Chip-scale Photonic Temperature Metrology Platform

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Temperature, the second most measured physical property after time and frequency, plays an essential role in almost all areas of modern technology. While there has been significant progress in developing novel thermometry approaches, resistance-based thermometry remains the standard method for disseminating the SI unit of temperature at the highest level of precision.[1] The fundamental limitations of resistance thermometry and the desire to reduce the calibration chain have ignited a substantial interest in developing alternative technologies, such as photonic thermometry.[2]

At the National Institute of Standards and Technology (NIST), we are developing an integrated photonics-based temperature measurement solution that has the potential to revolutionize how temperature is realized and disseminated to customers. One of the critical elements of our Photonic Thermometry program is an ultra-sensitive photonic thermometer (SPoT) – an on-chip integrated silicon nanophotonic resonator whose optical resonance frequency shifts with temperature due to high thermo-optic coefficient of silicon (Figure 1). SPoT's response can be used to trace temperature variations with high precision. We aim to evolve SPoT into a better alternative to state-of-the-art resistance thermometers, provide precise and accurate temperature metrology in the field, and reduce the calibration chain. Furthermore, we foresee the SPoT photonic technology as an enabling platform for numerous sensing applications beyond thermometry.

In this work, we describe the performance of the SPoT thermometer and the new photonic readout for SPoT. In our new read-out scheme, we employ a novel offset-locking technique for measuring the resonance wavelength of the SPoT. This method provides extremely high accuracy for relative temperature changes on a short time scale (<< 1s). This methodology, as well as other proposed methods, will be discussed. We also show a benchmark comparison of the SPoT thermometer to the Standard Platinum Resistance Thermometer (SPRT) – the best-in-class resistance thermometer, evaluating temperature resolution and repeatability.

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[1] SI Brochure – 9th edition (2019) – Appendix 2. " *Mise en pratique for the definition of the kelvin in the SI*"

[2] S Dedyulin *et al* 2022 *Meas. Sci. Technol.* **33** 092001

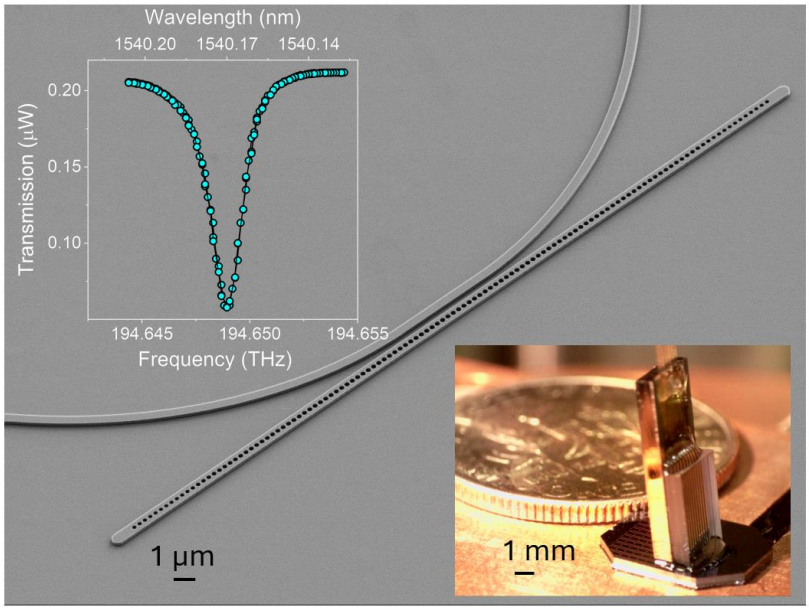

Figure 1: Sensitive Photonic Temperature Sensor (SPoT): SEM image of silicon photonic nanobeam cavity temperature sensor – one of the designs of Sensitive Photonic Temperature Sensor (SPoT). The device is fabricated from the silicon-on-insulator substrate with a 220 nm thick device layer. The upper insert shows the device's transmission spectrum. The lower insert shows an optical image of the fiber-coupled photonic chip.