The Future of Temperature Sensing
Room Ballroom A - Session TS-ThP
The Future of Temperature Sensing, Poster Session

TS-ThP-1 Progress Towards Simplified Measurement Schemes for Optomechanical Quantum-Correlation Thermometers*, Daniel Barker,* National Institute of Standards and Technology*; Ana Rakonjac,* Measurement Standards Laboratory, New Zealand*; Biswarup Guha, Kartik Srinivasan, Nikolai Klimov,* National Institute of Standards and Technology*; Thomas Purdy,* University of Pittsburgh

Optomechanical thermometry is a promising route to portable primary thermometry from room temperature down to a few kelvin. Quantum noise arising from the zero-point motion of a mechanical oscillator can provide *in situ* calibration of the oscillator's thermal motion. In an optomechanical system, the resonator undergoes thermal Brownian motion, driven motion from the light in the cavity, and optomechanical backaction. Noise correlators can be employed to separate thermal and quantum signals, thereby forming a quantum-correlation thermometer and enabling primary temperature measurements. The optomechanical cavity is chip-scale, which allows for integration with other chip-scale sensors. Fiber-optic readout makes optomechanical thermometers suitable for a variety of applications, including those in which conductive sensor leads cannot be used. However, the measurement precision of quantum-correlation thermometers is not presently competitive with existing secondary thermometers, and reducing systematic uncertainties is an ongoing challenge.

We use a waveguide-coupled GaAs nanobeam resonator with an optical resonance in the telecom wavelength range and a mechanical resonance around 2.6 GHz as our optomechanical thermometer. The optomechanical resonator is installed in a low-vibration cryostat along with a resistive cryogenic thermometer that independently monitors the temperature. Our detection scheme utilizes a double-mix-down technique, where optical carrier sidebands generated by an electro-optic modulator mix with the mechanical signal in the resonator and are then combined with a local oscillator in a heterodyne measurement. This method requires only a single channel for data acquisition, with subsequent phase-sensitive signal processing performed entirely in software. We report on progress towards primary thermometry using this simplified measurement scheme and provide an outlook for future work.

TS-ThP-2 Progress Towards Doppler Thermometry in Microfabricated Vapor Cells*, Ryan Johnson*, *Yu-Ting Chen, Sean Bresler, Erin Adkins, Matthew Hummon, Benjamin Reschovsky, Vladimir Aksyuk, Stephen Eckel, Tobias Herman, John Kitching, Daniel Barker,* NIST

We report on our effort to develop Doppler thermometers using microfabricated atomic vapor cells. The Doppler broadening of spectral lines relates gas temperature to physical constants and immutable gas properties, enabling primary thermometry. We present measurements of the Doppler broadening in a microfabricated rubidium vapor cell from 25 °C to above 100 °C. The accuracy of the fitted Doppler temperature is limited by parasitic etalons in the vapor cell. To reduce the temperature uncertainty, we are implementing improved physical models of the etalon transmission. We also discuss prospects for improving the accuracy and increasing the operating temperature range of atomic Doppler thermometers using microfabricated cesium and ytterbium vapor cells.

TS-ThP-3 Thermal Noise Measurements in a Cavity Electro-Optic System*, Griffin O'Neal-Freeman,* University of Pittsburgh

Resonant electro-optic transducers are a promising platform for high-sensitivity microwave detection and quantum frequency conversion. By utilizing a fully-resonant, all-dielectric architecture, we achieve high photon-number conversion efficiencies, enabling the up-conversion of thermal microwave photons into the optical domain. In this work, we explore the application of these transducers as high-precision temperature sensors. We are interested in investigating Raman sideband asymmetry thermometry, a technique employed in spectroscopy, fiber optic sensing, and cavity optomechanics to make calibrated temperature measurements. We present preliminary experimental results demonstrating the optical detection of the thermal occupation of a 16GHz microwave mode with a signal-to-noise ratio of a few. Ongoing efforts focus on mitigating material losses and optimizing resonator geometry to enhance coupling and further suppress technical noise. Ultimately, this electro-optic platform offers a path toward precision temperature sensing, quantum-limited radiometry and quantum communication.

TS-ThP-4 The Recent Advancement of Crystalline Core and Crystalline Cladding Sapphire Fibers for Extreme High Temperature Environment Sensing*, Shizhuo Yin,* Penn State University

In this paper, we report the recent progress of crystalline core and crystalline cladding sapphire fibers and its potential applications for extreme high temperature >1500 oC sensing. In particular, we will discuss the single-transverse-mode clad sapphire fiber.

TS-ThP-5 Chip-Scale Photonic AC –DC Thermal Transfer Device*, Pavan Challa*, *Kevin Douglass, Michal Chojnacky, Thinh Bui, Tam Duong,* NIST-Gaithersburg*; Michael Sherman, Dorin Shapira, Leeya Engel,* Technion Israel Institute of Technology, Israel*; Stefan Cular,* Howard Community College*; Nikolai Klimov,* NIST-Gaithersburg

We present a chip-scale photonic ac–dc thermal transfer device that provide an alternative to conventional multijunction thermal converters (MJTCs) for establishing the traceability link between dc electrical units and practical ac voltage and current measurements. While MJTCs offer the highest accuracy available today, they exhibit intrinsic ac–frequency–dependent transfer errors arising from parasitic capacitive coupling between the resistive heater and the thermocouple array. To overcome these limitations, we introduce an integrated photonics-based architecture that replaces the thermoelectric sensor with an electrically passive, silicon photonic microresonator thermometer – the Standard Photonic Thermometer (SPoT). In the SPoT sensor, Joule heating under ac or dc excitation produces a highly sensitive shift in the optical resonance frequency. Because the optical readout is electrically isolated from the heater, the device measures Joule-heating-induced temperature rise without capacitive pickup, thus eliminating fundamental error mechanics present in MJTC-based thermal-transfer metrology.

We report the first prototype of photonic ac–dc thermal transfer standard device, termed the thermal-transfer SPoT (T-SPoT). The device integrates a waveguide-coupled SPoT sensor with an on-chip microheater and is interrogated using resonance-scanning optical readout. Ac–dc difference measurements are performed as a function of ac frequency at fixed voltage and benchmarked against a calibrated MJTC standard using a drift-rejecting triplet measurement sequence. The initial T-SPoT results demonstrate performance consistent with expectations for a first-generation photonic thermal transfer device and reveal clear pathways for further improvement through enhanced optical-frequency readout and thermally optimized device architectures. These results establish a foundation for next–generation photonic ac–dc transfer standards with improved robustness, scalability, and long–term stability.

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