

# Unusual scaling laws for plasmonic nanolasers beyond the diffraction limit

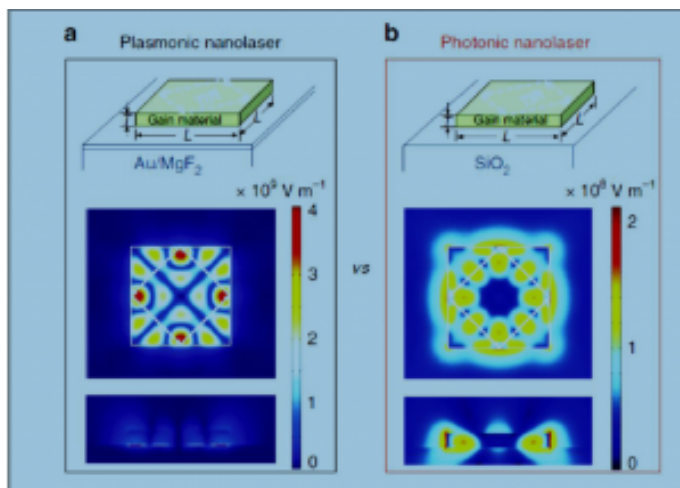


Fig. Schematic of plasmonic and photonic lasers and their cavity modes. a Top: schematic of the plasmonic nanolaser devices consisting of a nanosquare gain material on top of metal separated by a few nanometers of dielectric. Bottom: top and side views of electric field ( $|E|$ ) profiles of a cavity mode in a  $700 \times 700 \times 100 \text{ nm}$  plasmonic cavity. b Top: schematic of the photonic nanolaser devices consisting of a nanosquare gain material on top of dielectric. Bottom: top and side views of electric field ( $|E|$ ) profiles of a cavity mode in a  $700 \times 700 \times 100 \text{ nm}$  photonic cavity. In both panels,  $L$  and  $T$  are the length and thickness of the nanosquare, respectively, and TIR represents total internal reflection.

Plasmonic nanolasers are a new class of amplifiers that generate coherent light well below the diffraction barrier bringing fundamentally new capabilities to biochemical sensing, superresolution imaging, and on-chip optical communication. However, a debate about whether metals can enhance the performance of lasers has persisted due to the unavoidable fact that metallic absorption intrinsically scales with field confinement. Here, we report plasmonic nanolasers

with extremely low thresholds on the order of  $10 \text{ kW cm}^{-2}$  at room temperature, which are comparable to those found in modern laser diodes. More importantly, we find unusual scaling laws allowing plasmonic lasers to be more compact and faster with lower threshold and power consumption than photonic lasers when the cavity size approaches or surpasses the diffraction limit. This clarifies the long-standing debate over the viability of metal confinement and feedback strategies in laser technology and identifies situations where plasmonic lasers can have clear practical advantage.

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