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

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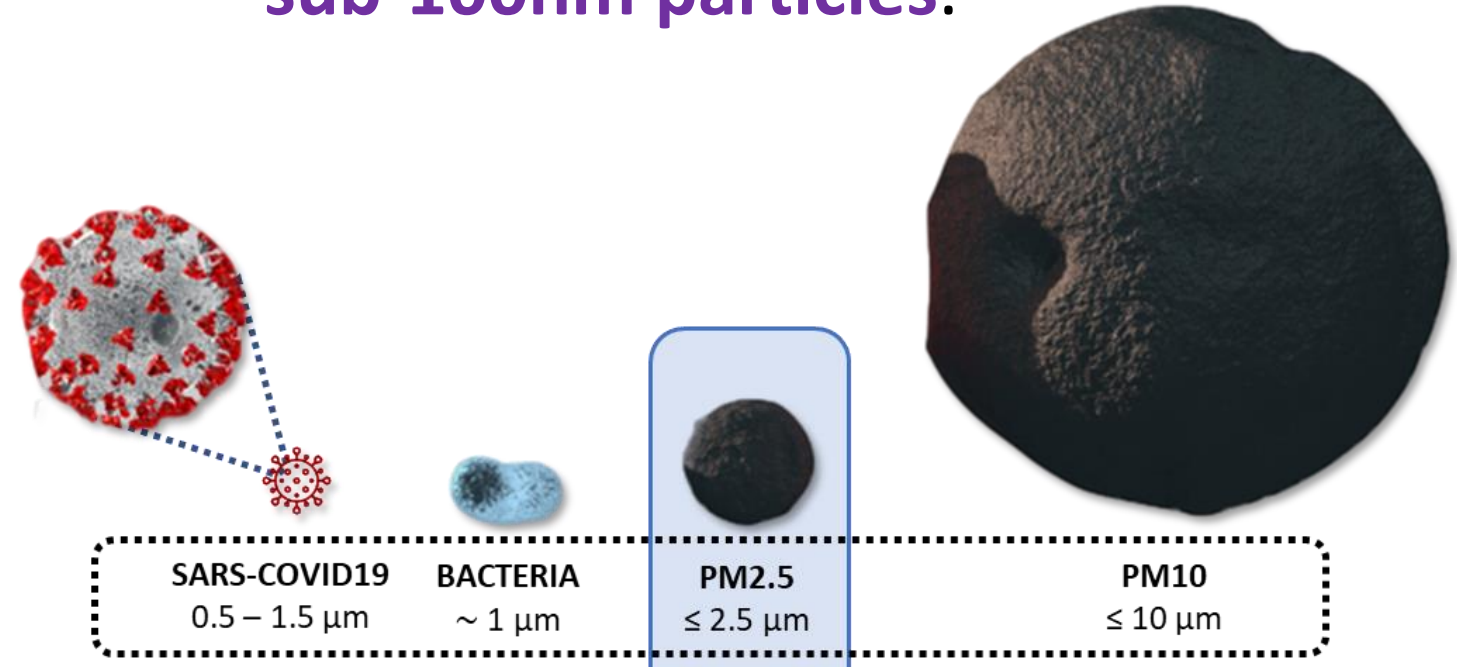
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<sup>4</sup> STMicroelectronics, Crolles, France



## 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

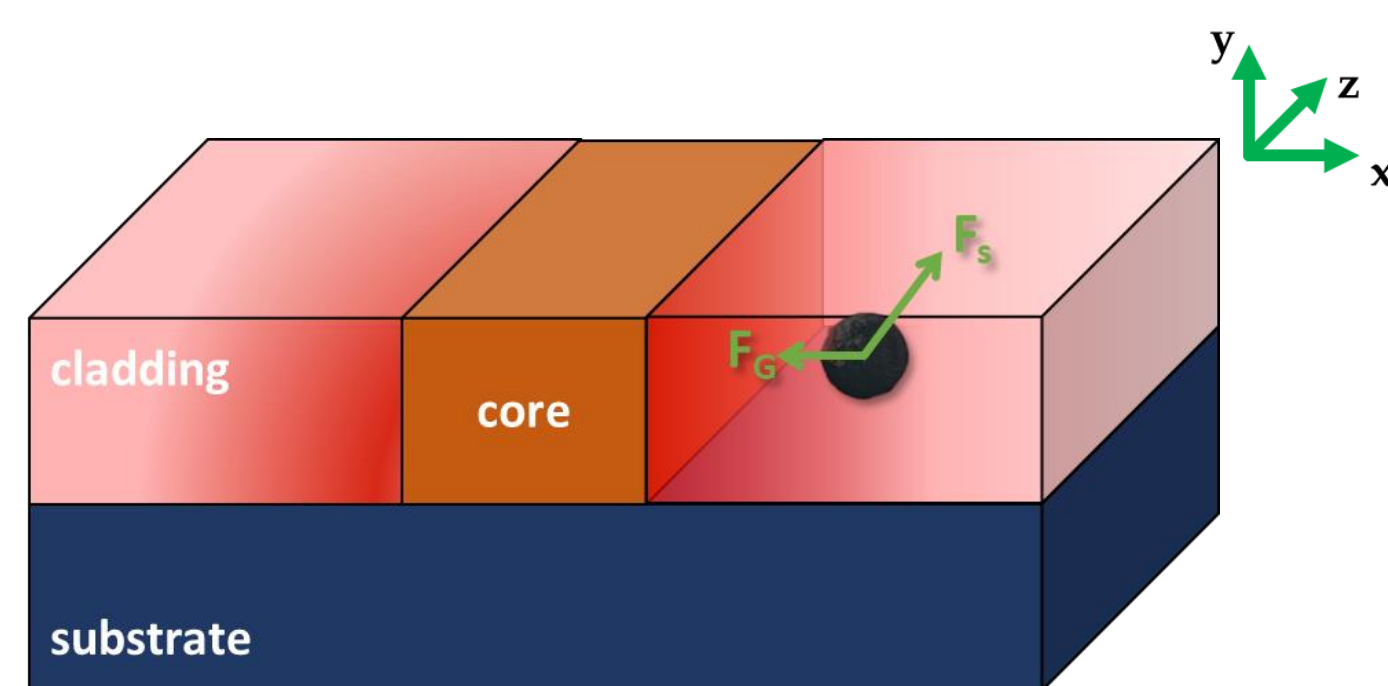
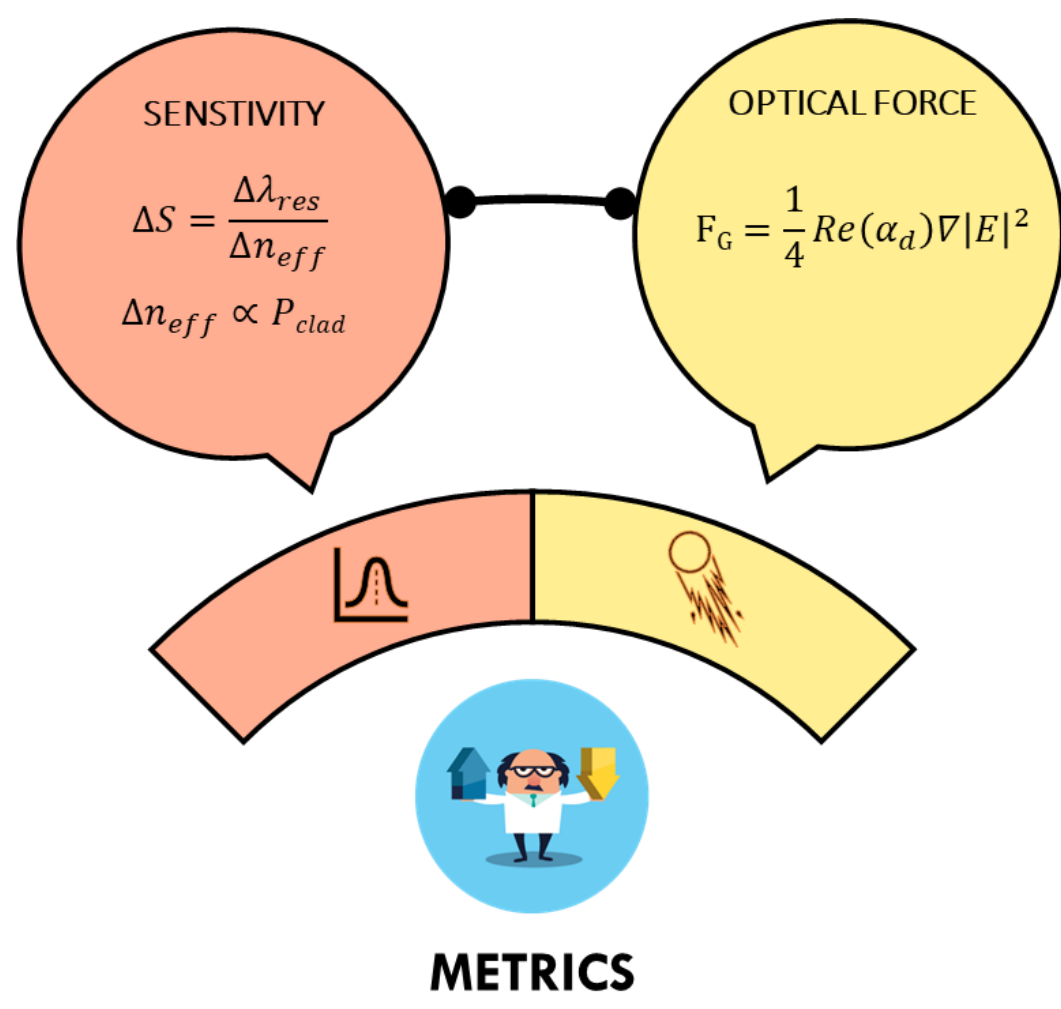
sense + trapped

Micro-ring resonators

Reliable and precise, compatible with CMOS fab

## 2. METHOD

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



For current application, the **gradient force (F<sub>g</sub>)** plays crucial role.

- $k_0$  = propagation constant
- $V$  = volume of a particle
- $\epsilon_m, \epsilon_p$  = permittivity of water and particle
- $n_{eff}$  = effective refractive index
- $\lambda_{res}$  = resonance wavelength
- $P_{clad}$  = power in the cladding
- $F_g$  = Gradient force
- $F_s$  = Scattering force

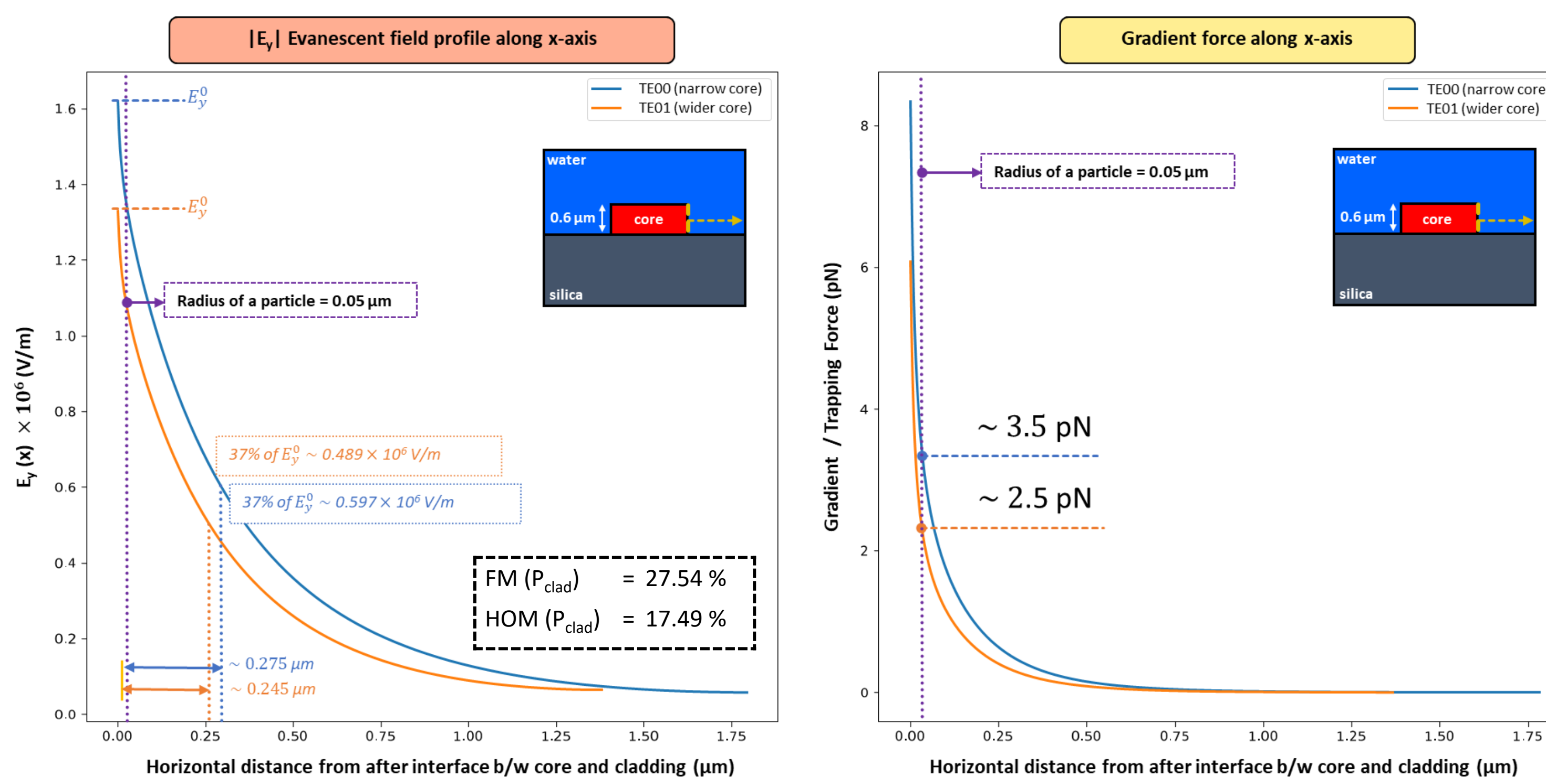
$$P_{clad} = \frac{\iint^{A_{clad}} |E(x, y)|^2 dx dy}{\iint^{\infty} |E(x, y)|^2 dx dy}$$

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

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

## 3. SIMULATION

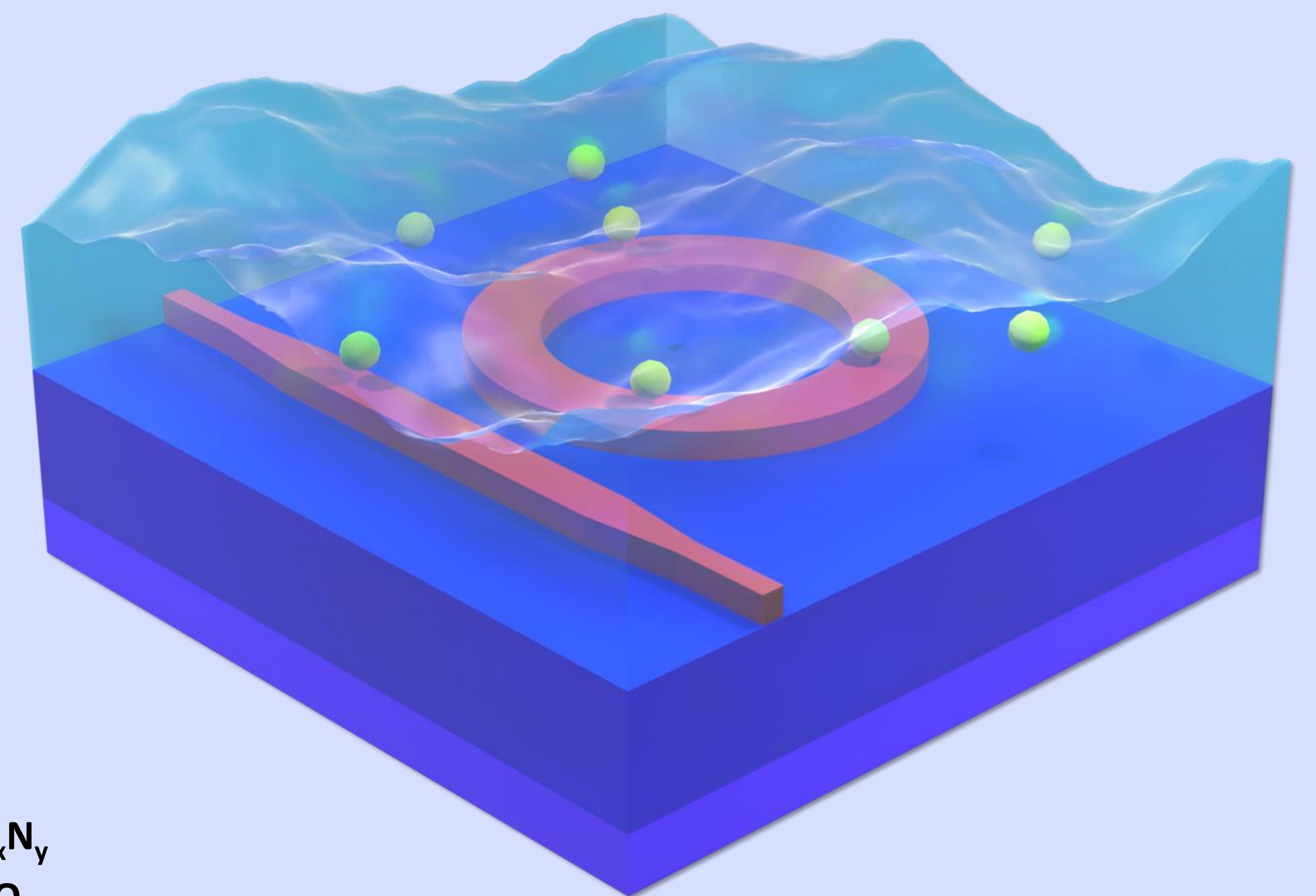
Fundamental and higher order modes have similar sensitivity and gradient force



Particle radius = 0.05 μm, λ = 1.310 μm, n<sub>particle</sub> = 1.57, P<sub>optical</sub> = 1 W, TE Polarization

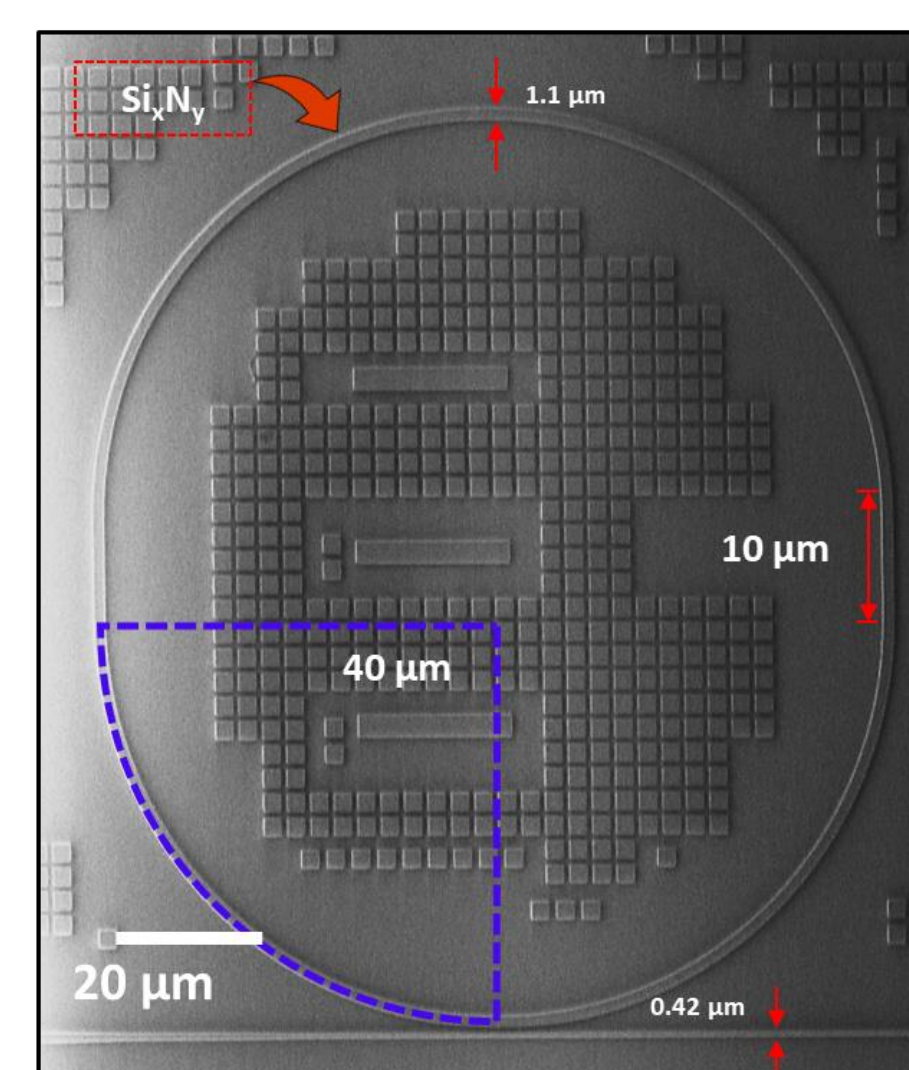
## HIGHLIGHTS:

- 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 potential<sup>1</sup> (≈ 10 K<sub>B</sub>T).
- Two maxima and minima intensities peaks of higher order modes offers **manipulation of multiple particles.**



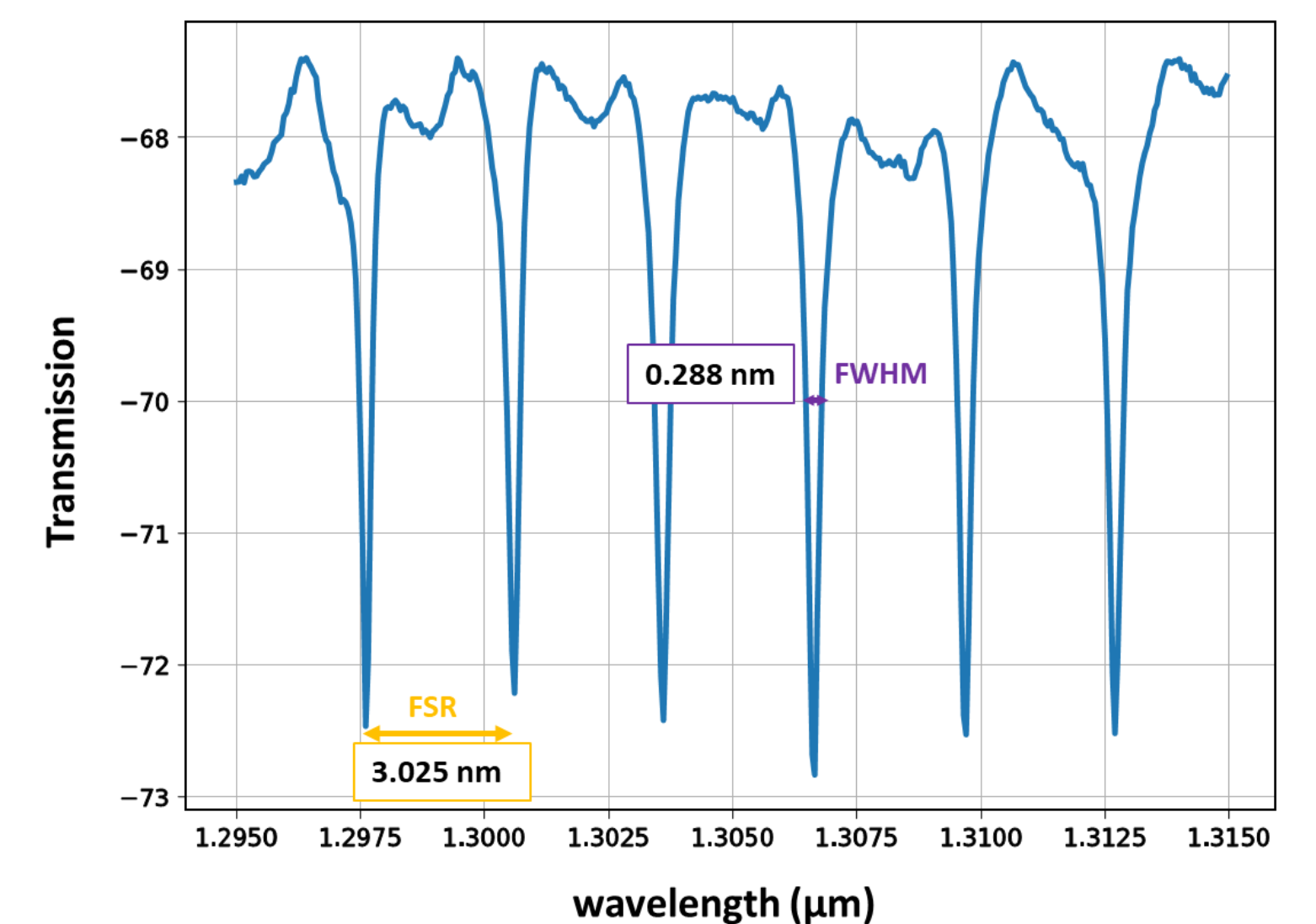
- Si<sub>3</sub>N<sub>4</sub>
- SiO<sub>2</sub>
- Si
- particle
- water

## 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

<sup>1</sup> A. Ashkin, Phys. Rev. Lett. 24, 156 – Published 26 January 1970.

