# Development of a Precise Measurement System of Radiative Heat Transfer between Parallel Plates Separated by Close Distances

Y. Tsurimaki[1,2], T. Kobari[1], J. Okajima[3], A. Komiya[3],
P-O. Chapuis[2], R. Vaillon[2], and S. Maruyama[3]

[1] Graduate school of Engineering, Tohoku University, Sendai, Japan
[2] Université de Lyon, CNRS, INSA de Lyon, UCBL, CETHIL, Villeurbanne, France
[3] Institute of Fluid Science, Tohoku University, Sendai, Japan

Project ELyT lab: F2 – Radiative properties of complex materials for design and control of engineering systems

Abstract :

Heat is transferred through radiation between bodies at different temperatures. The well-known theory of Planck's blackbody radiation allows accurate estimation of radiative heat flux provided that the characteristic dimensions are much larger than the mean wavelength of radiation. However, it is now well established that the theory breaks down when bodies are separated by a distance smaller than the wavelengths of radiation. This regime of distances is called the *near-field*. The collapse of Planck's theory originates from the appearance of the wave nature of radiation, which leads to various phenomena: interference, diffraction, and evanescent waves that exist near the surfaces decaying exponentially away from them. To compute radiative heat flux exchanged by bodies in configurations where the Planck's theory no longer holds, the analytical model based on fluctuational electrodynamics should be used. Experimental investigations done so far showed a good agreement with the theory in the near-field [1]. Our focus in the present study lies in the transition field from the far-field to the near-field where both effects of interferences and of evanescent waves emerge. The relation between the coherence length of thermal radiation, a typical distance below which interfaces are possible, and the decaying length of evanescent waves is still unclear and need to be investigated in detail. While it is in general specified that these two characteristic lengths are on the same order of magnitude as the mean wavelength of thermal radiation given by Wien's law, we demonstrated that the interferences appear at longer distances than the evanescent effects at low temperature [2].

We consider two parallel plates separated by a vacuum gap. As the distance between the plates decreases, radiative heat flux will progressively be influenced by effects of interferences and evanescent waves which lead respectively to a reduction and an enhancement of radiative heat flux compared to the one in the far-field. Theoretical calculations predict that the effect of interferences appears at longer distance, so that the reduction of the net radiative heat flux occurs just before the enhancement due to evanescent waves that will override it. The objective of this project is to measure the radiative heat flux between two aluminum plates located at the transition regime to verify the expectations. We report our progress on the development of the experimental device.

The experimental device is based on Guarded Hot Plate (GHP) method which is in general employed to measure thermal conductivity of thermally insulating materials. This method allows a precise control of heat loss, which is crucial for radiation measurement. Moreover, a Peltier module is inserted in the device and functions as a sensitive temperature sensor, allowing even more precise control of heat loss. The parallelism and the distance control between the two plates are the pivotal condition in this experiment and we employ three piezo-actuators controlled independently to displace the moving plate on the order of nanometers and capacitance sensors to monitor absolute gaps at three points between the two plates. The development of the device will allow us to precisely measure the radiative heat flux at the transition regime.

[1] R. Ottens et al., *Physical Review Letters*, **107**, 014301, (2011)
[2] Y. Tsurimaki et al., *Proceedings of 15th International Heat Transfer Conference*, IHTC-9188, (2014)
[3] T. Kobari et al., *The 20th European Conference on Thermophysical Properties*, O_D1.21, (2014)