DESIGN OF OPTIMISED NANOPHOTONIC RESONATORS FOR MICRO-SCALED THERMOMETERS BASED IN DIAMOND

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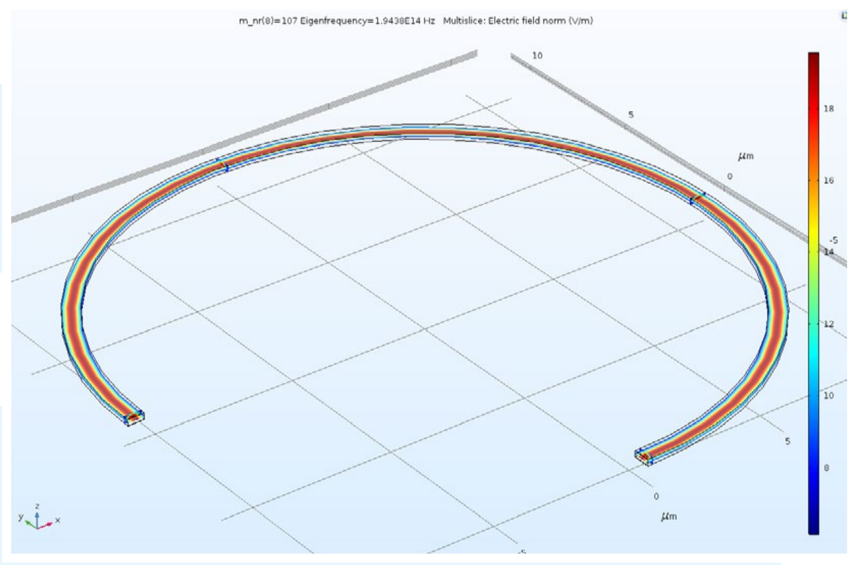
SUMMARY - A new EMPIR Project (17FUN05) devoted to the research in photonic and quantum optomechanic devices for temperature measurements at micro and nanoscale was launched in 2018. This project aims at exploring the potential of high resolution photonics and optomechanical sensors in terms of sensitivity, uncertainty and resolution for realising future quantum and nanoscale temperature standards. In the frame of this project, the Micro and Nanotechnology Institute of the Spanish National Research Council (INM-CSIC) and Centro Español de Metrologia (CEM) are involved in the design, fabrication and characterization of micro-scale thermometers based in photonic crystal cavities.

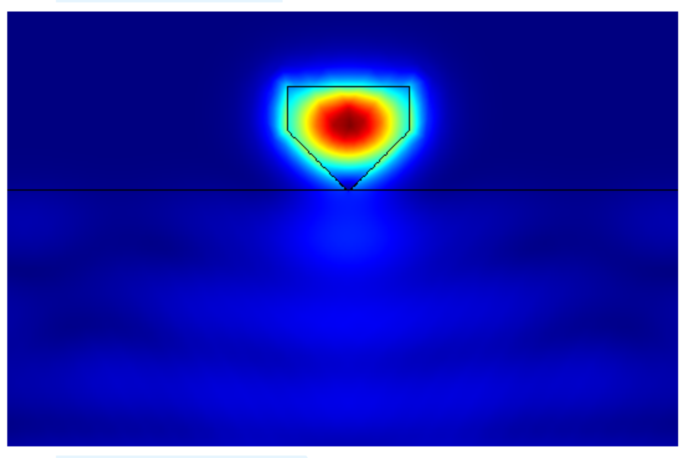
Design of the fotonic resonator:

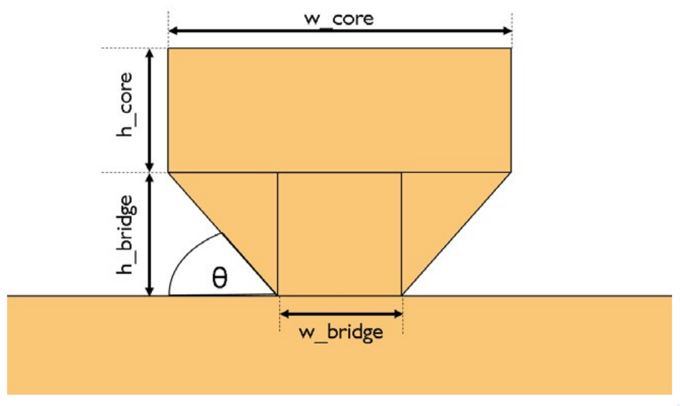
As a first step, IMN has conducted simulations of photonic ring resonators for temperature measurement using COMSOL Multiphysics in order to check the method:

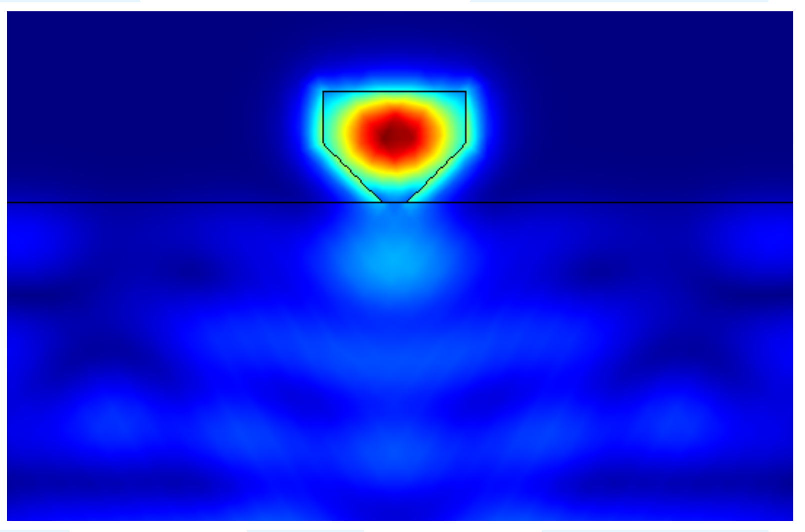
- 2D Simulations of existing experimental data using the effective index method were conducted to create a trustworthy verified model
- Simulation and partly optimization of novel waveguide design to accomplish mode propagation in diamond-based waveguide
- Initial 3D Model was created to improve simulation accuracy and implement more complex waveguide and resonator designs

Next step: simulations of photonic crystals





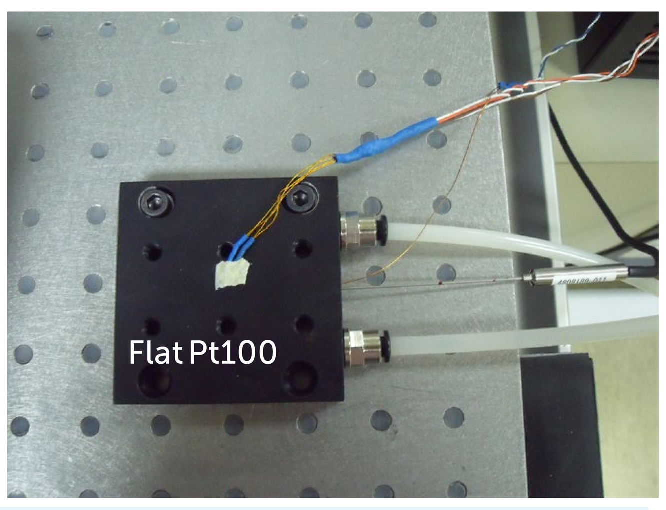




Characterization of the test thermostat:

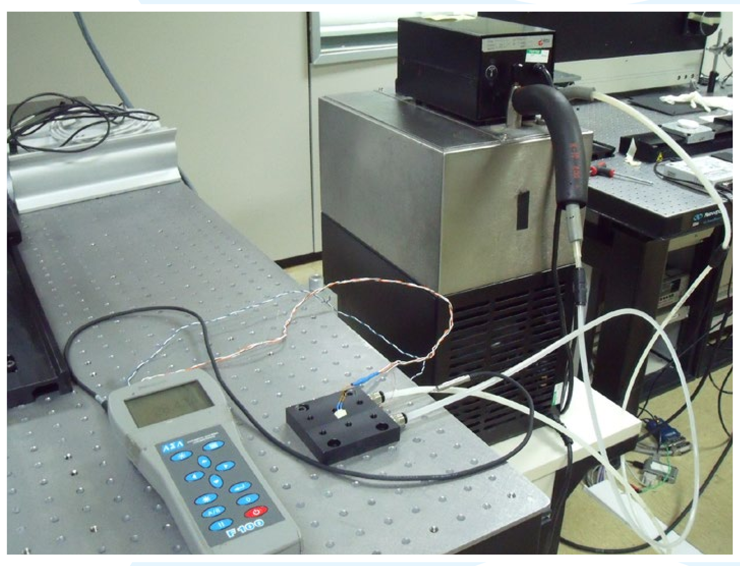
CEM has designed a first thermostat for measuring the photonic thermometer devices:

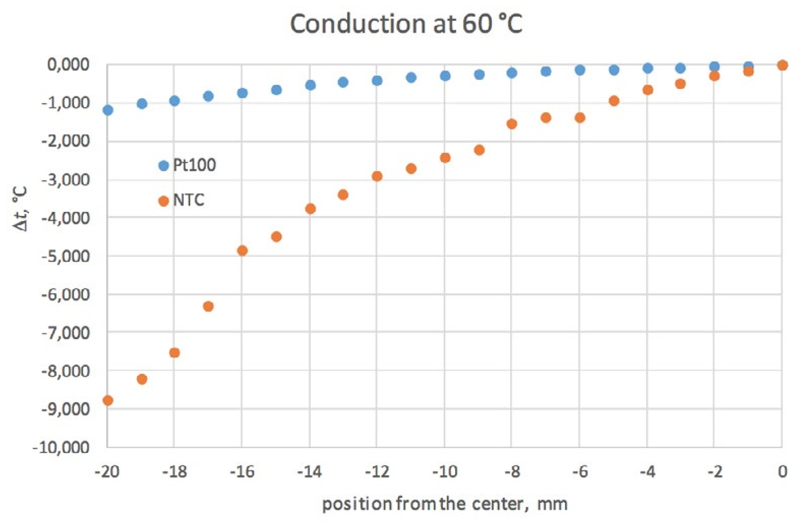
- In this first stage, it will be for free space light coupling measurement.
- The thermostat is a temperature controlled platform (using water from a high stability water bath). The platform have dimensions of 75 mm x 75 mm x 15 mm
- 3 contact thermometers can be installed at different places: inside the platform aluminium block (in the middle, "bulk, lower hole"), just behind the device ("bulk, upper hole") and on the platform surface ("surface"). The thermometers in the block can be NTC thermistors and mini-Pt100.
- Temperature range is 10 °C to 80 °C.
- Best stabilities obtained: 4 mK at 20 °C and 14 mK at 60 °C
- Temperature measurement needs correction because the conduction of the sensors.

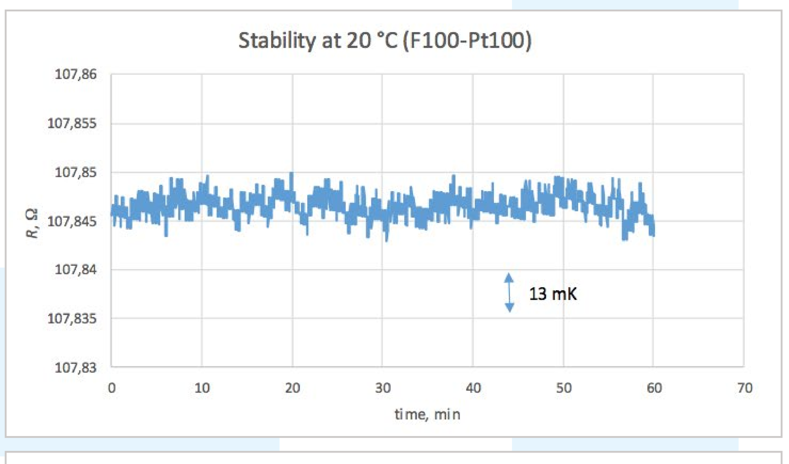


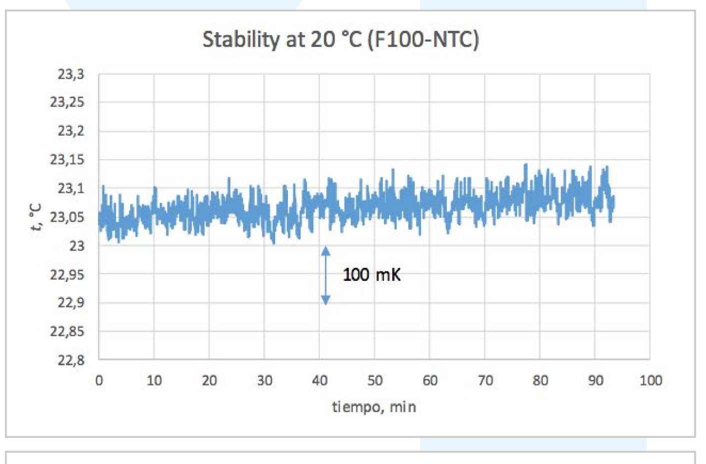
t, °C	sensor	stability, σ, mK
20	Pt100	4
60	Pt100	14
20	NTC	29
60	NTC	58

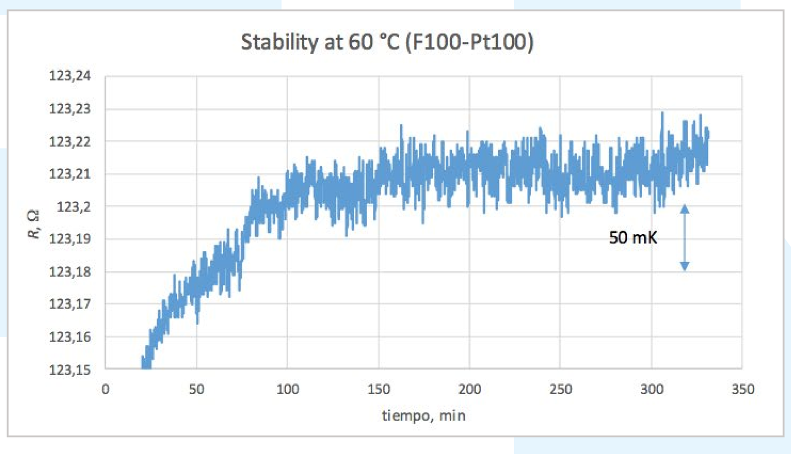
$t_{nominal}$, °C	Position	sensor	*t*, °C	Δ*t*, °C
20	bulk, upper hole	Pt100	19,876	0,006
20	bulk, lower hole	Pt100	19,870	
60	bulk, upper hole	Pt100	61,529	0,017
60	bulk, lower hole	Pt100	61,512	
60	bulk, upper hole	Pt100	61,674	4,534
60	surface	Pt100	57,140	

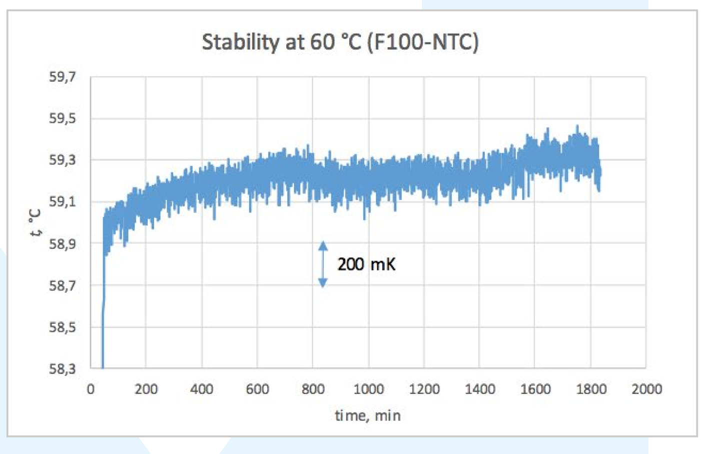












CONCLUSIONS

Initial design and simulation of nanophotonic optomechanical resonators in Si and in diamond have been performed. A new thermostat has been constructed to perform the temperature measurements with stability of 4 mK to 14 mK (20 °C to 60 °C). High differences between surface Pt100 sensor and Pt100 sensor inside the bulk have been found.

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