CASTS Talk

Hot Topics in Thermal Radiation

2015 - 06 - 09 (Tue.)
16:30 - 17:20
308, Mathematics Research Center Building (ori. New Math. Bldg.)

In this talk, we start with basic thermodynamics and work our way to modern twists on the old notion of radiant heat, including nanophotonic design of new classes of radiators.

Everyone knows that when an object gets hot enough, it glows. The quantitative mathematical theory of thermal radiation is over a century old, with the solution to the "ultraviolet catastrophe" of black-body radiation playing an important role in the origin of quantum mechanics. Well before Planck's law, Kirchhoff quantified the observation that a good absorber (a nearly black surface) is a good emitter, by presenting what is now known as "Kirchhoff's law" (of thermal radiation, not circuits!): the emissivity of a surface (the fraction of black-body radiation that it emits) is equal to its absorptivity (the fraction of incident light that it absorbs) at any given frequency. This statement, which can be derived from detailed balance in thermodynamics or alternatively from the fluctuation-dissipation theorem combined with electromagnetic reciprocity, has taken on a new significance in the design of synthetic thermal emitters. For applications from spectroscopy to thermophotovoltaics, many researchers are exploiting photonic crystals, surface-plasmon resonances, and other optical effects in wavelength-scale media in order to design nano-patterned surfaces that radiate a tailored spectrum, for example to radiate primarily in a narrow frequency range.

At first glance, Kirchhoff's law also seems to impose a fundamental limitation on radiated power: since you can never absorb more than 100% of incident light, you can never emit more than a black body. It turns out that this is not the case, however. By the 1950's, it was realized that "near-field" heat transfer, between two surfaces separated on the wavelength scale or less, could exceed the black-body limit, but the problem proved surprisingly challenging to study: theoretical predictions were only possible for flat surfaces until developments (at MIT and elsewhere) in the last few years, when an explosion of new developments has appeared in the literature. We have recently shown that there are still fundamental material-imposed upper bounds to near-field heat transfer, but these upper bounds suggest that planar surfaces are dramatically suboptimal. There has also been new work on thermal radiation from strongly nonlinear media, and we have recently shown that these can even exceed the black-body limit.