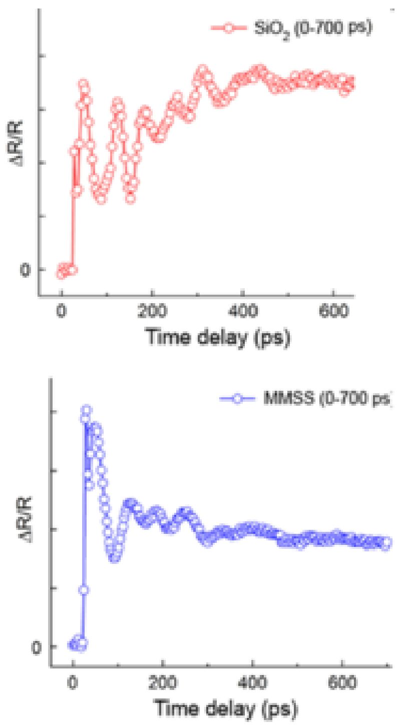
Controlling acoustic transport in hypersonic crystals

October 27 2014

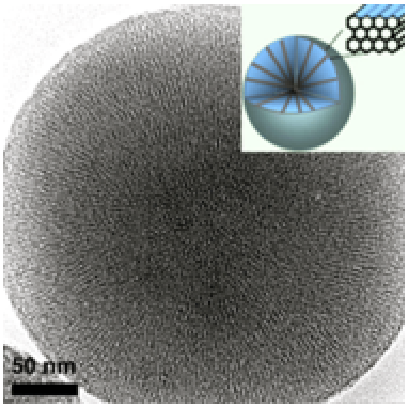


Measured relative reflectivity change (R/R0) for closely-packed solid (red) and nanoporous (blue) silica nanocrystals. Clear modulation of the reflectivity is apparent for both, but with greater damping for the latter. The coherent vibrations are produced following ultrafast pulse excitation within the lattice structures.

Center for Nanoscale Materials users from Toyota Research Institute of North America, working with CNM's Nanophotonics Group, have determined that bulk coherent acoustic vibrations are heavily damped by scattering from radially aligned nanosized pores within hypersonic crystals of closely packed colloidal silica. Surface acoustic modes are much less influenced, suggesting new ways to manipulate thermal transport via phonon propagation control.

Hypersonic crystals have periodic structures in the nanometer range and can coherently scatter both visible light (photons) and elastic waves (phonons), making them a simultaneous photonic and phononic crystal. This work provides insights for how to better understand how porosity would affect the acousto-optic properties of the hypersonic crystals and to exploit their possibilities for surface waveguide applications.

The decay of the acoustic vibrations was monitored by ultrafast pump-probe spectroscopy at the CNM. When the phononic crystal begins to vibrate following optical excitation with an ultrafast pulse, the vibrations modulate the phonon band gap and periodically alter the propagating phonon energy. Conventional silica nanocrystals do not show enhanced damping effects. Two types of coherent acoustic modes were observed, the propagating bulk mode and the localized surface mode. Porous structures demonstrated different effects on different modes of vibrations. While the bulk mode is heavily damped due to the scattering from the nanosized pores, the surface mode is much less influenced. One motivation for this work was as a means to manipulate/control thermal transport via control of phonon propagation. More specifically, when the "phononic" crystal begins to vibrate following optical excitation with an ultrafast pulse, the vibrations modulate the phonon band gap and periodically alter the phonon energy that can propagate in the crystal (where crystal = the self-assembled nanoparticles).



TEM image of bundled nanosized pores inside a porous colloidal hypersonic crystal

More information: G. Zhu, G. P. Wiederrecht, C. Ling, S. Wu, D. Banerjee, K. Yano, *Appl. Phys. Lett* .105, 051903 (2014).

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