Development of Optical WGM Resonators for Biosensors

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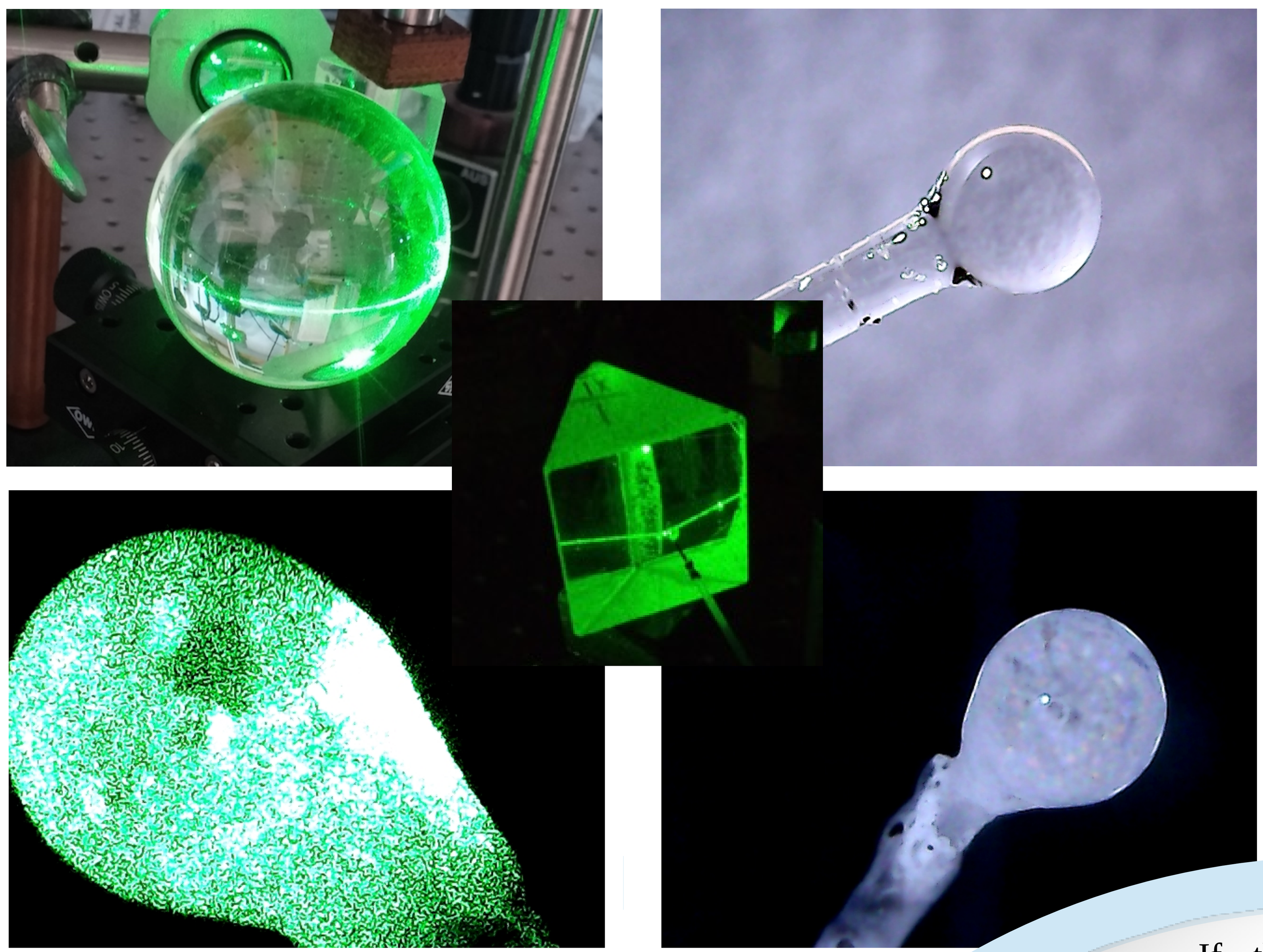
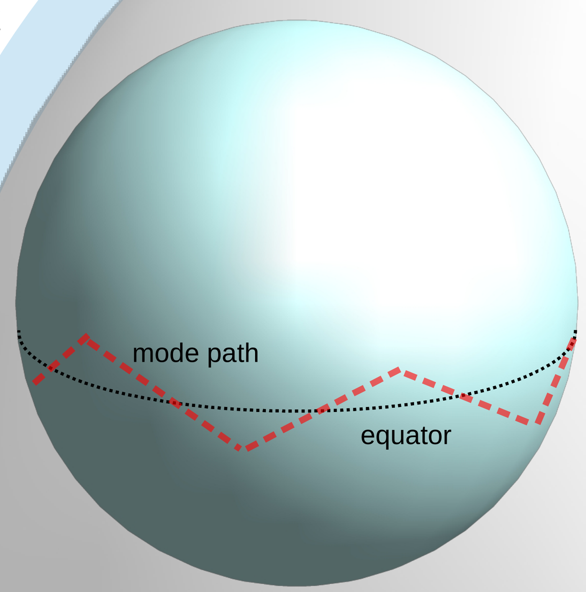
Whispering gallery modes inside resoanator



It is very inefficient to just shine a laser beam straight onto the resonator, because barely any light will be coupled inside. Thus one must use other methods to couple light into the resonator. One of them is evanescent coupling using a prism. It is easy, efficient and cheapest method but it is a bulky component and requires collimation optics.

Some resonators are visually clear, some are cloudy. Resonators which are cloudy have significant light scattering on the surface. For smaller resonators the obtained result are similar to bigger resonator when using green 532 nm or an infrared 760nm laser.

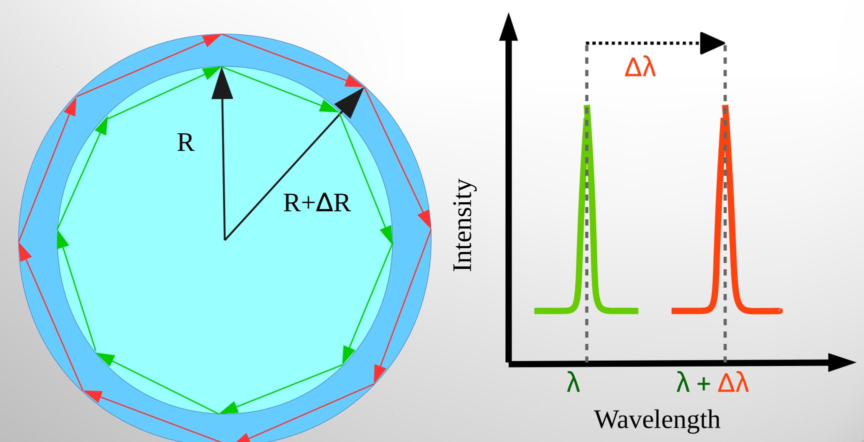


If the radius of the resonator is significantly larger than wavelength (R >> λ) then for constructive interference to occur after making a whole round-trip around the resonator because of total internal reflection the length of the optical path has to equal whole number of wavelengths in the medium:

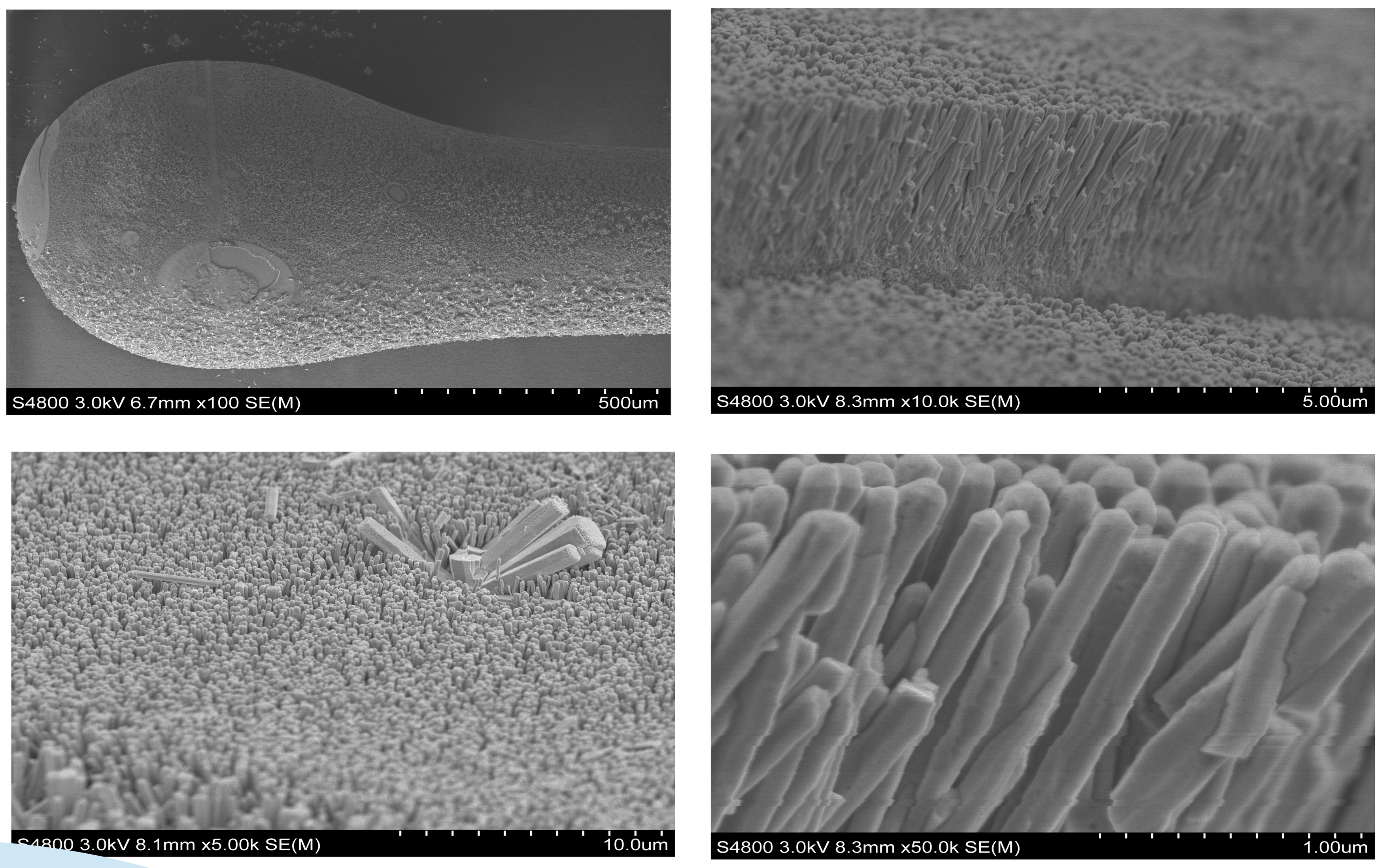
$$l \approx \frac{2\pi R N}{\lambda}$$

is the resonance condition, where N is the index of refraction, R is the radius, λ is the wavelength and l is an integer linked to the angular momentum of a circulating photon in a spherical microresonator.

Sensors are tools used to acquire information about our surroundings. The resonant wavelength of the WGMR depends on the precise geometric properties - size, shape, and composition. Any changes to size of the radius ΔR or refraction index Δn of the resonator will lead to a significant shift of the resonance wavelength Δλ[1]. WGM resonators allow to significantly increase the effective light path length allowing sensitive detection of molecule attaching to the surface [2].



Chemical growth of ZnO nanorods on WGM resonator



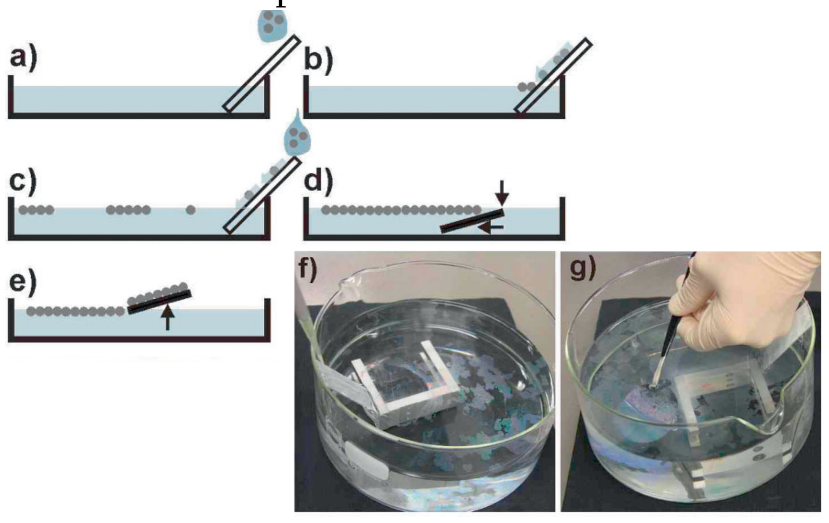
Surface coated with ZnO nanorods.

The ability to detect small changes in refractive index and/or size allows researchers to measure low concentrations. However, to obtain the sensitivity of WGM resonators on certain biomolecules, they have to be covered with special nanolayers. ZnO was chosen as low cost and simply produced nanomaterial with high surface to volume aspect ratio [3].

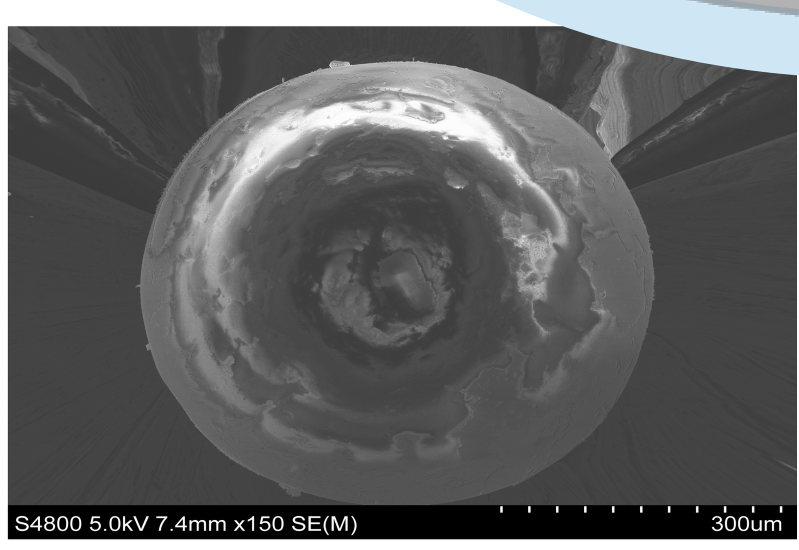
Structure properties of the WGM materials coated with ZnO are being studied with Scanning electron microscopy. ZnO nanorods form a dense “forest like” structure on the microsphere surface. Some larger structures are also present.

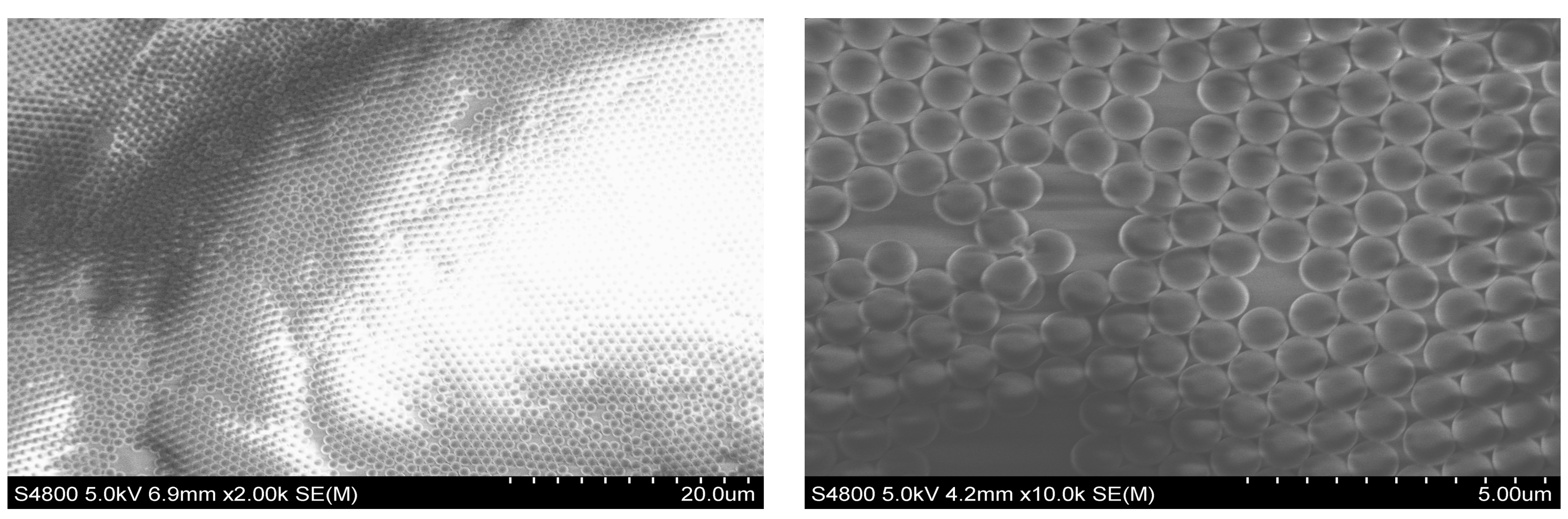
Nanospheres lithography

Optical fiber resonators (OFR) were cleaned. Then the substrates were treated by O_2 plasma to have a hydrophilic surface. After the pretreatment, an ordered monolayer of polystyrene spheres (PSS) was prepared by self-assembly. The floating-transferring technique was utilized to deposit PSS on OFR. The polystyrene solution (40 µl) diluted by an equal amount of ethanol, was applied onto the glass substrate, dipped into water solution. Then, one drop of 10% sodium dodecyl sulfate (SDS) solution was added to the water to change the surface tension and to consolidate the particles.



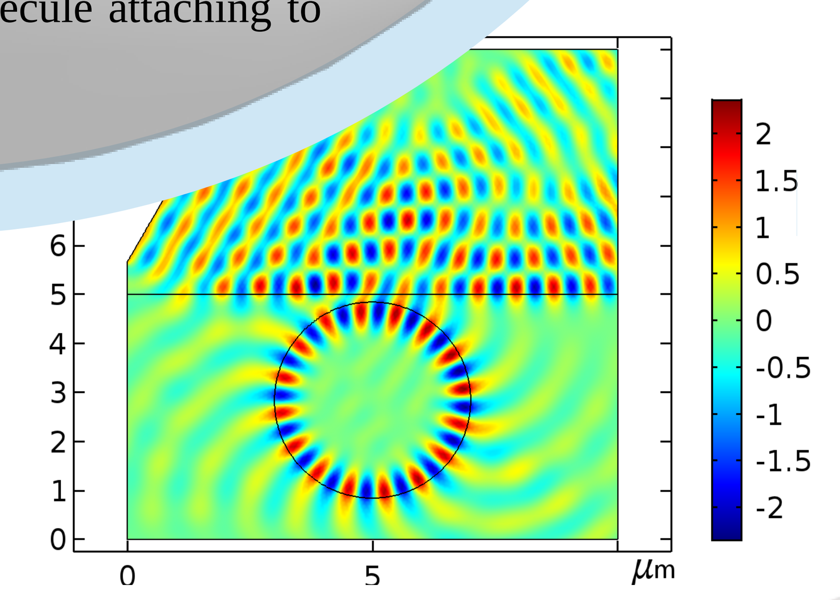
Surface coated with nanospheres.

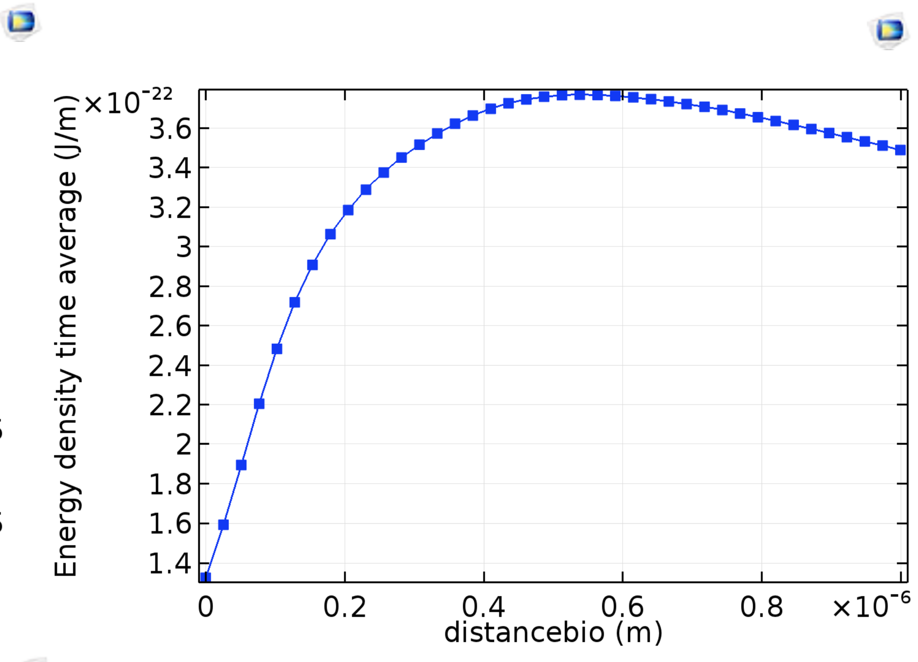


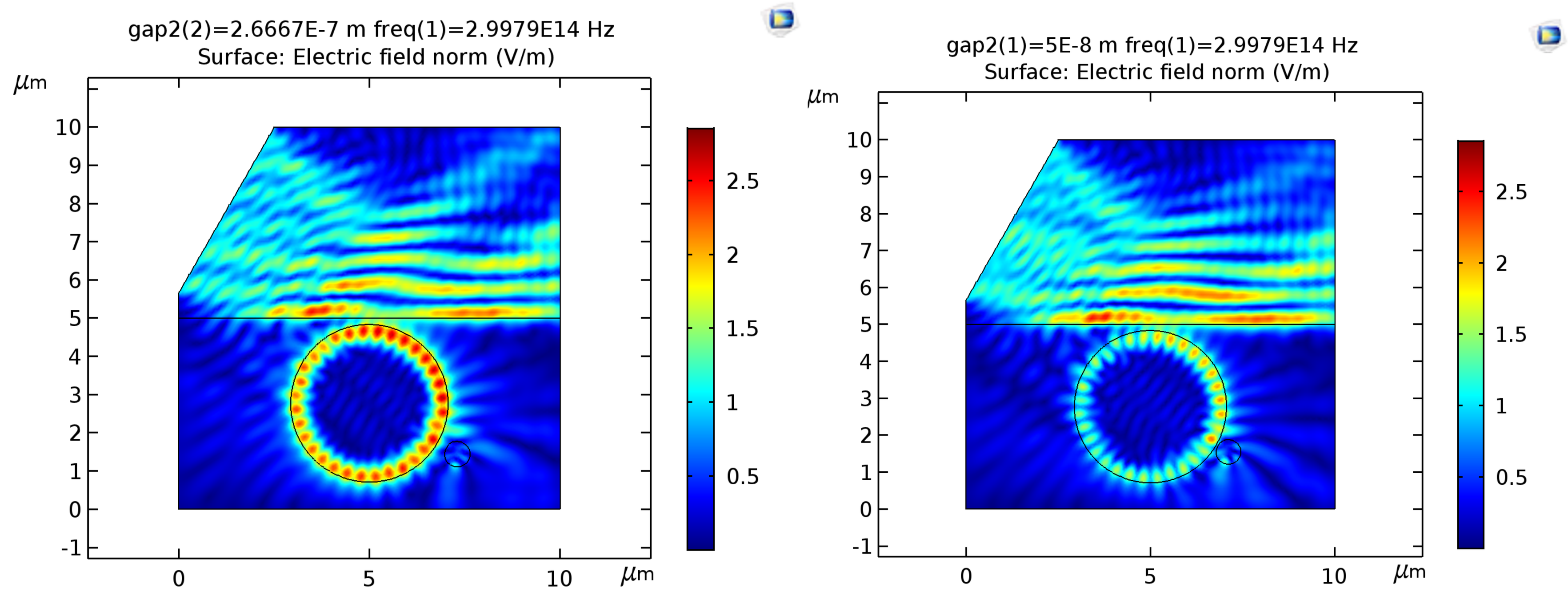


Modelling

Theoretical modelling using program COMSOL Multiphysics was performed to observe weather any changes could be observed when a small particle approaches the resonator. The particle has to be close enough but not necessary touching the resonator since it can interact with the evanescent field of the WGM. Furthermore, the energy density peaks when the particle is a certain distance away from the surface.







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[1] M.R. Foreman, J.D. Swaim and F. Vollmer, Whispering gallery mode sensors, Advances in Optics and Photonics 7(2) (2015)

[2] F. Vollmer, S. Arnold, Whispering-gallery-mode biosensing, Nature Methods **5**, 591 (2008).

[3] A. Tereshchenko, M.. Bechelany, R. Viter et al., Optical biosensors based on ZnO nanostructures: advantages and perspectives. A review, Sensors and Actuators B: Chemical **229**, 664-677 (2016)

Acknowledgements:

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