Fluctuational electrodynamics and near-field thermal radiation

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The classical theory of thermal radiation is based on the blackbody concept. In this framework, transport is treated as incoherent and thermal emission is conceptualized as a surface process. The blackbody concept is, however, based on the assumption that all characteristic lengths, which include the size of the bodies and their separation distance, are larger than the wavelength [1]. When the size of the bodies and/or their separation distance is comparable to or smaller than the wavelength, the wave characteristic of the energy carriers must be taken into account. In addition to these coherence effects, radiation heat transfer between bodies separated by subwavelength separation gaps may exceed by a few orders of magnitude the blackbody prediction due to tunneling of evanescent modes. Finally, when the size of a heat source is comparable to or smaller than the wavelength, thermal emission may experience size effect.

Coherence effects, emission and tunneling of evanescent modes, and volumetric thermal emission that are important in the near-field regime of thermal radiation (i.e., when the characteristic lengths are smaller than the wavelength) are modeled via fluctuational electrodynamics [2]. The fluctuational electrodynamics framework is based on Maxwell's equations into which fluctuating currents representing thermal emission are added. The link between the fluctuating currents and the local temperature of a heat source is provided by the fluctuation-dissipation theorem, which is valid under the assumption of local thermodynamic equilibrium.

In this talk, the basics of fluctuational electrodynamics applied to near-field thermal radiation will be reviewed. Recent experimental measurements demonstrating the validity of fluctuational electrodynamics will be overviewed [3]. Finally, the limit of validity of fluctuational electrodynamics in the extreme near-field regime (i.e., sub-10 nm separation gaps) will be discussed.

References

[1] Planck, M., 1991: *The Theory of Heat Radiation*, Dover Publications, New York.

[2] Rytov, S. M., Kravtsov, Y. A., Tatarskii, V. I., 1989: *Principles of Statistical Radiophysics 3: Elements of Random Fields*, Springer, New York.

[3] Bernardi, M. P., Milovich, D., Francoeur, M., 2016: Radiative heat transfer exceeding the blackbody limit between macroscale planar surface separated by a nanosize vacuum gap. *Nat. Commun.* **7**, 12900.