Optical bistability in nano-silicon with record low Q-factor

In this work, we reported a optical bistability in a single silicon nanostructure with a low Q-factor < 10 and cavity volume size of 10^{-3} μm^3. Optical bistability has been utilized as fundamental toward key applications, for example, all-optical switching and super-resolution optical imaging. Conventionally, the requirement of high-Q cavities has been a critical bottleneck in size reduction of the cavity, and thus the applications to the nanophotonic devices have been limited. Here, we relaxed the requirement of the high-Q cavity by utilizing the giant optical nonlinear responses in silicon nanocuboids based on the interaction between Mie resonance and photothermal effect. We theoretically and experimentally confirmed the optical bistable scattering response manifested by an abrupt super-linear jump of scattering intensity with hysteretic switching.

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Multipole engineering by displacement resonance: a new degree of freedom of Mie resonance

In this study, we found that when a focused light spot diameter and a silicon nanostructure are of similar sizes, changing their relative positions triggers formerly unseen resonances. Specifically, displacement resonance leads to a counterintuitive situation that the light-matter interactions, including scattering and absorption-induced nonlinear optical effects, are not maximal when laser focus is aligned with the particle, but become maximized when the focus spot is about 100 nanometers off-center. Traditional studies of Mie scattering mainly explored how the scattering intensity is influenced by the relative "wavelength" and "structure" dimensions, with most theories and experimental setups based on plane wave incidence or aligning focused light at the center of the nanostructure. Conceptually, our discovery opens up a new spatial dimension, revealing that when the focused light "spots diameter" and "displacement" scale are similar, new resonances are generated when the focus is NOT aligned with nanostructures. Besides advancing fundamental physical concepts, we expect displacement resonance will find applications in interdisciplinary fields of nonlinear nanophotonics and super-resolution microscopy.

Yu-Lung Tang, Te-Hsin Yen, Kentaro Nishida, Chien-Hsuan Li, Yu-Chieh Chen, Tianyue Zhang, Chi-Kang Pai, Kuo-Ping Chen, Junichi Takahara*, Xiangping Li*, and Shi-Wei Chu*, Multipole engineering by displacement resonance: a new degree of freedom of Mie resonance. *Nature Communications,* 14, 1, 7213 (2023).