Finite element modelling of thermal noise in whispering gallery mode cavities

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Introduction: Whispering-gallery mode (WGM) resonators are promising elements for future photonic devices, as they combine ultra-high quality factor with small size. We develop a method to calculate thermal noises and test it on experimental data from [1] and [2].

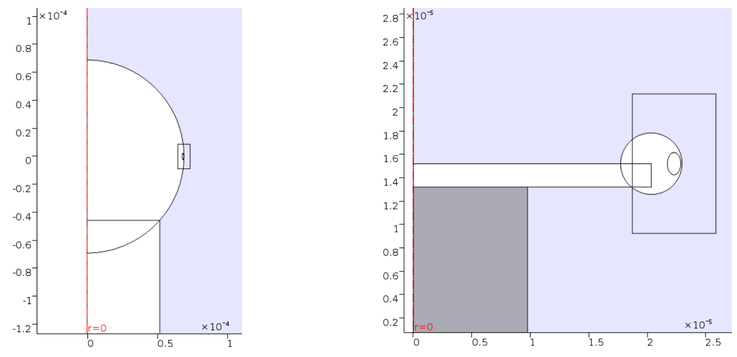

Figure 1. Modelled systems. Microsphere [1] (left) and microtoroid [2] (right)

Computational Methods:
Noise estimations can be done following the Fluctuation-Dissipation theorem [3]. Essential is

- Cylindrically symmetric geometry
- Azimuthal mode number sweep

Electric field is used as a harmonic pump for thermal or mechanical problem and the noise spectral density is then proportional to the energy loss during one pump period.

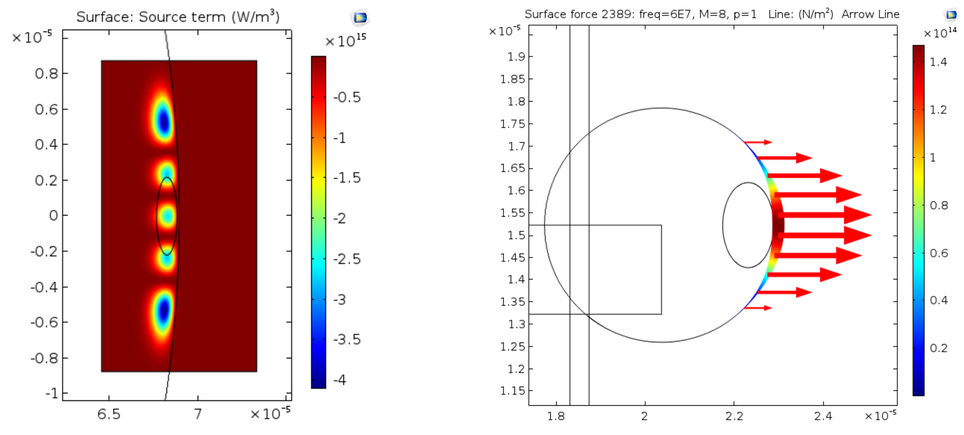

Figure 2. Thermal pump for m=995, p=4 mode (left), Mechanical pump for m=185, p=1 mode (right)

Standard Comsol heat transfer modules are not able to do frequency domain studies and presume the solutions to have zero azimuthal number only

- Coefficient Form PDE user interface was used to calculate thermorefractive noise.

Solid Mechanics module was also found inappropriate for Brownian noise computation being written in assumption of zero torsional displacements and zero azimuthal numbers.

- A suitable interface was made with Physics Builder to reflect the features of mechanical modes in cylindrical geometry

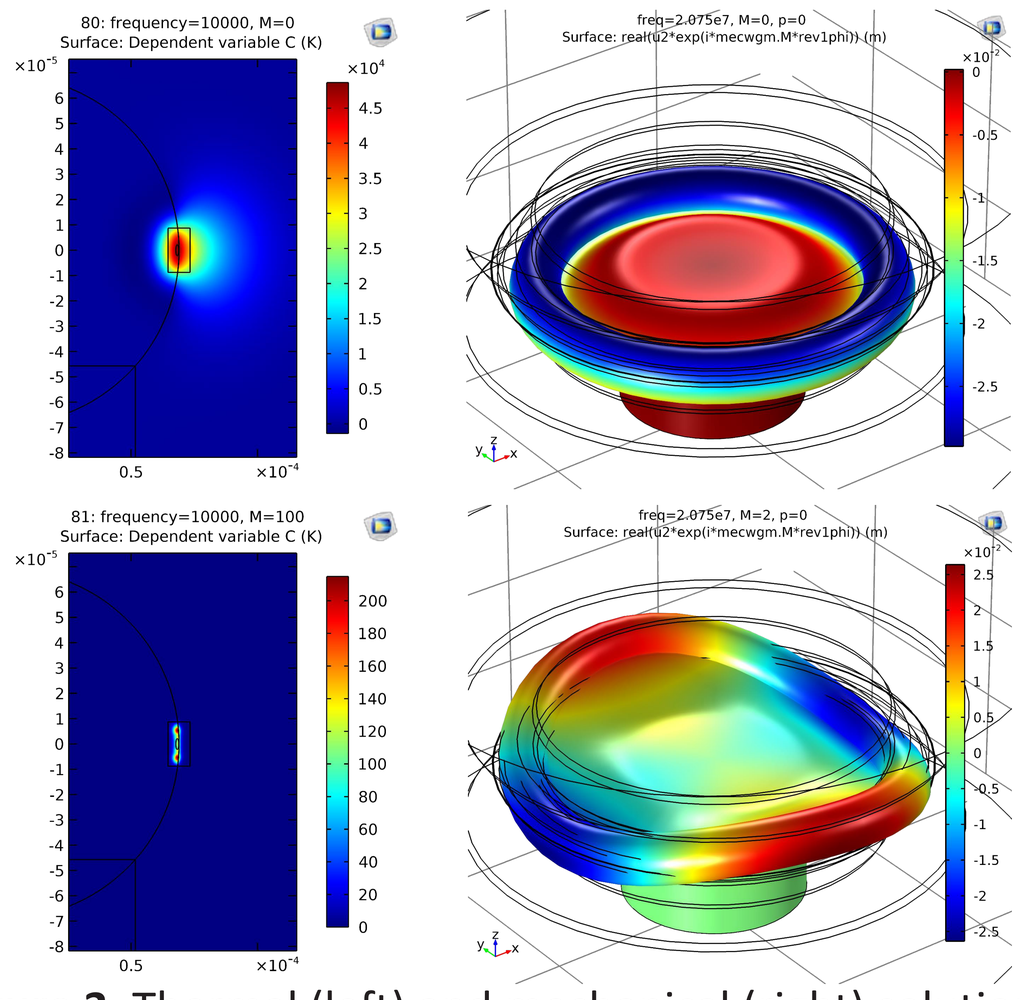

Figure 3. Thermal (left) and mechanical (right) solutions for zero (up) and nonzero azimuthal number

Results: We show that the real form of the resonator makes small influence on the thermorefractive noise spectrum and old infinite-space formula is quite universal .

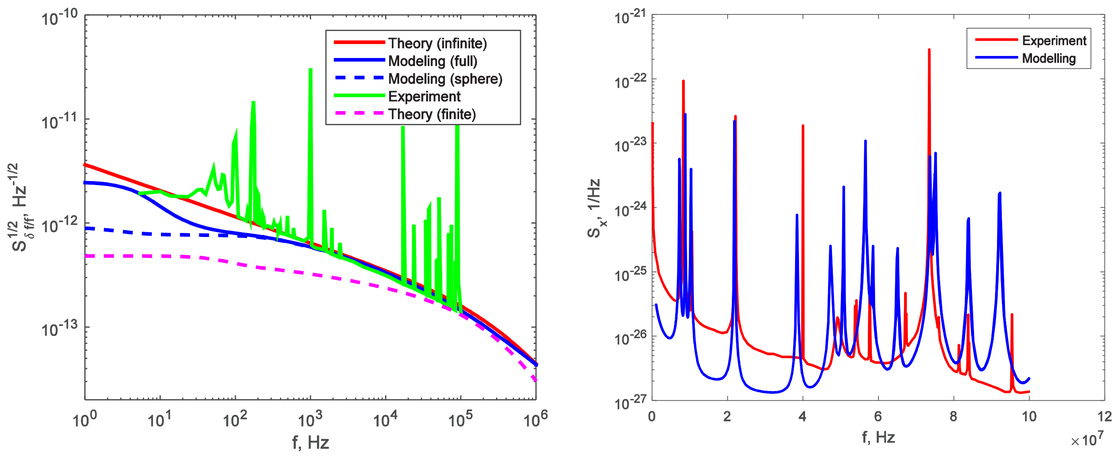

Figure 4. Thermorefractive noise of microsphere and mechanical noise of microtoroid

Conclusions: An efficient and precise method of dispersion and noise calculation is developed and verified using experimental data.

References:

1. Michael L. Gorodetsky and Ivan S. Grudinin. J. Opt. Soc. Am. B, 21(4): 697–705 (2004)
2. A Schliesser et. al. New Journal of Physics, 10(9):095015 (2008)
3. Yuri Levin. Physics Letters A, 372(12):1941–1944 (2008).

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