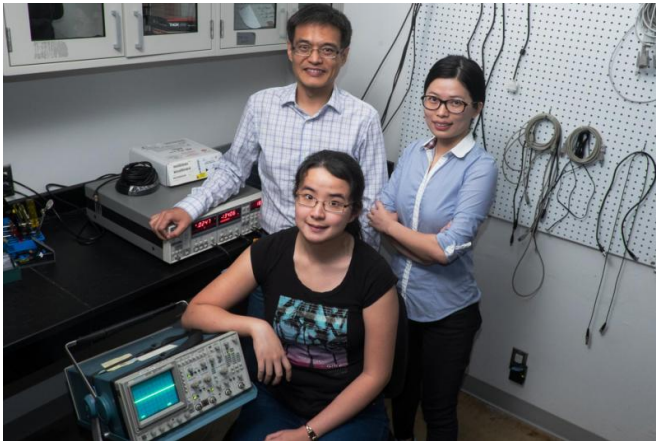


Scientists use light to probe acoustic tuning in gold nanodisks

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Rice researchers (clockwise from front) Man-Nung Su, Wei-Shun Chang and Fangfang Wen.

In a study that could open doors for new applications of photonics from molecular sensing to wireless communications, Rice University scientists have discovered a new method to tune the light-induced vibrations of nanoparticles through slight alterations to the surface to which the particles are attached.

In a study published online this week in *Nature Communications*, researchers at Rice's Laboratory for Nanophotonics (LANP) used ultrafast laser pulses to induce the atoms in gold nanodisks to vibrate. These vibrational patterns, known as acoustic phonons, have a characteristic frequency that relates directly to the size of the nanoparticle. The researchers found they could fine-tune the acoustic response of the particle by varying the thickness of the material to which the nanodisks were attached.

"Our results point toward a straightforward method for tuning the acoustic phonon frequency of a nanostructure in the gigahertz range by controlling the thickness of its adhesion layer," said lead

researcher Stephan Link, associate professor of chemistry and in electrical and computer engineering.

Light has no mass, but each photon that strikes an object imparts a minuscule amount of mechanical motion, thanks to a phenomenon known as radiation pressure. A branch of physics known as optomechanics has developed over the past decade to study and exploit [radiation pressure](#) for applications like gravity wave detection and low-temperature generation.

Link and colleagues at LANP specialize in another branch of science called plasmonics that is devoted to the study of light-activated nanostructures. Plasmons are waves of electrons that flow like a fluid across a metallic surface.

When a [light pulse](#) of a specific wavelength strikes a metal particle like the puck-shaped gold nanodisks in the LANP experiments, the light energy is converted into plasmons. These plasmons slosh across the surface of the particle with a characteristic frequency, in much the same way that each phonon has a characteristic vibrational frequency.

The study's first author, Wei-Shun Chang, a postdoctoral researcher in Link's lab, and graduate students Fangfang Wen and Man-Nung Su conducted a series of experiments that revealed a direct connection between the resonant frequencies of the plasmons and phonons in nanodisks that had been exposed to laser pulses.

"Heating nanostructures with a short light pulse launches acoustic phonons that depend sensitively on the structure's dimensions," Link said. "Thanks to advanced lithographic techniques, experimentalists can engineer plasmonic nanostructures with great precision. Based on our results, it appears that plasmonic nanostructures may present an interesting alternative to

conventional optomechanical oscillators."

Chang said plasmonics experts often rely on substrates when using electron-beam lithography to pattern plasmonic structures. For example, gold nanodisks like those used in the experiments will not stick to glass slides. But if a thin substrate of titanium or chromium is added to the glass, the disks will adhere and stay where they are placed.

"The substrate layer affects the mechanical properties of the nanostructure, but many questions remain as to how it does this," Chang said. "Our experiments explored how the thickness of the substrate impacted properties like adhesion and phononic frequency."

Link said the research was a collaborative effort involving research groups at Rice and the University of Melbourne in Victoria, Australia.

"Wei-Shun and Man-Nung from my lab did the ultrafast spectroscopy," Link said. "Fangfang, who is in Naomi Halas' group here at Rice, made the nanodisks. John Sader at the University of Melbourne, and his postdoc Debadi Chakraborty calculated the acoustic modes, and Yue Zhang, a Rice graduate student from Peter Nordlander's group at Rice simulated the optical/plasmonic properties. Bo Shuang of the Landes' research group at Rice contributed to the analysis of the experimental data."

More information: Tuning the acoustic frequency of a gold nanodisk through its adhesion layer, *Nature Communications* 6, Article number: 7022
[DOI: 10.1038/ncomms8022](https://doi.org/10.1038/ncomms8022)

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