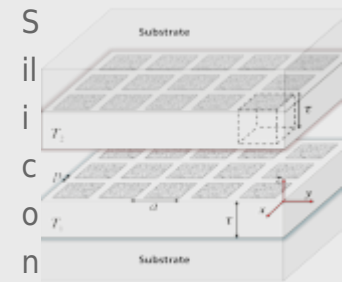


## Enhancing Radiative Heat Transfer With Silicon Metasurfaces



metasurfaces made of 2D periodic arrays of square holes.

Article: published in [Physical Review Letters](#) by Víctor Fernández Hurtado, [Francisco J. García Vidal](#) and [Juan Carlos Cuevas](#), IFIMAC researchers and members of the Department of Theoretical Condensed Matter Physics.

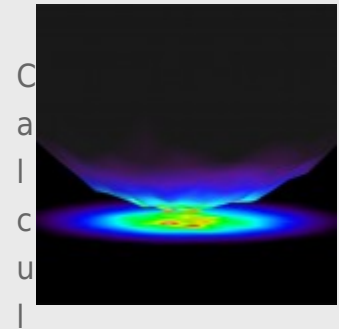
**T**hermal radiation is a universal physical phenomenon of great importance for different disciplines of science and engineering. In recent years, there has been a renewed interest in this topic due to the discovery that radiative heat transfer between two bodies can be drastically enhanced if they are brought sufficiently close to each other. This enhancement, which occurs when the separation is smaller than the thermal wavelength (10 microns at room temperature), is due to the contribution of evanescent waves that dominate the near-field regime. The fact that this near-field radiative heat transfer (NFRHT) between closely spaced bodies can overcome the far-field limit set by the Stefan-Boltzmann law for black bodies has now been verified in a variety of experiments exploring different materials, geometrical shapes, and gaps ranging from micrometers to a few nanometers.

In this context, the question on the fundamental limits of thermal emission is attracting a lot of attention. So far, the largest NFRHT enhancements have been reported for polar dielectrics (SiC, SiO<sub>2</sub>, SiN, etc), in which thermal radiation is dominated by surface phonon polaritons. Now, in a work published in [Physical Review Letters](#), the IFIMAC researchers Víctor Fernández Hurtado, [Francisco J. García Vidal](#) and [Juan Carlos Cuevas](#), together with Professor Shanhui Fan (Stanford University), have shown that metasurfaces of doped silicon can be used to boost NFRHT. In particular, they demonstrate that one can design silicon metasurfaces that not only exhibit a room-temperature NFRHT much larger than that of bulk Si or other proposed periodic structures, but they also outperform the best unstructured polar dielectric. The underlying physical mechanisms responsible for this striking behavior are the existence of broadband spoof surface-plasmon polaritons (SPPs) in doped silicon and the ability to

tune via nanostructuring the dispersion relation of these SPPs that dominate NFRHT in this structure. This work illustrates the great potential of metasurfaces for the field of radiative heat transfer. [\[Full article\]](#)

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## Radiative Heat Transfer In The Extreme Near Field



ated distribution of the radiative heat transfer between a SiO<sub>2</sub> AFM tip and a SiO<sub>2</sub> substrate separated by a few nanometers.

Article: published in [Nature](#) by Víctor Fernández-Hurtado, Johannes Feist, [Francisco J. García-Vidal](#) and [Juan Carlos Cuevas](#), Department of Theoretical Condensed Matter Physics and IFIMAC researchers.

**R**adiative heat transfer between objects at different temperatures is of fundamental importance in applications such as energy conversion, thermal management, lithography, data storage, and thermal microscopy. It was predicted long ago that when the separation between objects is smaller than the thermal wavelength, which is of the order of 10  $\mu\text{m}$  at room temperature, the radiative heat transfer could be greatly enhanced over the theoretical limit set by the Stefan-Boltzmann law for blackbodies. This is possible due to the contribution of the near field in the form of evanescent waves (or photon tunneling). In recent years, different experimental studies have confirmed this long-standing theoretical prediction. However, and in spite of this progress, recent experiments exploring the radiative thermal transport in nanometric gaps have seriously questioned our present understanding of thermal radiation at the nanoscale. In particular, these experiments cast some doubt on the validity of fluctuational electrodynamics, which is presently the standard theory for the description

of near-field radiative heat transfer (NFRHT).

This fundamental puzzle has now been resolved in a work published in Nature by a collaboration between the groups of Pramod Reddy and Edgar Meyhofer (University of Michigan), the IFIMAC researchers Víctor Fernández-Hurtado, Johannes Feist, Francisco J. García-Vidal and Juan Carlos Cuevas, and Homer Reid (Massachusetts Institute of Technology). In this work, the authors used a novel type of scanning thermal probes with embedded thermocouples to measure the NFRHT between different materials (dielectrics and metals) down to gaps as small as 2 nm. In particular, it was shown how heat transfer between silica-silica, silicon nitride-silicon nitride and gold-gold surfaces exhibits a dramatic enhancement as the gap is reduced down to a few nanometers. Moreover, state-of-the-art simulations using the framework of fluctuational electrodynamics were able to reproduce all the experimental observations without any adjustable parameters. These results unambiguously demonstrate that fluctuational electrodynamics based on Maxwell's equations provides an accurate description of the NFRHT between both metals and dielectrics all the way down to nanometer-size gaps. This work clarifies the fundamental mechanisms that govern the radiative heat transfer at the nanoscale and establishes a firm basis for the future design of novel technologies that make use of nanoscale radiative heat transfer. [\[Full article\]](#)

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