Near-field plasmonics for generation of (phonon) lasing

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Recent advances in near-field plasmonics, i.e. metamaterials, have demonstrated the ability to generate localized fields of high intensity to maintain relatively large nanoscale heat gradients. A plasmonic near-field transducer (NFT) can achieve such large gradients, making population inversion achievable within photonic (or phononic) media.

We develop a thermal nanomachine composed of a nanoscale (phononic) laser that uses an NFT as a plasmonic energy source. Our vertically stacked system consists of a central three-level system in ladder-type configuration interacting with a two-level subunit at each side, coupled to a heat bath, i.e. created by the NFT and the cryostat, at the top and bottom, respectively. The different temperatures of the baths impose a heat gradient, which for certain parameters, at the central quantum system, could accompany the flow by the coherent (phonon) lasing.

In this contribution, we present a conceptionally new idea of a thermal nanomachine composed of a nanoscale (phononic) laser with an NFT as a source of plasmonic energy. Our description of the system kinetics is based on the Jaynes-Cummings Model, and the coupling to the external field given via a dipole approximation, with a single mode, quantized radiation field and phonon coupling. Indeed, we show that the positive inversion can be harnessed to generate coherent output having full control of the proposed phonon lasing medium.

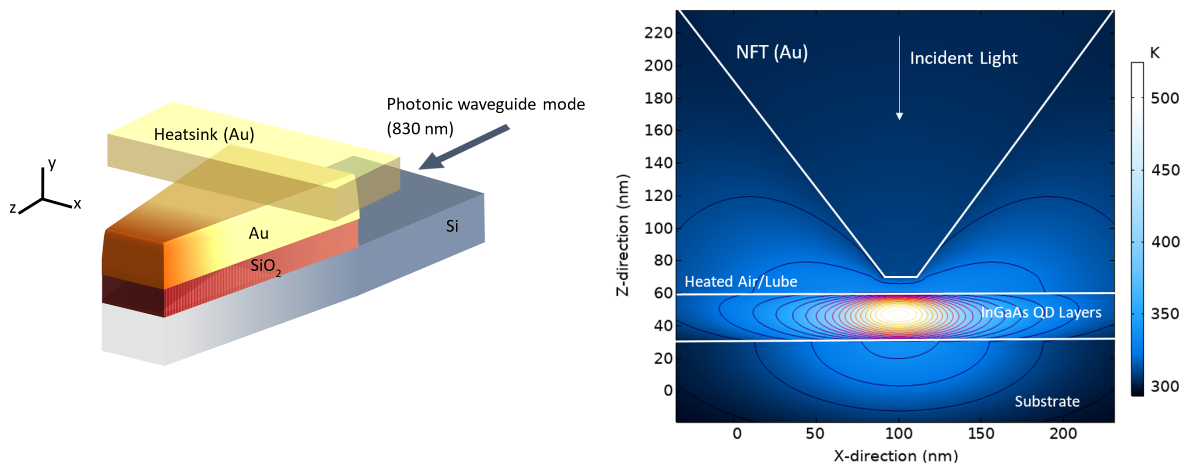

Figure 1: *Left:* Sketch of minimal model of the plasmonic near-field transducer (NFT); *Right:* Contour plot where lines follow the region of strongest temperature gradients necessary for the nanoscale (phonon) laser.

[1] P. Karwat, G. Pasławski, P. Damery, F. Bello, and O. Hess, arXiv:2112.15170 (2022),
[2] F. Bello, S. Sanvito, O. Hess, and J. F. Donegan *ACS Photonics* **6**, 1524 (2019),
[3] P. Karwat, D. E. Reiter, T. Kuhn, and O. Hess, *Phys. Rev. A* **98**, 053855 (2018).