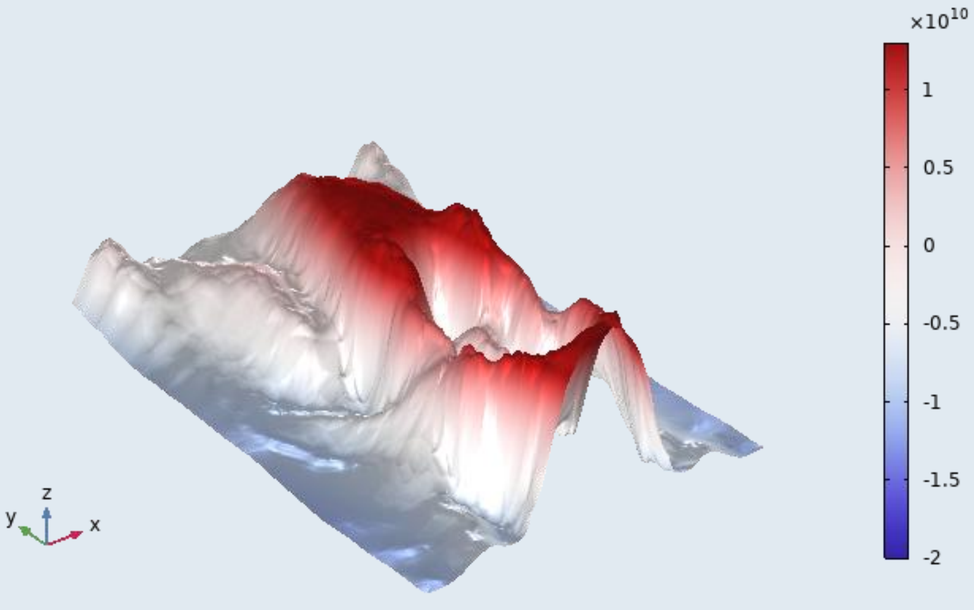


Numerical Study of Kerr Nonlinearity in Gold Nanoparticles under Dual-Wavelength Vectorial Focusing

A 3D full-wave electromagnetic model reveals intensity-dependent reshaping of dual-wavelength vectorially focused optical fields induced by Kerr nonlinearity.

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Introduction & Goals

Optical tweezers enable the non-contact trapping and manipulation of micro- and nanoparticles using highly localized optical fields, while the optical response of metallic nanoparticles is closely related to the spatial distribution, polarization state, and intensity of the focused light field.

To investigate the effects of Kerr nonlinearity on vectorially focused optical fields and the optical trapping of gold nanoparticles, a three-dimensional full-wave electromagnetic model was developed in COMSOL Multiphysics.

Methodology

A three-dimensional full-wave electromagnetic model was developed in COMSOL Multiphysics. An 800 nm azimuthally polarized beam and a 532 nm left-circularly polarized beam were vectorially focused through a focusing system with a numerical aperture of 0.85 in water.

$$\varepsilon_p = \varepsilon_{p,0} + \chi^{(3)}|E|^2$$

Kerr nonlinearity was introduced through an intensity-dependent refractive index. The optical response of a 30 nm-radius gold nanoparticle was described using its complex polarizability under the electric dipole approximation.

A parametric study was conducted by varying the incident electric-field amplitude to investigate the focused electromagnetic field at different excitation intensities.

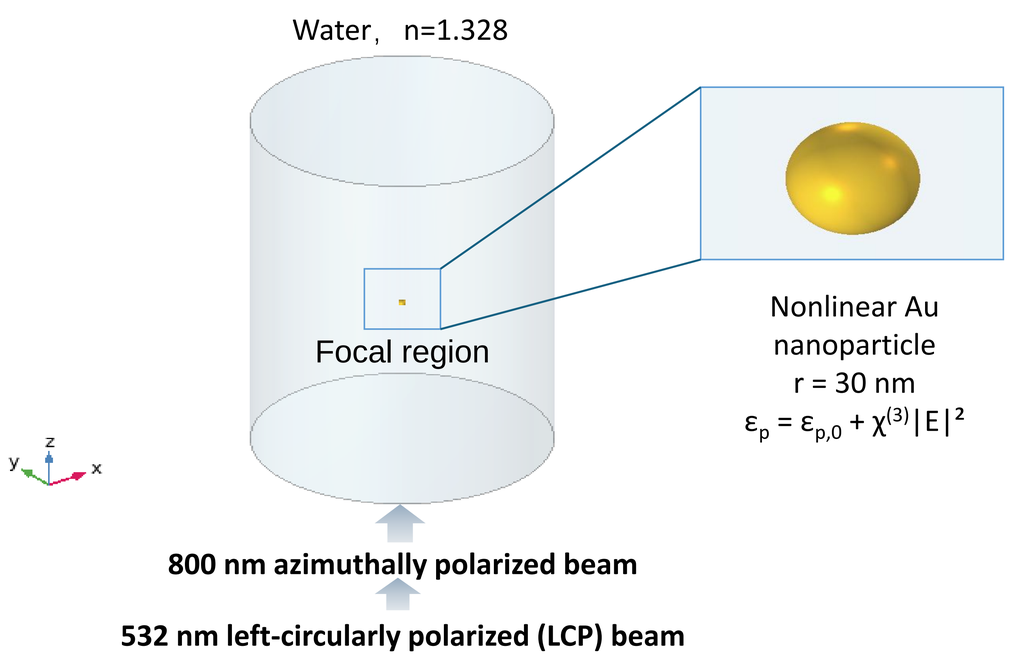


Figure 1. Schematic of the nonlinear optical model. A 30 nm-radius Au nanoparticle in water is illuminated by focused 800 nm azimuthally polarized and 532 nm LCP beams, with the nonlinear response described by $\varepsilon_p = \varepsilon_{p,0} + \chi^{(3)}|E|^2$.

Results

Numerical simulations show that Kerr nonlinearity significantly reshapes structured focused optical fields, producing local field enhancement and suppression within the focal region. The maximum field modulation $\Delta E_{\max}$ increases with the input amplitude E_{index}, demonstrating clear intensity dependence. The 532 nm LCP and 800 nm azimuthally polarized beams exhibit distinct radial field-reshaping behaviors, particularly at higher input amplitudes. These results demonstrate effective control of focused-field distributions through wavelength, polarization, and optical nonlinearity.

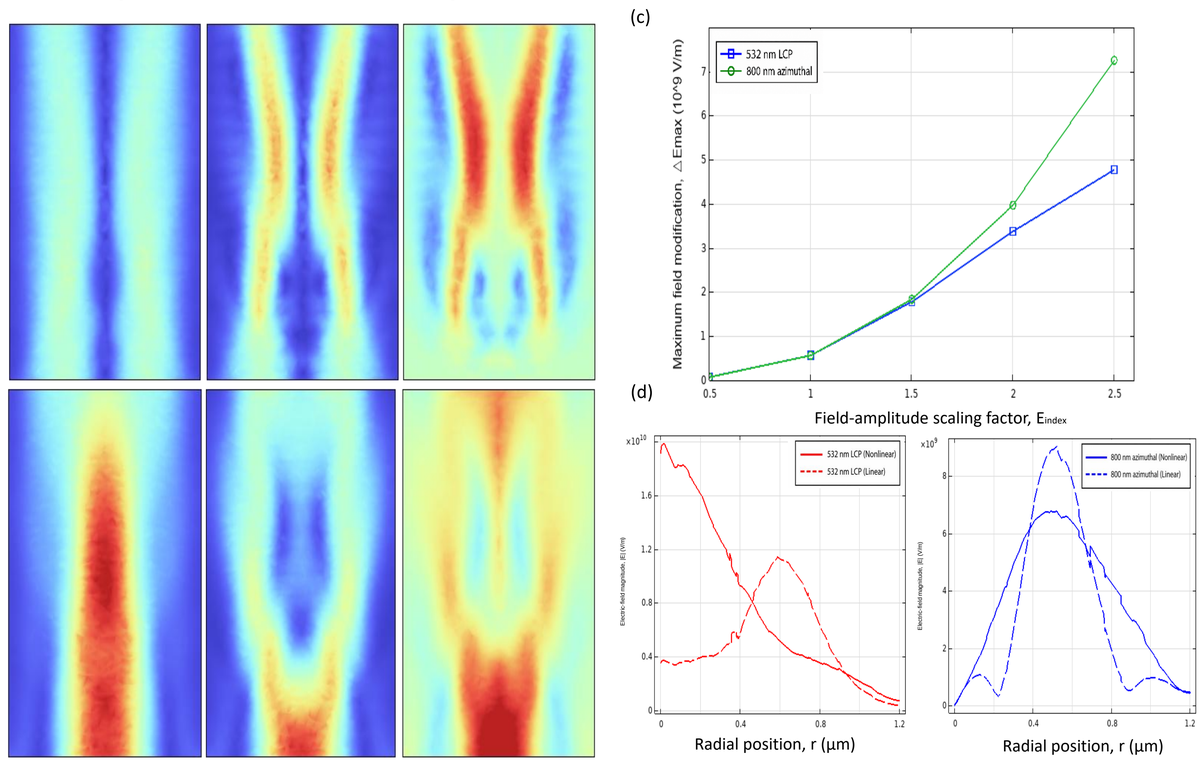


Figure 2. Nonlinear reshaping of focused electric fields. (a,b) Linear, nonlinear, and differential Δ|E| field distributions for the 800 nm azimuthal and 532 nm LCP beams. (c) Maximum field modification ΔE_{max} versus Eindex. (d) Linear and nonlinear radial field profiles for both beams.

REFERENCES

1. Y. Zhang et al., "Nonlinearity-induced multiplexed optical trapping and manipulation with femtosecond vector beams," Nano Lett. 18, 5538–5543 (2018).

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