ntu beats
National Taiwan University Official Quarterly

ACHIEVEMENTS

A Nanophotonic Breakthrough: Mie-Tronics Under Microscopy

Share:

For centuries, the mesmerizing colors of stained glass windows and the Lycurgus Cup captivated us, their physics shrouded in mystery. It took Gustav Mie's electromagnetic wave scattering theory in the 20th century to explain the magic behind these colors – grinding metals to specific sizes creates optical resonances, intensifying absorption and scattering to produce vivid hues. Fast forward to the 21st century, this nanoscale Mie resonance now extends to high-refractive-index semiconductors like silicon.

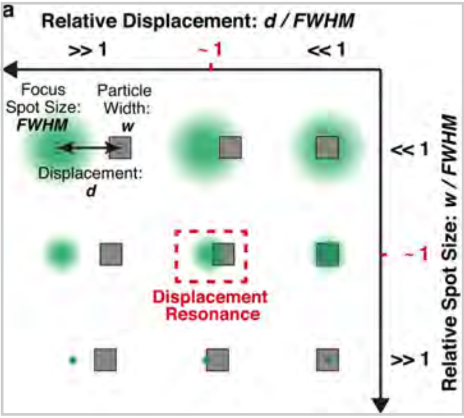
Conventionally, the Mie theory clarifies how structuring metals or semiconductors generates optical resonances, focused on normalized frequency, overlooking non-paraxial incidence symmetry. However, an international collaboration involving Osaka University, Jinan University, National Tsing Hua University, and National Taiwan University revealed a groundbreaking phenomenon that altering the relative positions of the light spot and nanostructures triggers previously unseen resonances, termed “displacement resonance”.

The discovery was enabled through the amalgamation of a common tool in life science, the confocal laser scanning microscope, and nanoscale resonance in material science. Intriguingly, when the focused light spot diameter and a silicon nanostructure are comparable in size, shifting their relative positions initiates displacement resonance, leading to unexpected results.

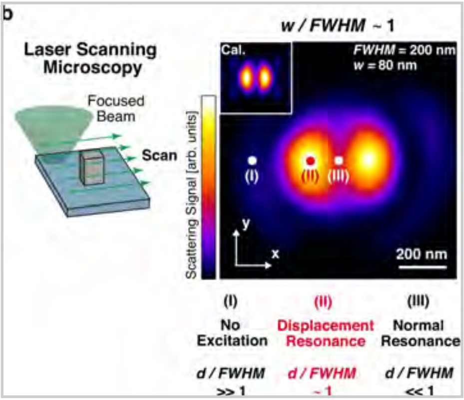
The study challenges established perceptions, indicating that the most effective interactions between light and matter happen when the laser focus deviates approximately 100 nanometers from the center. This unorthodox displacement resonance, linked to higher-order multipolar modes, expands upon the century-old light scattering theory and presents fresh opportunities for diverse applications.

One highlighted potential application involves the all-optical switching of a single nanoparticle, demonstrating the capability of displacement resonance in nonlinear nanophotonics. The research introduces an innovative tuning mechanism, illustrating that scattering nonlinearity changes sign by slightly moving the light spot, offering novel perspectives for applications in optical computing and super-resolution microscopy. The enhanced light-matter interaction at nanoscale may assist the signal read/write efficiency for quantum computing as well.

In essence, the revelation of displacement resonance introduces a novel spatial dimension in nanophotonics, challenging established resonance concepts and presenting intriguing possibilities for interdisciplinary applications.



Schematic illustration of displacement resonance. The green circles and gray rectangular, respectively, indicate a focus spot with the size of FWHM and a dielectric particle with the width of w. The displacement d indicates the distance between the focus spot and the particle. We defined the condition of displacement resonance, in the case that both d/FWHM (relative displacement) and w/FWHM (relative spot size) are close to unity.



Example of displacement resonance. When a crystalline silicon particle diameter (w = 80 nm) is comparable to the focus spot size (FWHM = 200 nm), the particle shows maximum scattering intensity as the beam center is slightly displaced, forming a non-gaussian laser scanning image. Each pixel in the laser scanning image corresponds to a unique displacement between particle and beam center, as indicated by the (I), (II), and (III) spots in the scanning image. The upper left inset shows the simulated LSM image.

Click or Scan the QR code to read the journal article in *Nature Communications*.