Optical Control over Thermal Distributions in Individual Nanoparticle Clusters and Topologically Trivial and Non-Trivial Plasmon Lattices

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A consequence of thermal diffusion is that heat, even when applied to a localized region of space, has the tendency to produce a temperature change that is spatially uniform throughout a material. The degree of spatial correlation between the heat power supplied and the temperature change that it induces is therefore likely to be small. Yet, the ability to control heat flow and thus temperature at both nanoscale (<100 nm) and micron-scale (~1-100 um) dimensions has important implications for applications ranging from big data to nanomedicine.

In this talk I will discuss collaborative work between the groups of Stephan Link at Rice University, Katherine A. Willets at Temple University, and my own at the University of Washington aimed at overcoming thermal diffusion through the theoretical design and experimental realization of a new class photothermal metamaterials composed of clusters of plasmonic nanoparticles [1,2] as well as photonic crystal lattices composed of plasmonic nanoparticle clusters located within each unit cell [3]. Specifically, I will discuss the ability of:

(1) individual nanoparticle clusters to host spatially-controllable nanoscale thermal profiles that are actively controllable by tuning the wavelength and polarization state of light [1,2] (Fig. 1 left)
(2) periodic 1-D and 2-D plasmonic nanoparticle lattices to support long-range (~1-100 um) thermal gradients spanning across the entire lattice domain as well as nanoscale thermal gradients localized within each unit cell that are actively controllable by tuning the wavelength, polarization state, and wave vector of light to excite specific points in the Brillouin zone [3] (Fig. 1 right)
(3) periodic nanoparticle lattices to host exotic non-equilibrium thermal edge states, localized to the lattice edges, in certain non-Bravais unit cell motifs tuned into their topologically non-trivial regime [3]

despite the deleterious effects of heat diffusion to wash out thermal gradients in favor of a uniform temperature rise across the system.

Taken together this work establishes a class of extraordinary thermal responses that are unconventional in ordinary materials and exposes a new direction in thermoplasmonics research that has only just now begun to be explored. Leveraging these properties, such thermal metamaterials are anticipated to provide new platforms for studying a variety of photothermal applications in the catalytic, energy, chemical, and biological sciences and engineering.

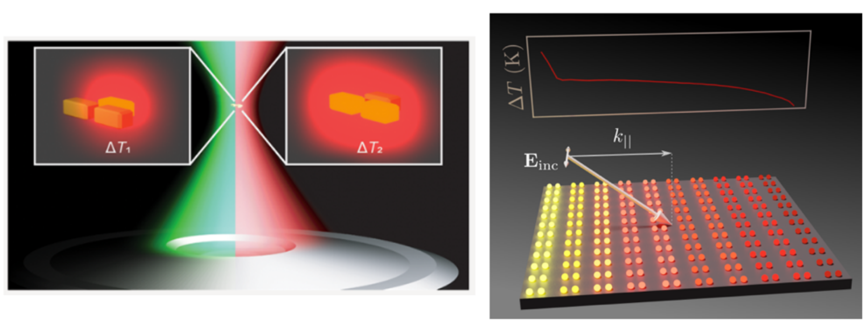

Fig. 1 (left) Illustration of light-induced nanoscale thermal gradients profiles exhibited in a plasmonic nanorod trimer at two different excitation wavelengths [2]. (right) Controllable long-range light-induced thermal gradient profile in a periodic plasmonic nanoparticle lattice driven at a specific point in the Brillouin zone to excite its collective surface lattice resonance [3].

References

[1] Bhattacharjee, U.; West, C.A.; Hosseini Jebeli, S.A.; Goldwyn, H.J.; Kong, X.-T.; Hu, Z.; Beutler, E.K.; Chang, W.-S.; Willets, K.A.; Link, S.; and Masiello, D.J. 2019 *ACS Nano* 13, 9655–9663.
[2] Hosseini Jebeli, S.A.; West, C.A.; Lee, S.A.; Goldwyn, H.J.; Bilchak, C.R.; Fakhraai, Z.; Willets, K.A.; Link, S.; and Masiello, D.J. 2021 *Nano Letters* 21, 5386–5393.
[3] Bourgeois, M.R.; Rossi, A.W.; Khorasani, S.; and Masiello, D.J. 2022 *ACS Photonics* 9, 3656–3667.