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Higher order mode ring resonator for trapping dielectric particulate matter in air

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► **To cite this version:**

C B Chander Bhan, M Calvo, G Beaudin, S Monfray, F Boeuf, et al.. Higher order mode ring resonator for trapping dielectric particulate matter in air. Photonic North 2023, Jun 2023, Montreal (Canada), Canada. hal-04701262

HAL Id: hal-04701262

<https://hal.science/hal-04701262v1>

Submitted on 18 Sep 2024

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1. INTRODUCTION

CONTEXT: Current **commercialized air particulate sensors (LoD: 0.3 – 10 μm)**, based on the gravimetric method and light scattering, rely on several assumptions that result in **insufficiently reliable and inaccurate results for the detection of sub-100nm particles.**



Fluoranthene and Pyrene (< 0.1 μm)

Leading to:

- cardiovascular and renal diseases
- pulmonary-to-systemic inflammation

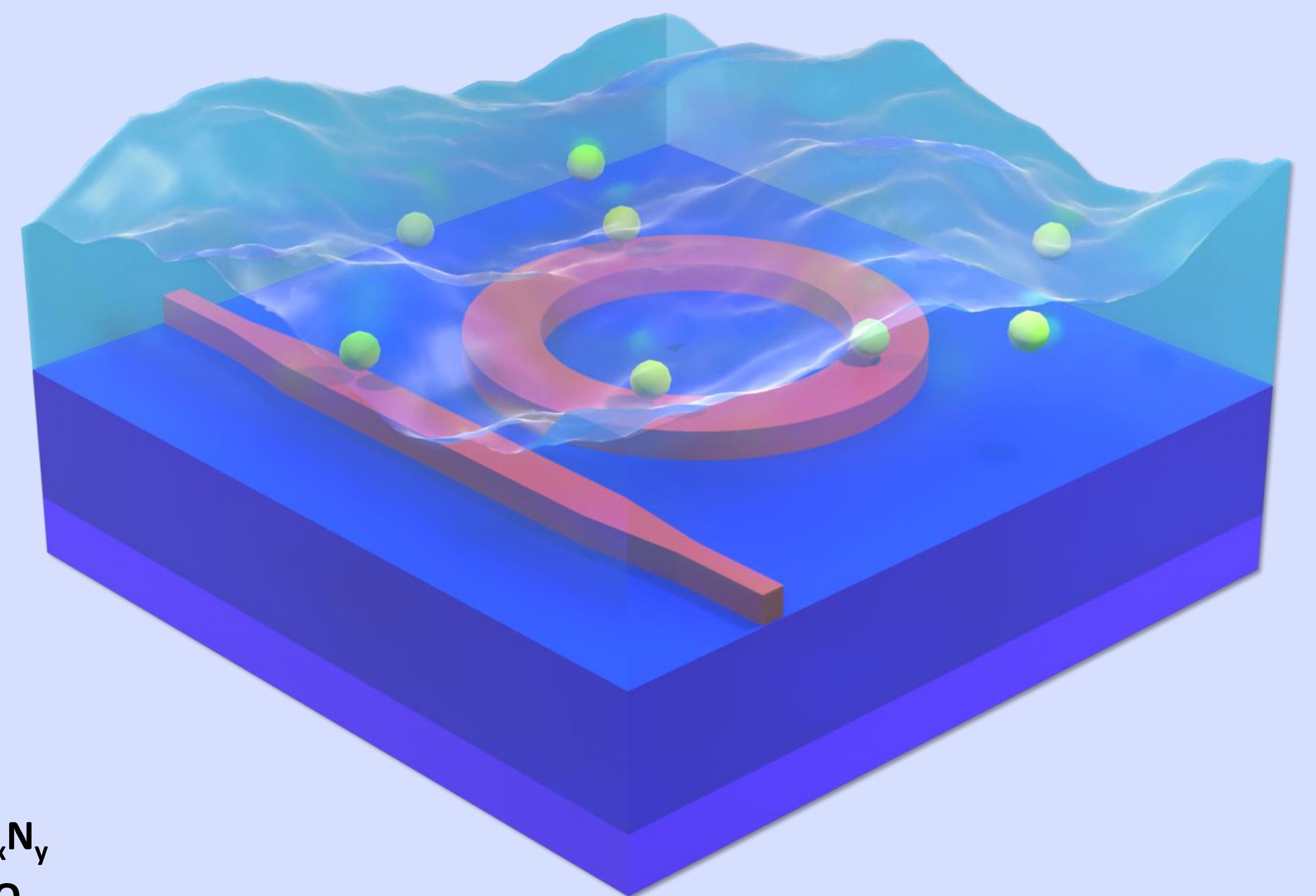
sense + trapped

Micro-ring resonators

Reliable and precise, compatible with CMOS fab

HIGHLIGHTS:

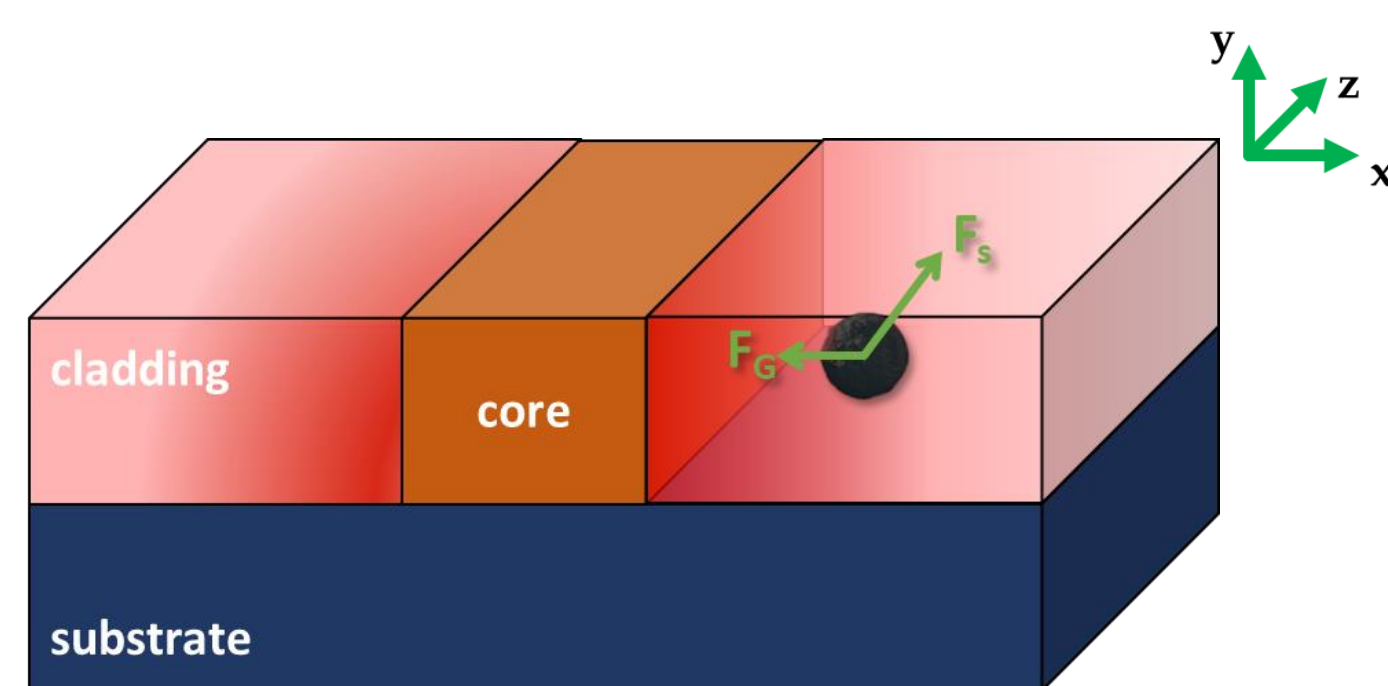
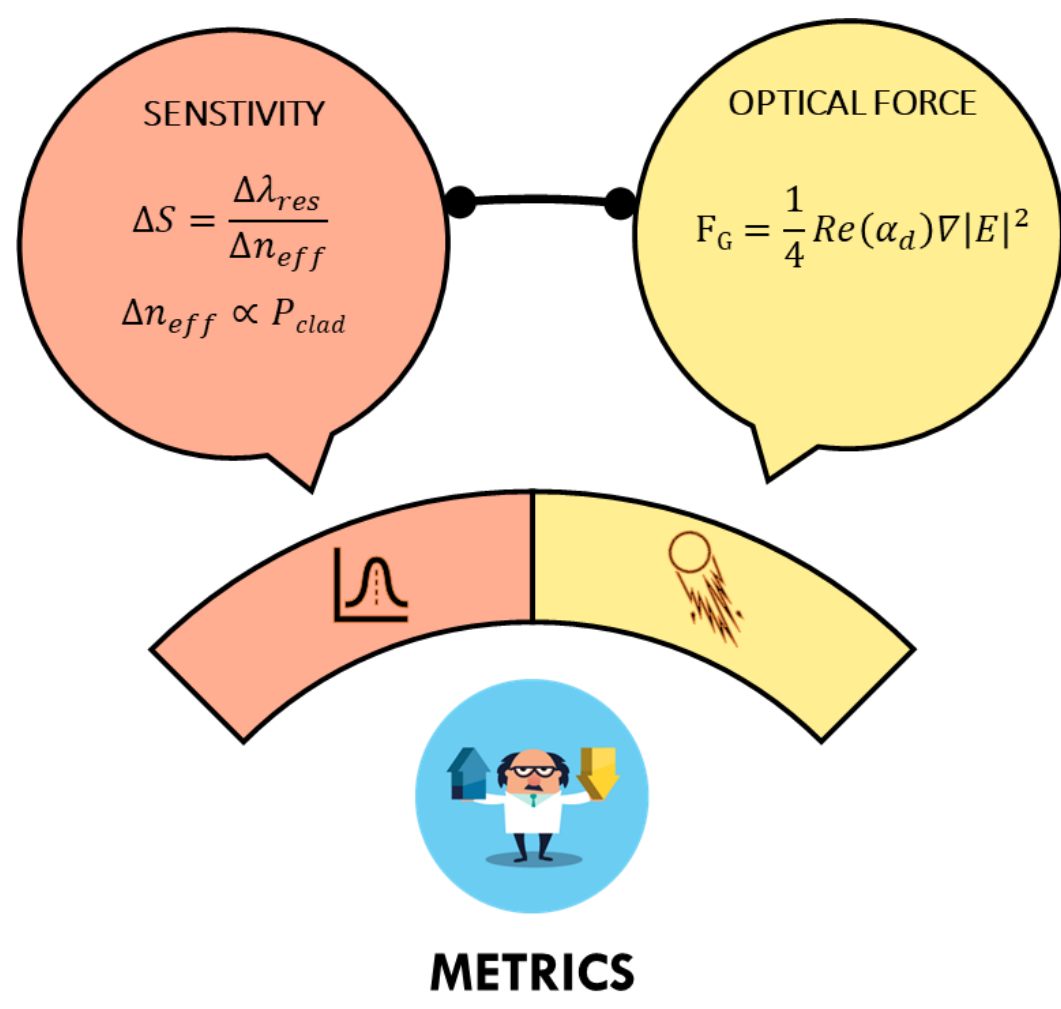
- Core waveguide with wider width provides **relaxed fabrication.**
- Due to the large mode area of higher order modes, it provides a **broader trapping region**, but optical power must be increased to reach the minimum trapping potential¹ ($\approx 10 K_B T$).
- Two maxima and minima intensities peaks of higher order modes offers **manipulation of multiple particles.**



- Si₃N₄
- SiO₂
- Si
- particle
- water

2. METHOD

Device must be optimized for both high sensitivity and optical trapping force.



For current application, the **gradient force (F_G)** plays crucial role.

- k_0 = propagation constant
- V = volume of a particle
- ϵ_m, ϵ_p = permittivity of water and particle
- n_{eff} = effective refractive index
- λ_{res} = resonance wavelength
- P_{clad} = power in the cladding
- F_G = Gradient force
- F_S = Scattering force

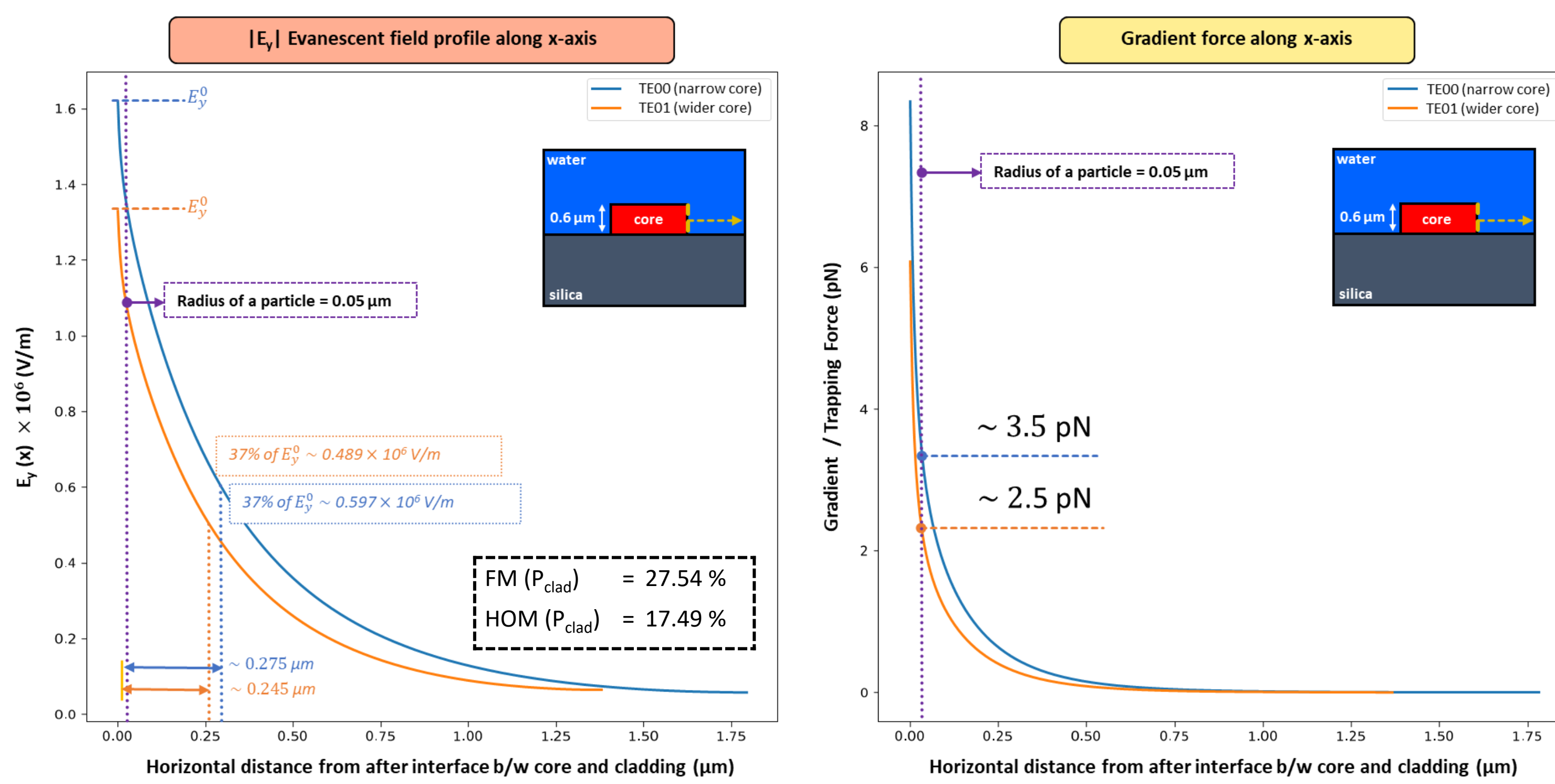
$$P_{clad} = \frac{\iint^{A_{clad}} |E(x, y)|^2 dx dy}{\iint^{\infty} |E(x, y)|^2 dx dy}$$

$$\text{Draine polarizability, } \alpha_d = \frac{\alpha_{CM}}{1 - i \frac{k_0^3}{6\pi} \alpha_{CM}}$$

$$\text{Clausius Mossotti reation, } \alpha_{CM} = 3V \frac{\epsilon_m - \epsilon_p}{\epsilon_m + 2\epsilon_p}$$

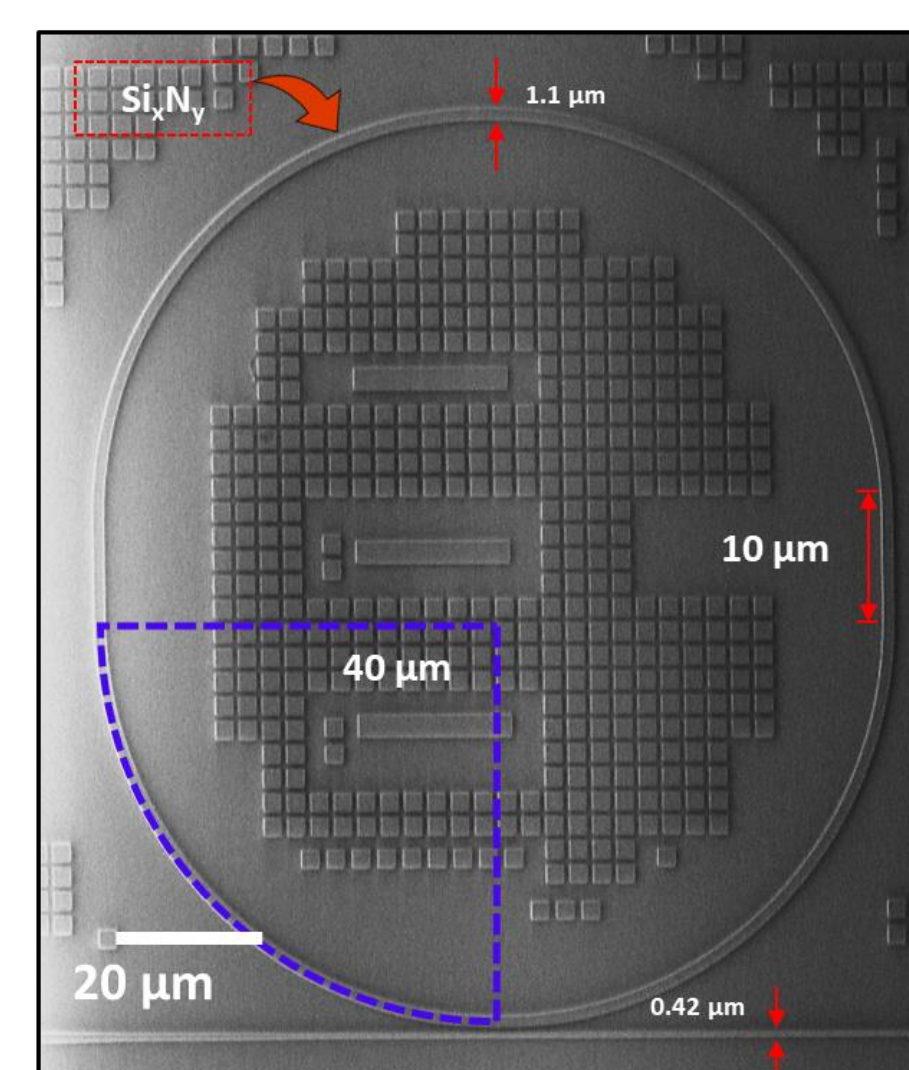
3. SIMULATION

Fundamental and higher order modes have similar sensitivity and gradient force



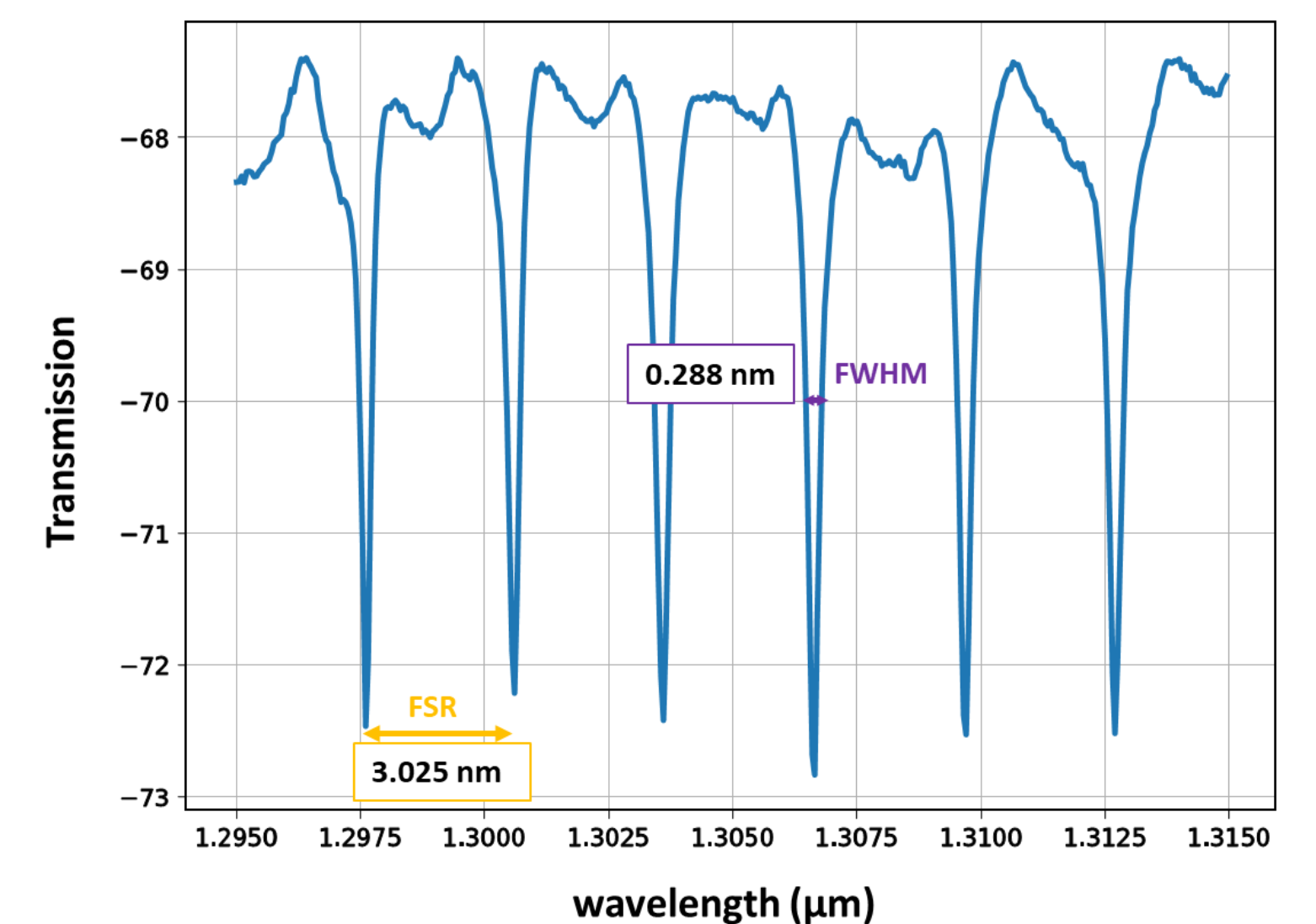
Particle radius = 0.05 μm, λ = 1.310 μm, n_{particle} = 1.57, P_{optical} = 1 W, TE Polarization

4. CHARACTERIZATION



Higher order mode racetrack ring resonator
Thickness : 0.6 μm, coupling gap : 0.6 μm

Fabricated with an industrial platform (STMicroelectronics)



results	experimental	simulated
FSR	3.025 nm	4.61 nm
FWHM	0.288 nm	0.184 nm
Q	5928	7147

Optical trapping and sensitivity experiment is currently in progress. Furthermore, an aspect of our research involves conducting a comparative analysis of both devices, which **will be fabricated at the 3IT**, thus ensuring comprehensive and meaningful results.

5. CONCLUSION

- Higher order modes provides an alternative solution with relaxed fabrication tolerances to fundamental modes ring resonators with almost having the **same sensitivity and optical forces.**
- It would be interesting to do **study coupling of two different modes** with respect to varying losses due to fabrication.
- Frequency spectral characteristics of ring resonators fabricated with an industrial platform (STMicroelectronics) shows **good agreement with our simulation.**

REFERENCES

- A. Ashkin, Phys. Rev. Lett. 24, 156 – Published 26 January 1970.

