Near-field radiation heat transfer between arbitrarily-shaped objects and a surface

Sheila Edalatpour\textsuperscript{a,*} and Mathieu Francoeur\textsuperscript{b}

\textsuperscript{a}Department of Mechanical Engineering, University of Maine, Orono, ME 04469
\textsuperscript{b}Department of Mechanical Engineering, University of Utah, Salt Lake City, UT 84112

\textsuperscript{*}Presenting author (sheila.edalatpour@maine.edu)


In this work, a general framework for modeling near-field radiation heat transfer between arbitrarily-shaped objects and a large surface, modeled as infinite, is provided. The interaction between the objects and the surface is treated analytically using Sommerfeld’s theory of electric dipole radiation above an infinite surface (\textit{Ann. Phys.} \textbf{81}, 1135, 1926). The volume integral equation for the total electric field derived from the stochastic Maxwell equations is solved using the thermal discrete dipole approximation (T-DDA). The T-DDA is a numerical method that has been previously used for predicting near-field radiative heat transfer between arbitrarily-shaped objects embedded in an infinite, homogeneous medium (Edalatpour and Francoeur, \textit{J. Quant. Spectrosc. Radiat. Transfer} \textbf{133}, 364, 2014; Edalatpour \textit{et al.}, \textit{Phys. Rev. E} \textbf{91}, 063307, 2015).

The T-DDA with surface interaction is first verified against exact results of heat rates between a sphere and a surface. A good agreement between the exact results and those obtained from the T-DDA with surface interaction is found. The framework is then applied to the case of a probing tip interacting with a surface. This problem is of particular interest in near-field thermal spectroscopy, where a probing tip is used to scatter the near-field thermal spectrum emitted by a surface. Recently, two independent experimental studies reported a spectral redshift of the measured scattered signal compared to the thermal emission spectrum of the surface (Jones and Raschke, \textit{Nano Lett.} \textbf{12}, 1475, 2012; Babuty \textit{et al.}, \textit{Phys. Rev. Lett.} \textbf{110}, 146103, 2013). Using the T-DDA with surface interaction, the physical mechanisms responsible for the redshift are elucidated by analyzing the spectral distributions of heat rate and power scattered by the probing tip. The framework proposed in this study is likely to assist in the development of thermal spectroscopy techniques for probing the near-field thermal spectrum of heat sources.

Preferred mode of presentation: Oral