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STEM

Thermophotovoltaic Direct Thermal Emission Measurement

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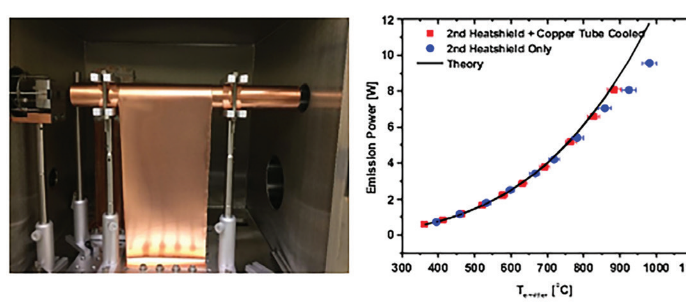
Thermophotovoltaics (TPV) provides a new pathway to harvest waste heat as electricity. TPV relies on thermal radiation from a high-temperature radiation emitter, to illuminate photovoltaic (PV) diodes. Photons with energy above the bandgap energy of PV diodes are converted into electricity. In this approach, extremely high theoretical efficiency exceeding 50% could be achieved. Furthermore, TPV can be made compact enough for man-portable power generators with quiet and reliable operation. The efficiency of the TPV system is the ratio of the electrical power generated from the PV diodes to the emitted thermal power from the emitter. In many TPV experiments, huge losses from the heating stage make it extremely hard to quantify this efficiency by measuring the electrical input and output power. Therefore, directly measuring the thermal emission from the emitter becomes a critical step in TPV experiments to determine the performance benefits associated with certain improvements.

In a direct thermal emission measurement (DTEM) setup, a metallic waveguide collects the emission from the carbon nanotube (CNT) emitter and guides it through the viewports toward the sensor. The experimental setup is validated at high emitter temperatures in the vacuum chamber (used to help minimize the thermal convection between source and receiver). Real-time emitter temperature measurement via thermocouples is performed to calibrate the DTEM measurements at different temperatures. The simulation model is developed mathematically to compare theoretical expectations with experimental data. Two non-idealities, the thermal emission contributed by the heat shield and the spectral modulation caused by the temperature dependent reflectance of aluminum, are found to be the major causes of errors in calibration. To reduce these non-idealities, a double heat shield design is proposed that blocks and recycles thermal radiation going to unwanted locations. The outer heat shield can both block the emission of the inner heat shield and cool itself via thermal conduction through the sidewalls, thus remaining at a significantly lower temperature. In addition, passive cooling through thermal conduction is applied to the metallic waveguide to reduce the impact of its temperature-dependent reflectance.

The final calibration result shows that the calculated and measured emission power fit well even at higher temperatures. To characterize its spectral distribution, the observed emission will be guided through a carefully designed optical path into a Fourier Transform InfraRed (FTIR) spectrometer. For further calibration, the real time emitter temperature measurement and FTIR calibration will be repeated with the CNT emitter replaced by metal emitters and selective emitters.

Graduate research mentor Zhiguang Zhou writes: "Directional thermal emission measurement is an important step toward the demonstration of high-performance thermophotovoltaics (TPV). It also has the potential of providing emission spectra of thermal emitters as an experimental verification of selective emitter designs."



Double heat shield and passive cooling for the waveguide are designed to alleviate the non-idealities in the calibration. The final calibration result shows that the theoretical and experimental data fit well after both corrections.

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