2002).

Objective

1. Demonstrate **high sensitivity** and **small size** using a silica toroid microcavity

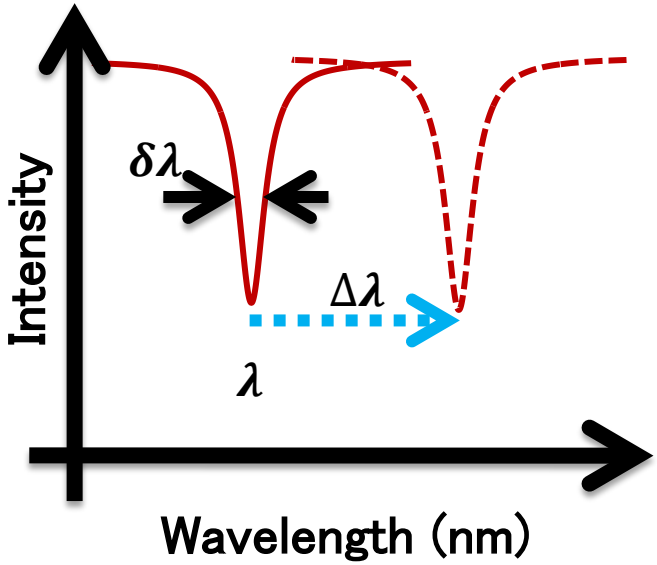
2. Show the comparison between **toroid microcavity** vs. **microsphere**

Sensing operation of a WGM cavity

Detection is performed according to resonant shift

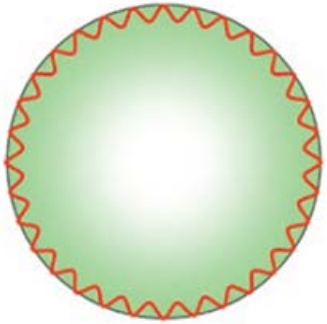
$$\frac{\Delta\lambda}{\lambda_0} = \frac{\alpha_{ex}\sigma}{\varepsilon_0(n_s^2 - n_0^2)R_0} \approx \frac{\Delta R}{R_0} + \frac{\Delta n}{n_0}$$

Radius Refractive index

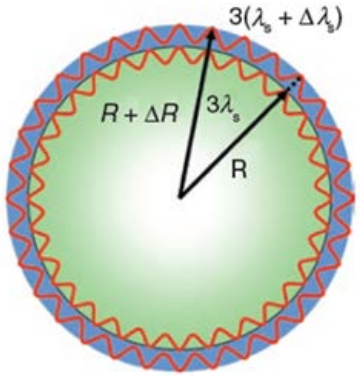


Model (with only radius enlarged)

Before adsorption



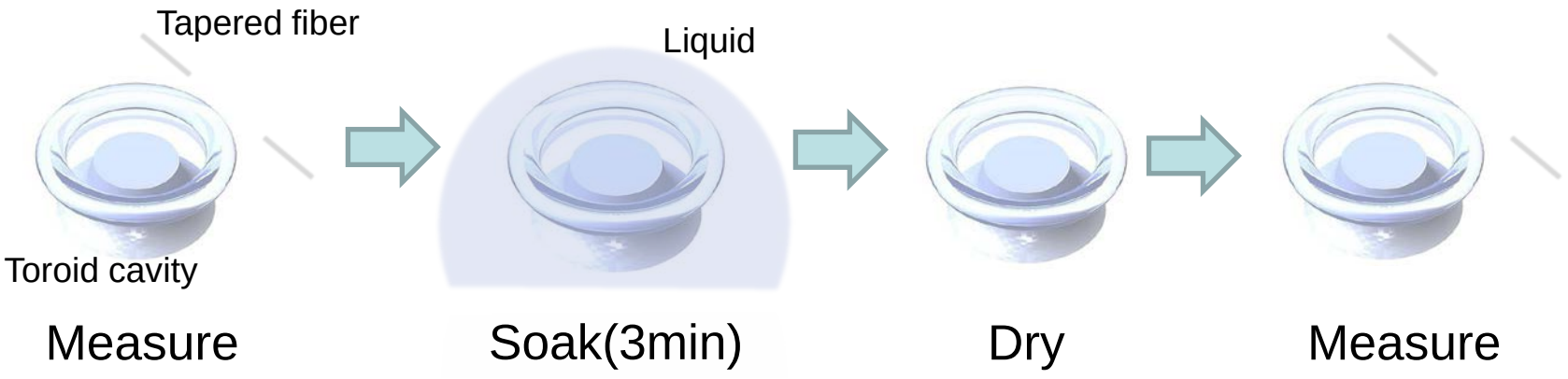
After adsorption

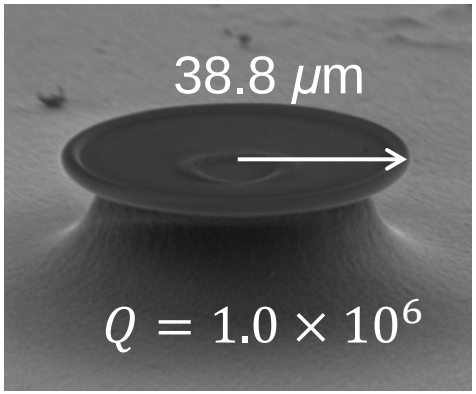


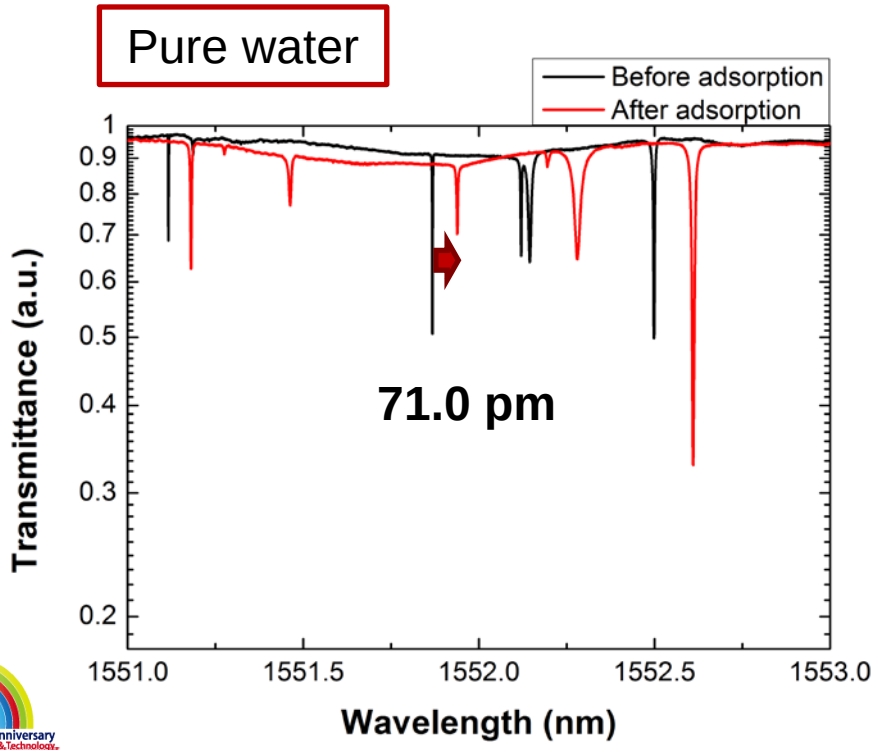
F. Vollmer, *et al.*, Nat. Methods **5**, 591 (2008).

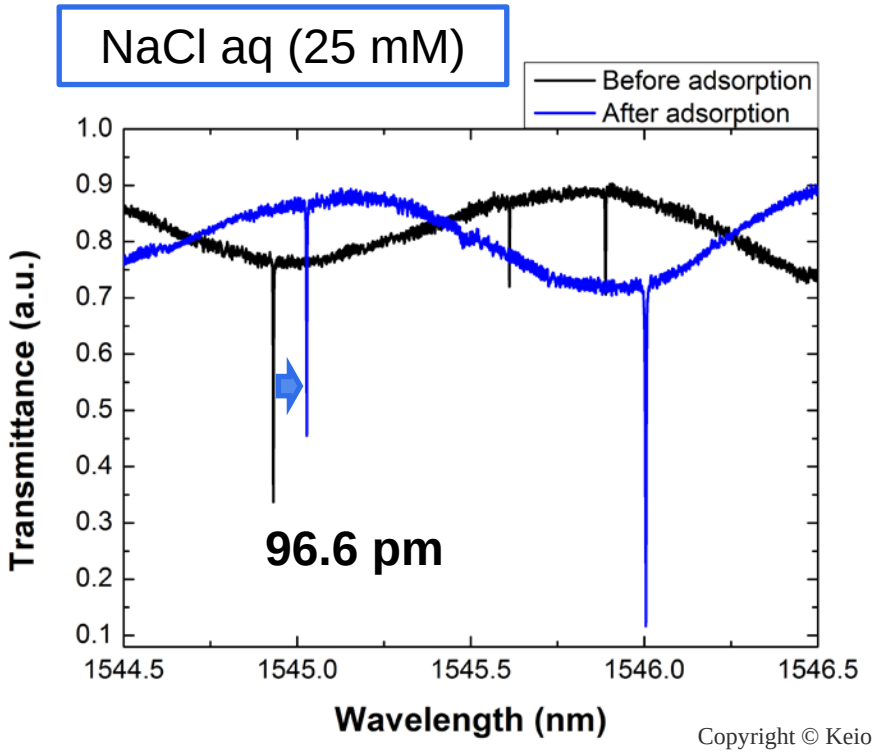
Experiment using silica toroid microcavity

Experimental procedure

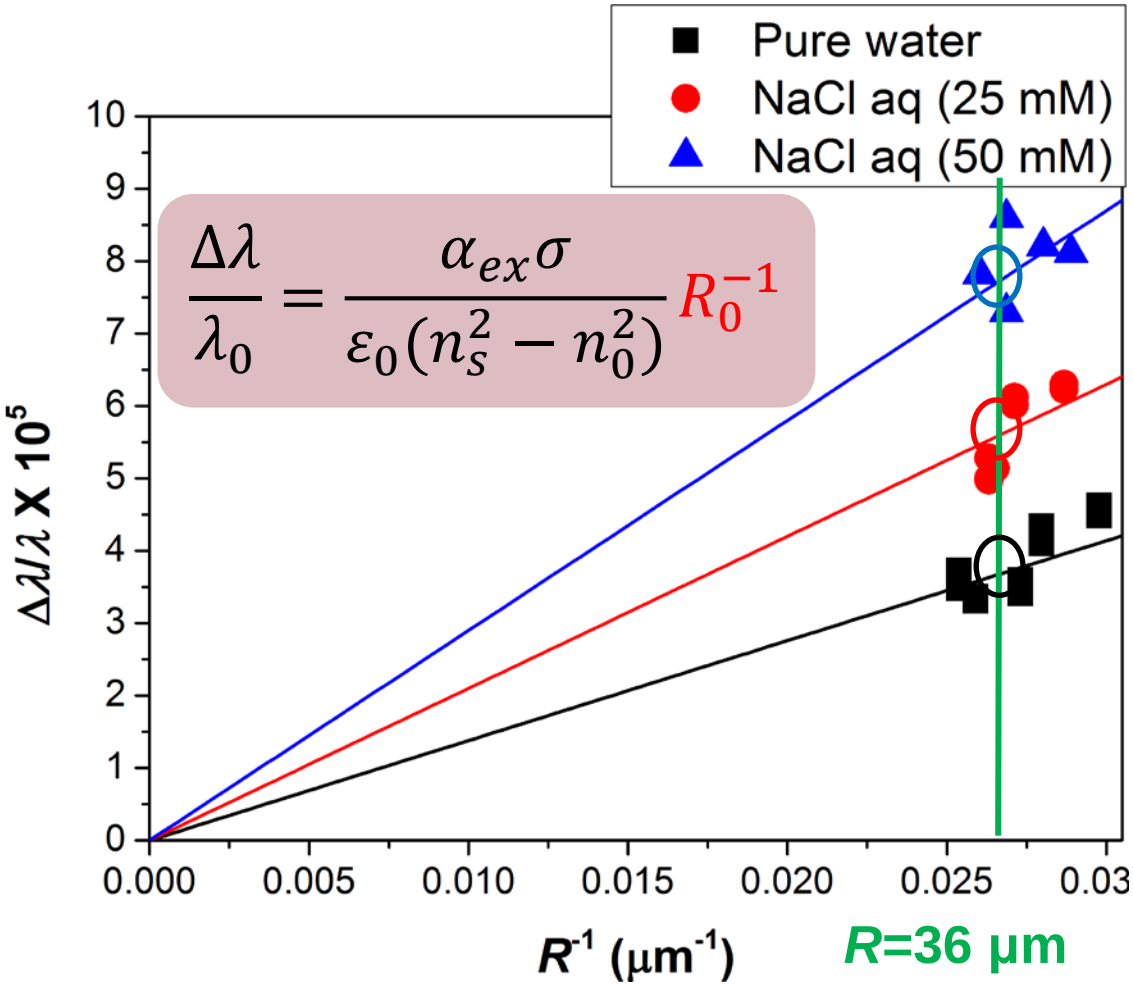


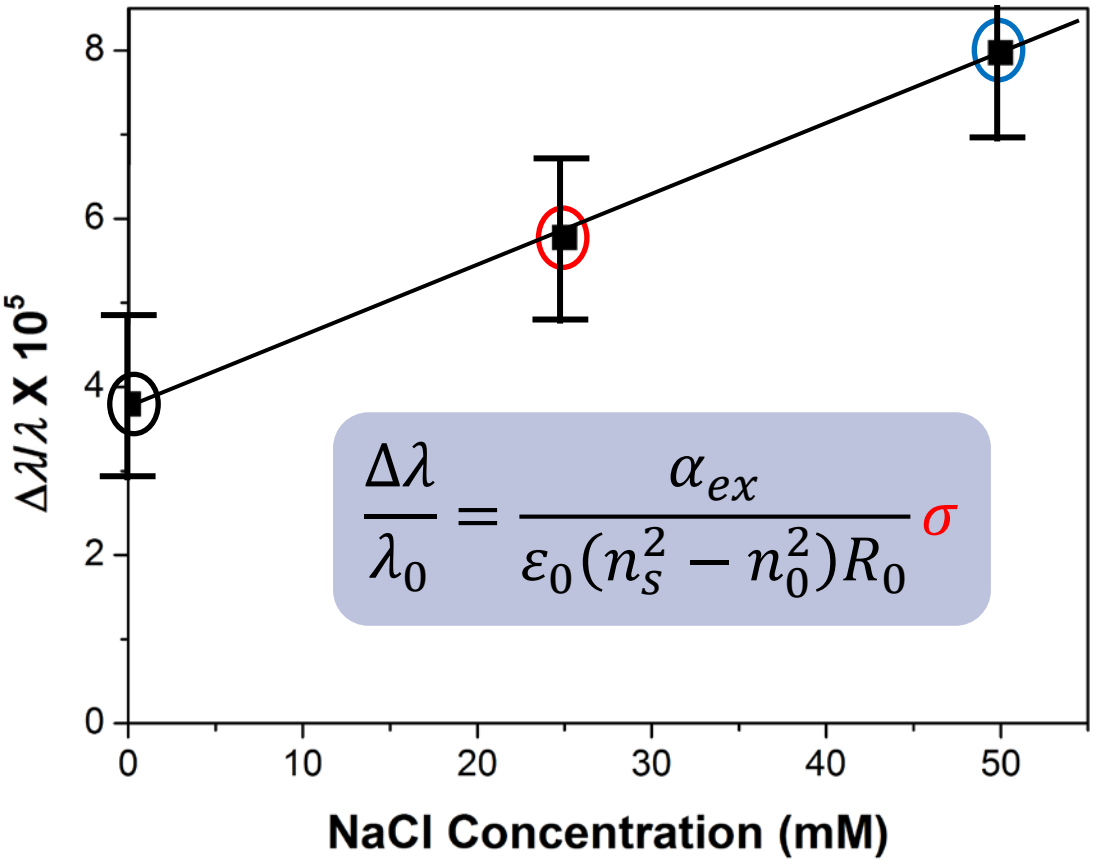






NaCl detection w/ toroid microcavity



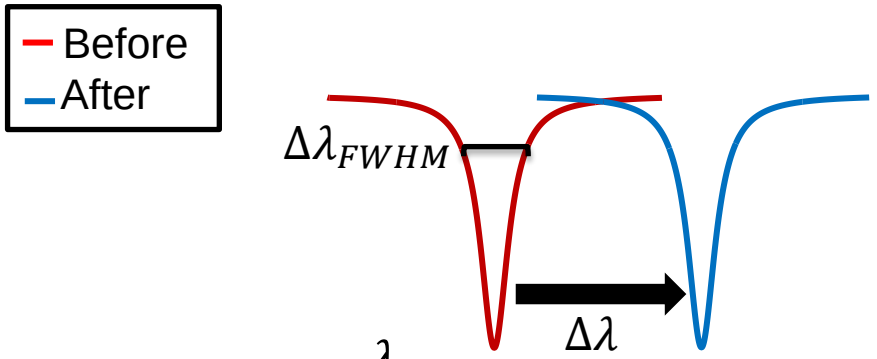


Experimental results agrees well w/ theory

Detection limit

Resonant shift vs. Linewidth

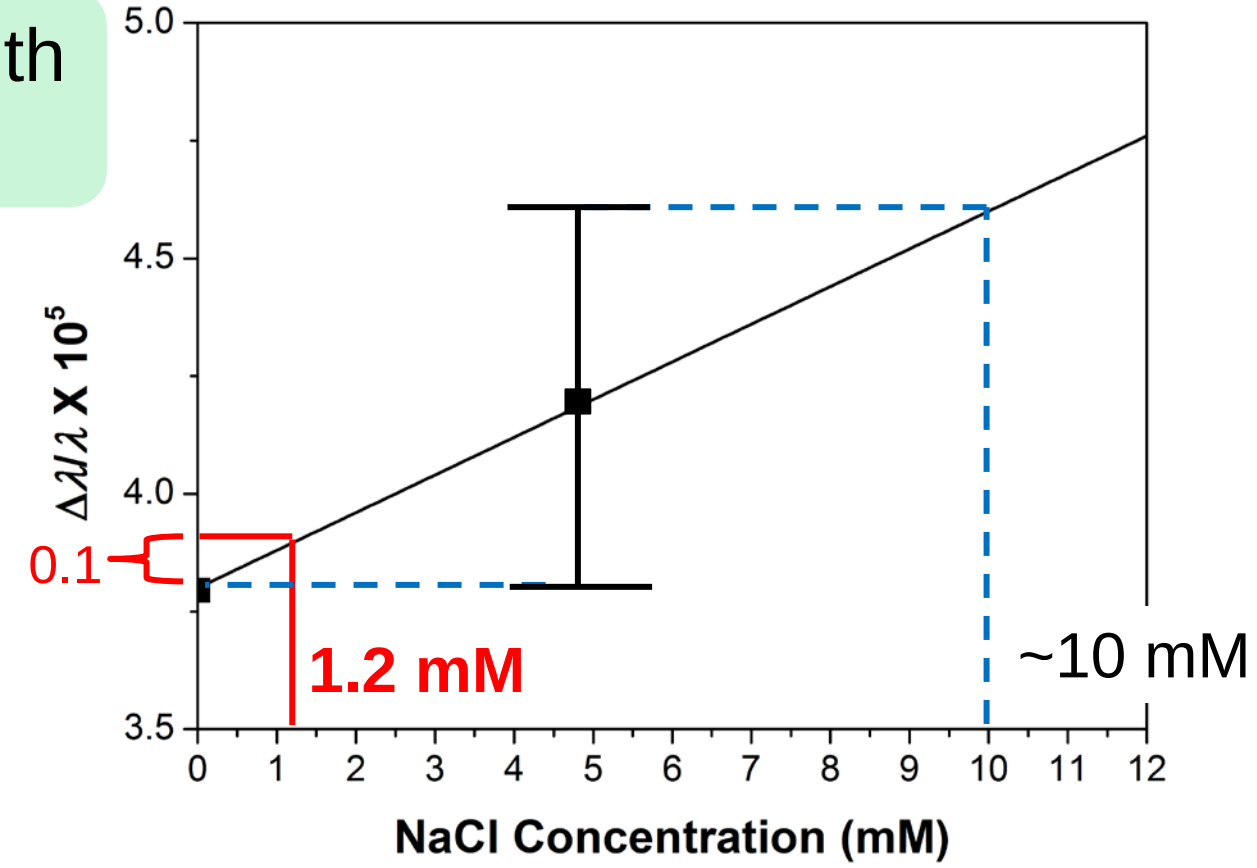
$$\Delta\lambda > \Delta\lambda_{FWHM}$$



$$Q = \frac{\lambda}{\Delta\lambda_{FWHM}}$$

$$Q = 1.0 \times 10^6$$

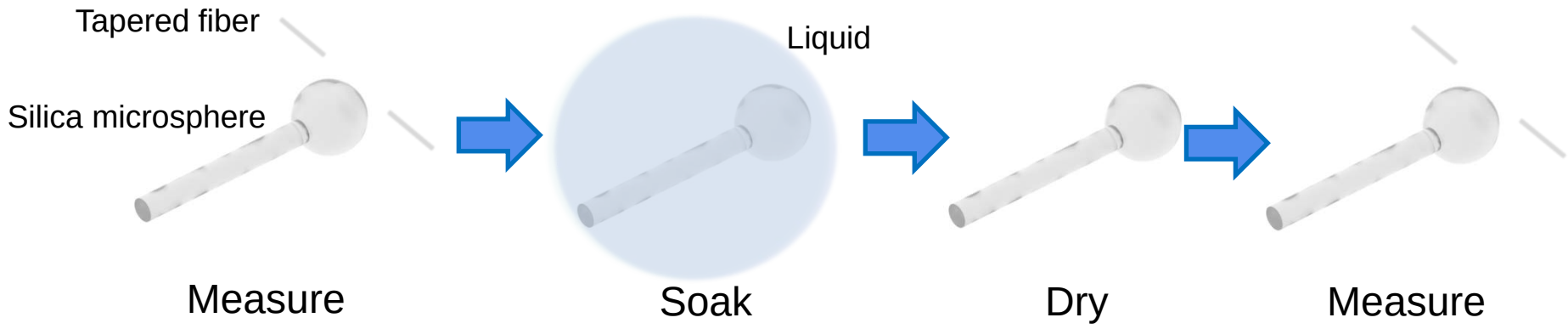
$$\frac{\Delta\lambda_{FWHM}}{\lambda} = \frac{\Delta\lambda_{mini}}{\lambda} = 0.1 \times 10^5$$

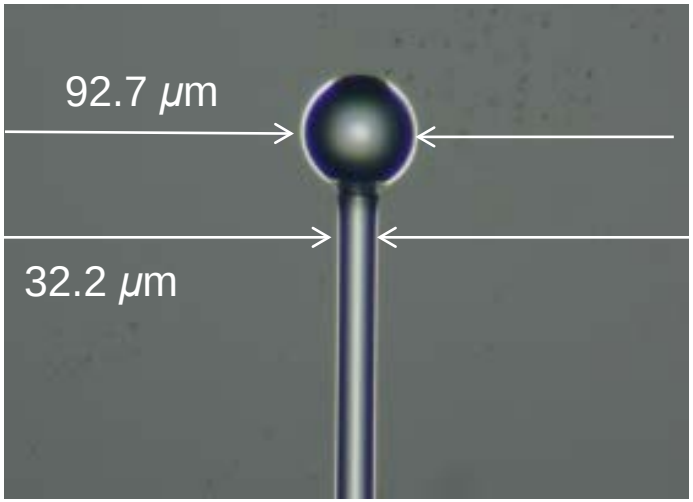


	Our method	Commercial method
Detection limit	1.2 mM	1.7 mM
Sample volume	**0.1 nL**	0.3 mL

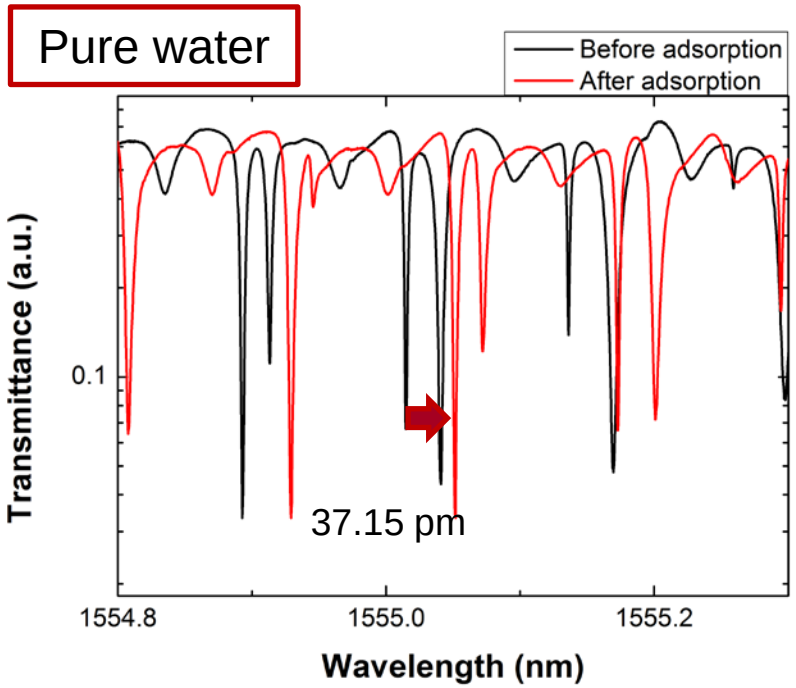
Experiment using silica microsphere

Experimental procedure

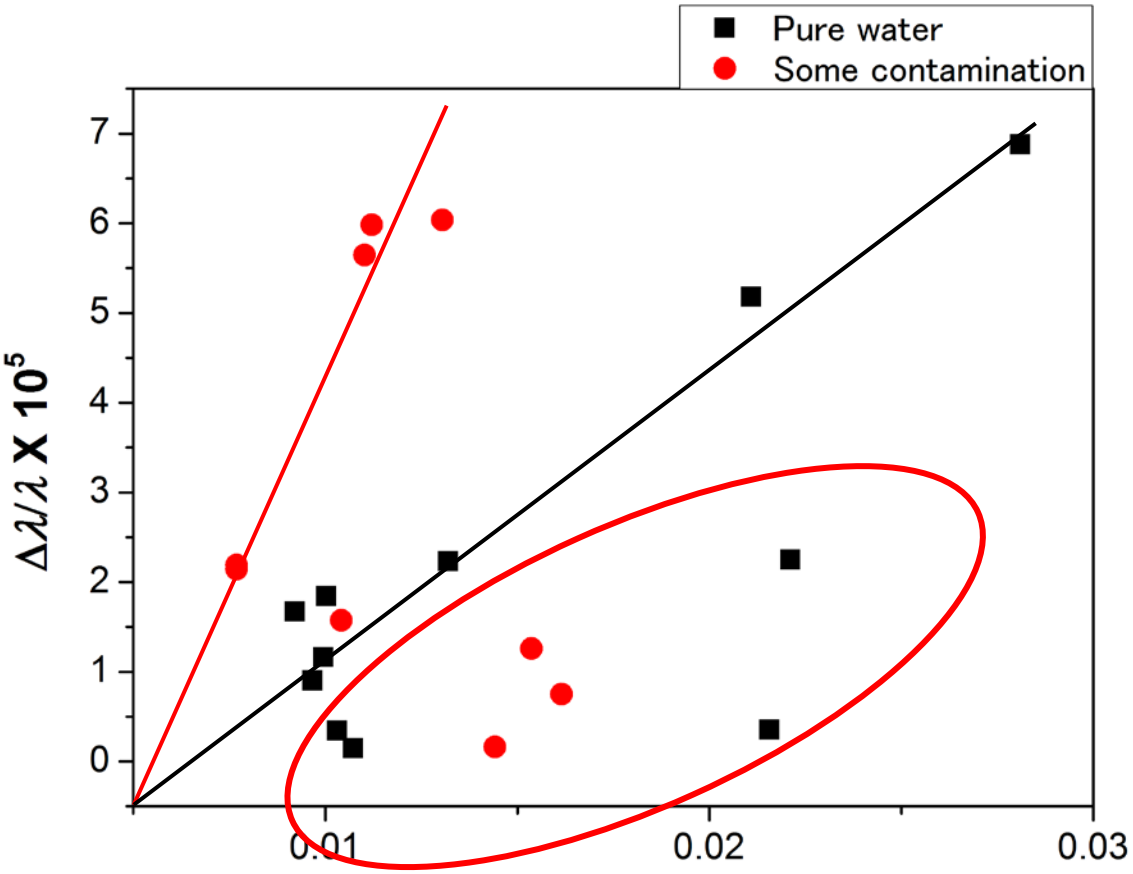


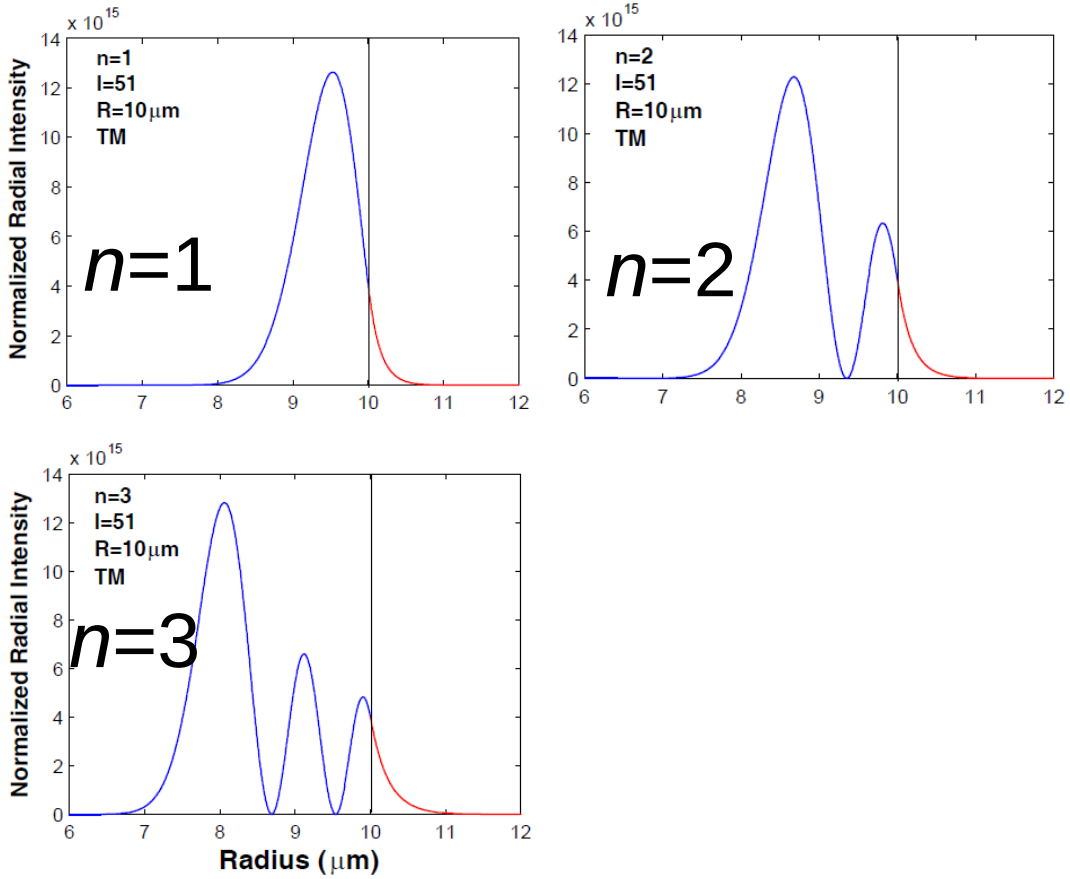


$$Q = 1.0 \times 10^6$$



Azimuthal number vs. shift

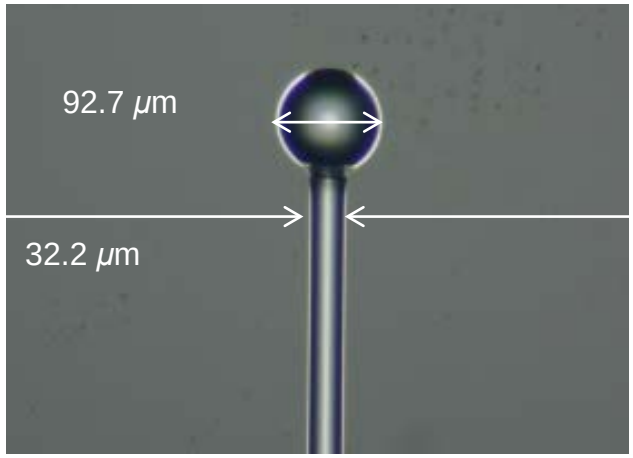




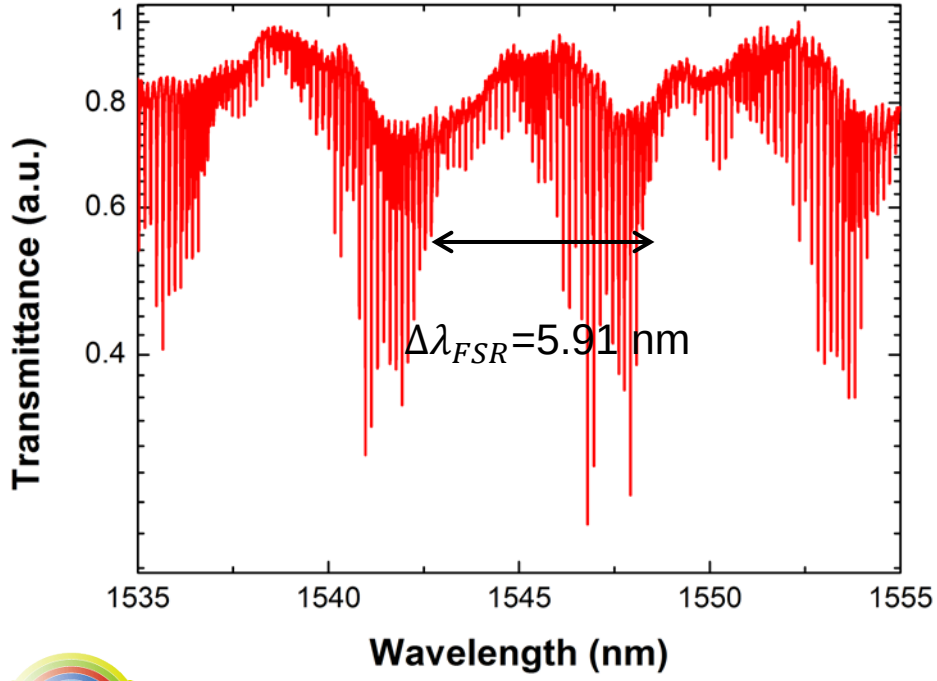
T. J. Kippenberg, Ph. D. Tehesis (2004).

Comparison between silica microsphere and silica toroid cavity

Silica microsphere

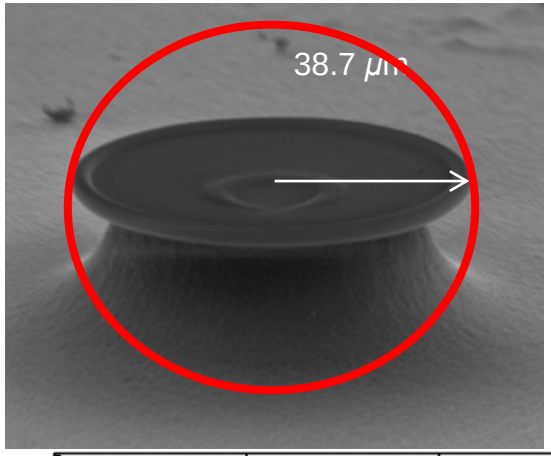


Many azimuthal modes are excited

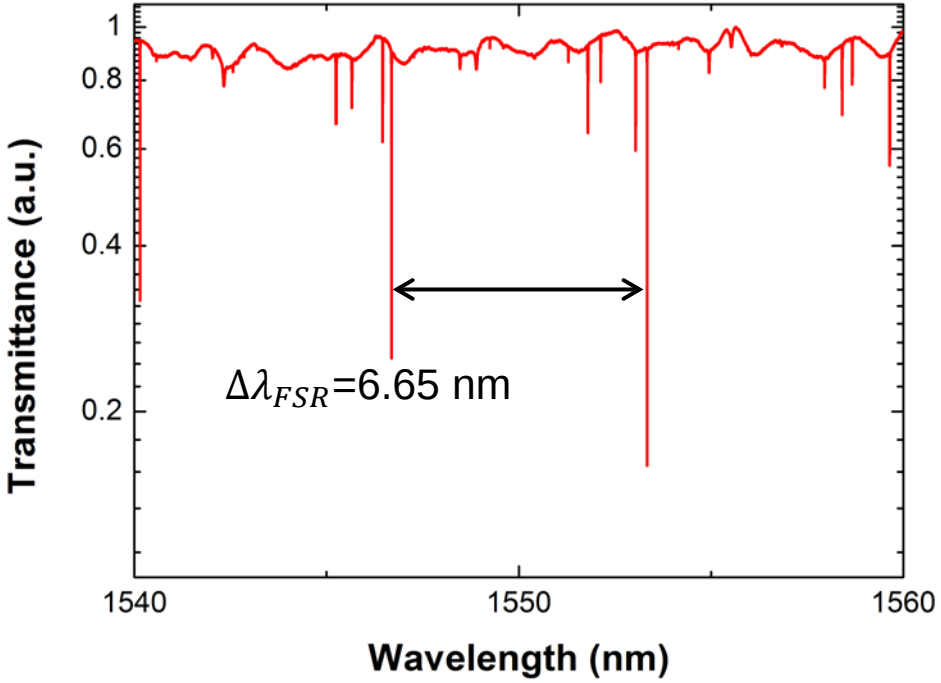


A number of modes

Toroid cavity



Easy!!



A few modes

Summary

1. Demonstrated NaCl detection in water w/ silica toroid microcavity
   - ✓High detection sensitivity: ~10 mM (can reduce to 1.2 mM)
   - ✓Small sample volume: 0.1 nL

2. Discussed the comparison between microtoroid vs. microsphere
   - ✓Toroid microcavity is more appropriate than microsphere

Thank you very much