Lensing and enhanced single atom detection via a single-pixel nanostructure

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We propose and demonstrate a general mechanism for nanoscale lensing based on the phase gradient imposed by a single nanostructure scattering light in its near field. We verify this effect using an optical waveguide on a substrate, with single atoms serving as quantum probes that sample the near-field intensity through their fluorescence. This quantum probing technique provides a unique, non-destructive approach to characterizing focused optical fields and reveals a 4-fold enhancement in single-atom detection efficiency. This work establishes on-chip nanostructures as a multi-functional quantum optics platform that can efficiently route photons, localize fields, and enhance atom-photon coupling, offering new opportunities for trapping and manipulating single atoms and realizing hybrid nanophotonic-atomic systems for quantum applications.

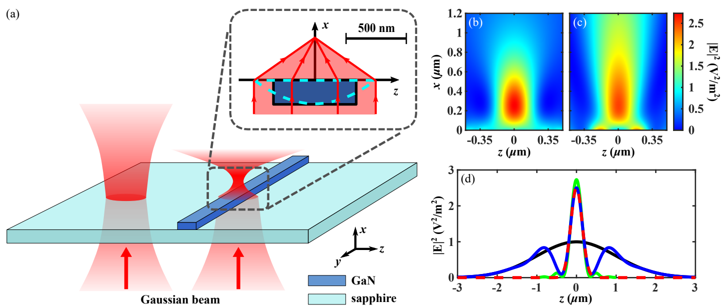

FIG. 1. (a) Schematic of lensing effect. (b)(c) Calculated and numerical simulated light field distribution of lensing effect. (d) Green, blue and black line: The transverse $|\mathbf{E}|^2$ profile at the focal plane of (b), (c) and the input Gaussian beam.

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