



## Near-field characterization of deep sub-wavelength confinement in InP cavities

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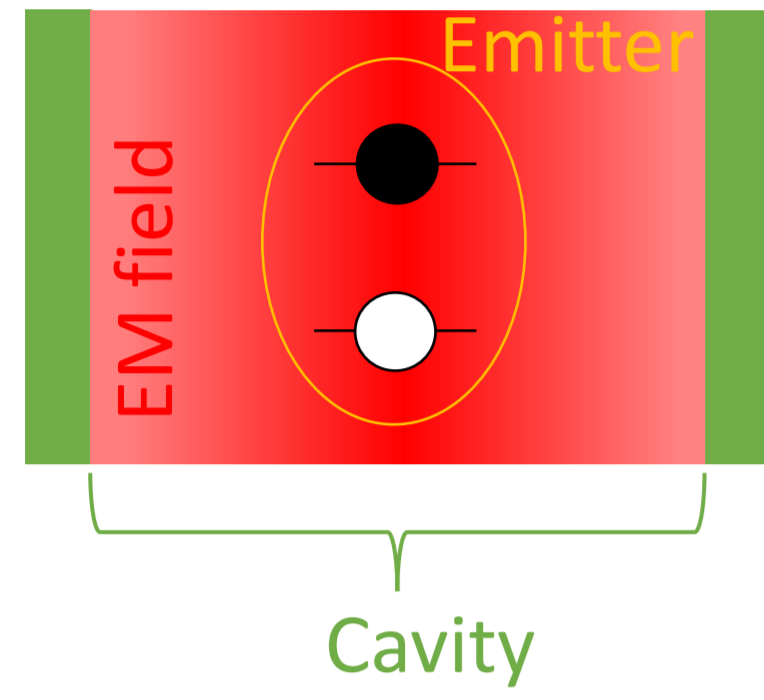
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## Abstract

We have achieved electromagnetic field confinement in an InP nanocavity with a mode volume  $< (\lambda/2n)^3$ . The experimental demonstration of sub-wavelength confinement is carried out by scattering-type scanning near-field optical microscopy with a pseudo-heterodyne detection scheme. Demodulation at higher harmonic orders of the tip tapping frequency enables retrieval of the scattered electric field with a nanoscale spatial resolution.

## Motivation

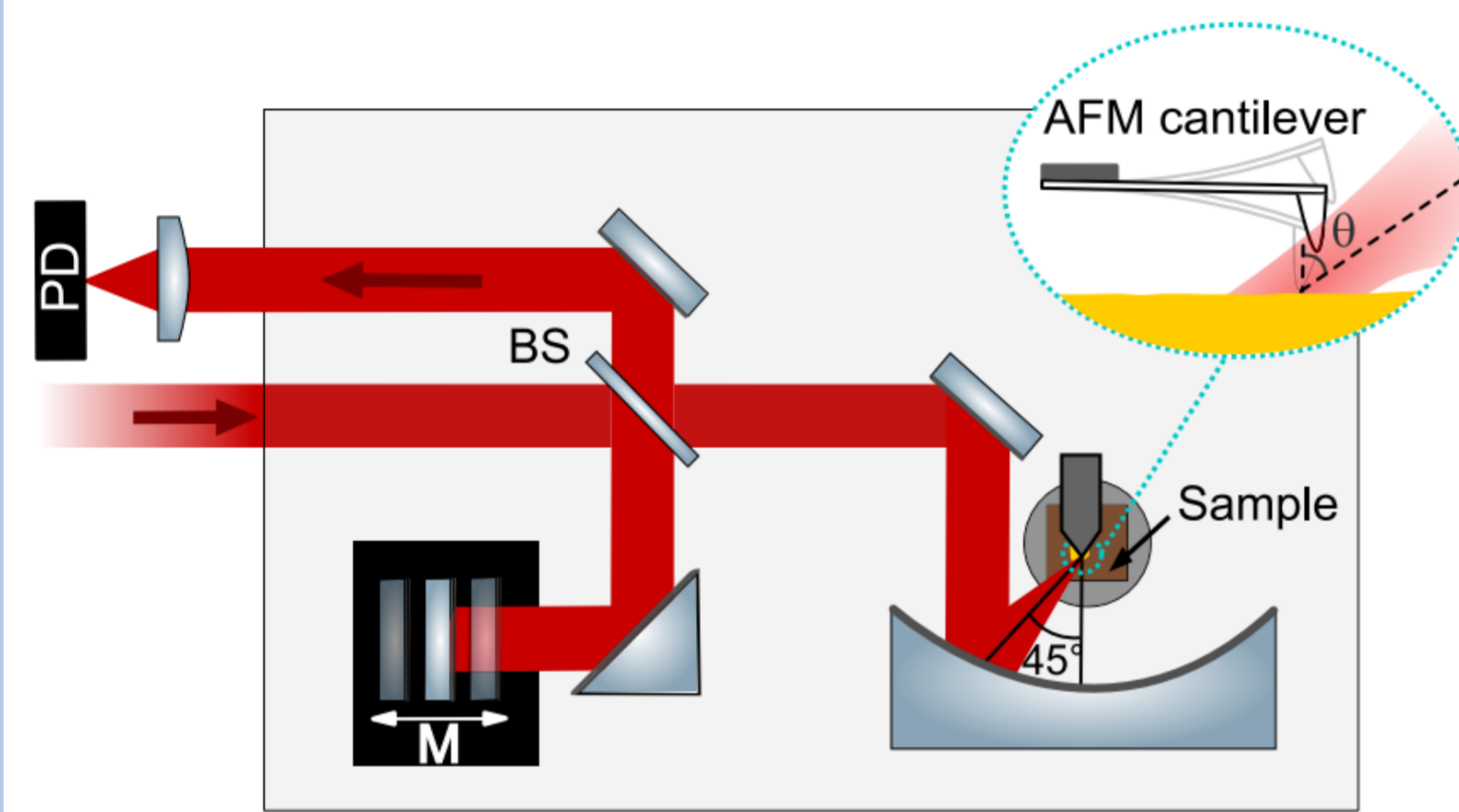


$$F_p = \frac{\tau_{3D}}{\tau_{\text{Emitter}}} \propto \frac{Q}{V}$$

Decreasing  $V$  in dielectric structures increases the Purcell factor. Sub-wavelength light confinement has recently been demonstrated in a Si-bowtie cavity [1]. For integration with active materials, a direct bandgap semiconductor like InP is favorable.

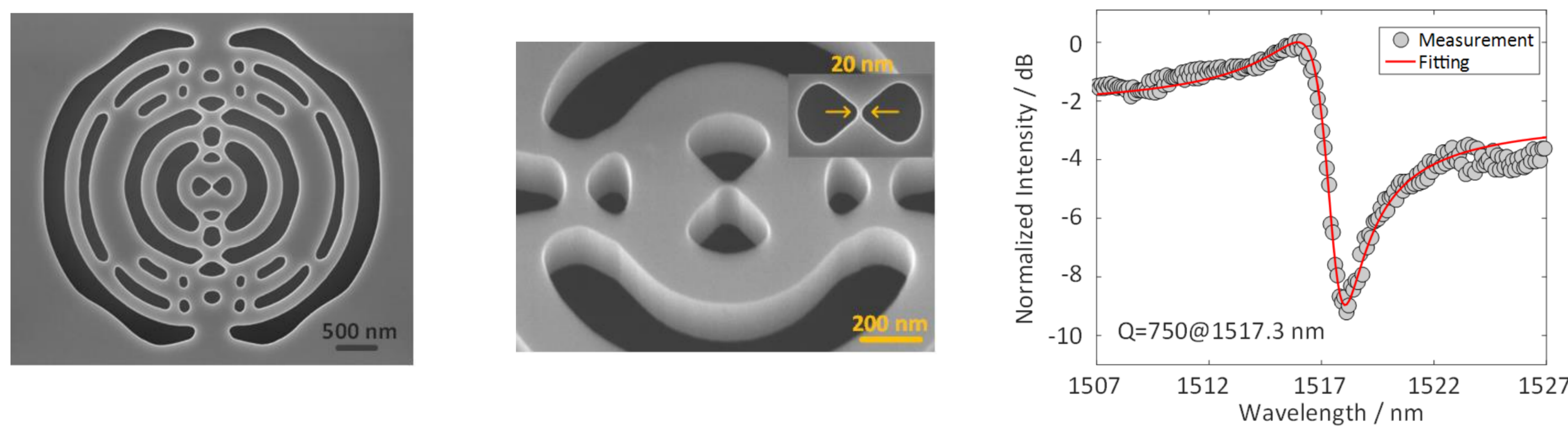
## Setup

### Scattering-type scanning near-field optical microscopy (sSNOM) [2]



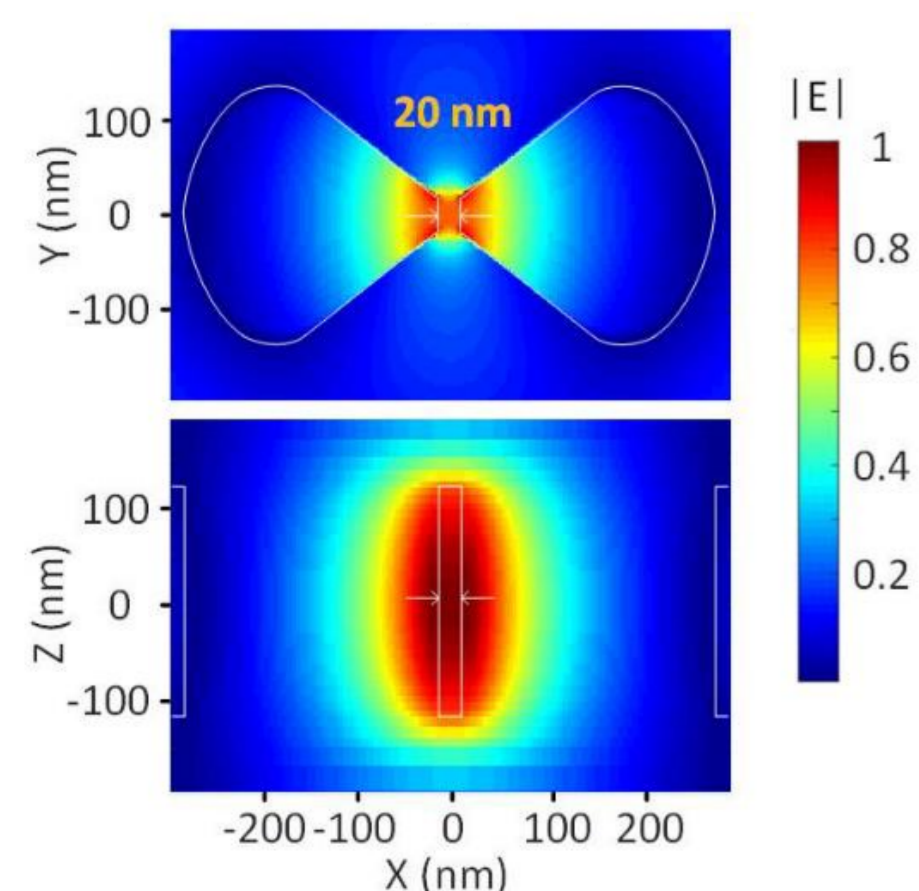
In a sSNOM, a laser beam from a tunable CW laser is focused on an oscillating AFM tip, yielding spatial field localization at the tip apex. Demodulation of the scattered light from the tip at higher harmonic orders of the tip tapping frequency and pseudo-heterodyne detection enables retrieval of the near-field information with a spatial resolution on the nanoscale.

## Fabrication and far-field characterization



Designing the extreme dielectric confinement (EDC) cavity exploits topology optimization [3], where the figure-of-merit  $Q/V$  is optimized. The structure is fabricated in InP with electron-beam lithography and inductively coupled plasma etching. Far-field measurements yield  $Q \sim 750$  at a resonance wavelength of  $\lambda_c = 1517.3$  nm for a bowtie spacing of 20 nm and  $Q \sim 600$  at  $\lambda_c = 1507.8$  nm for a bowtie spacing of 15 nm.

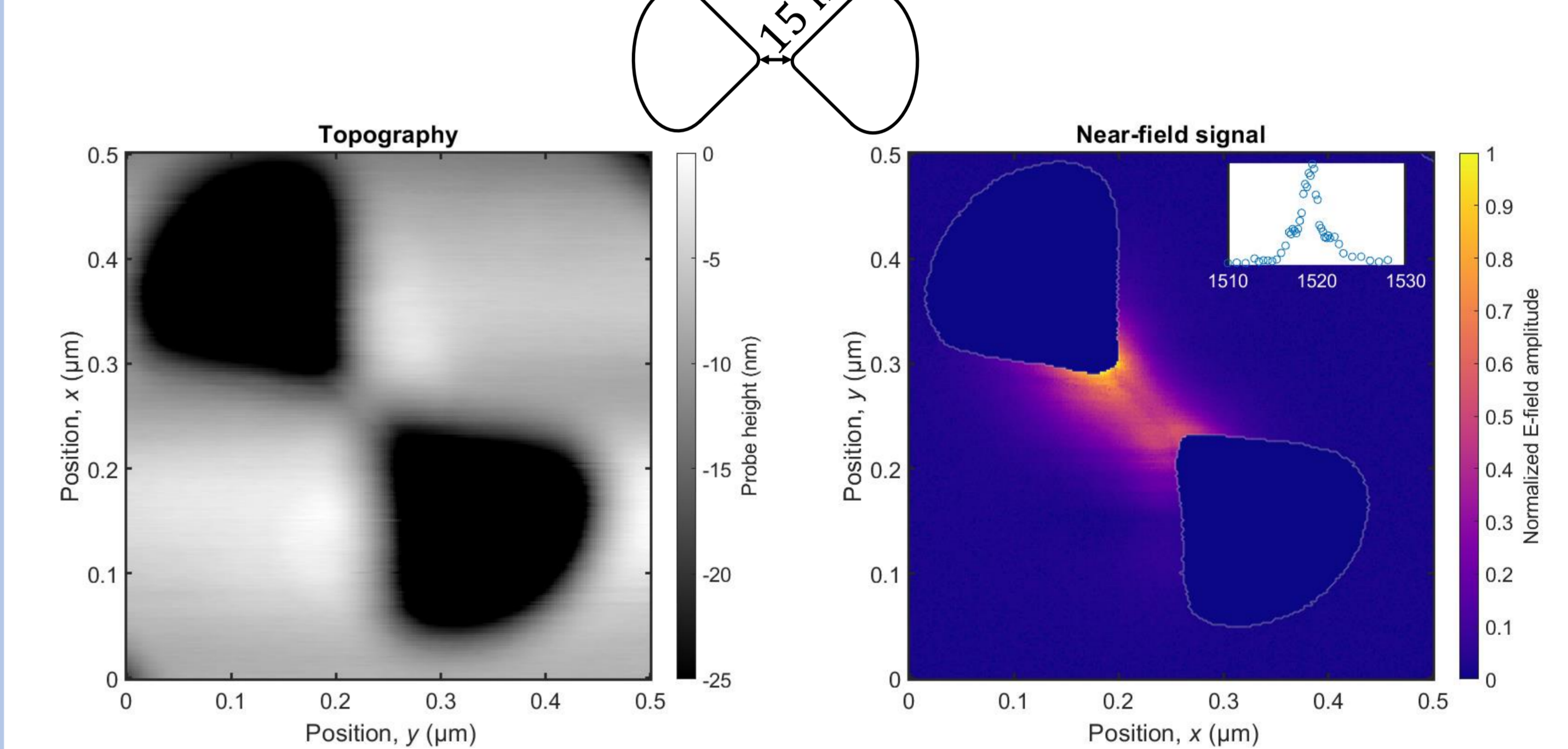
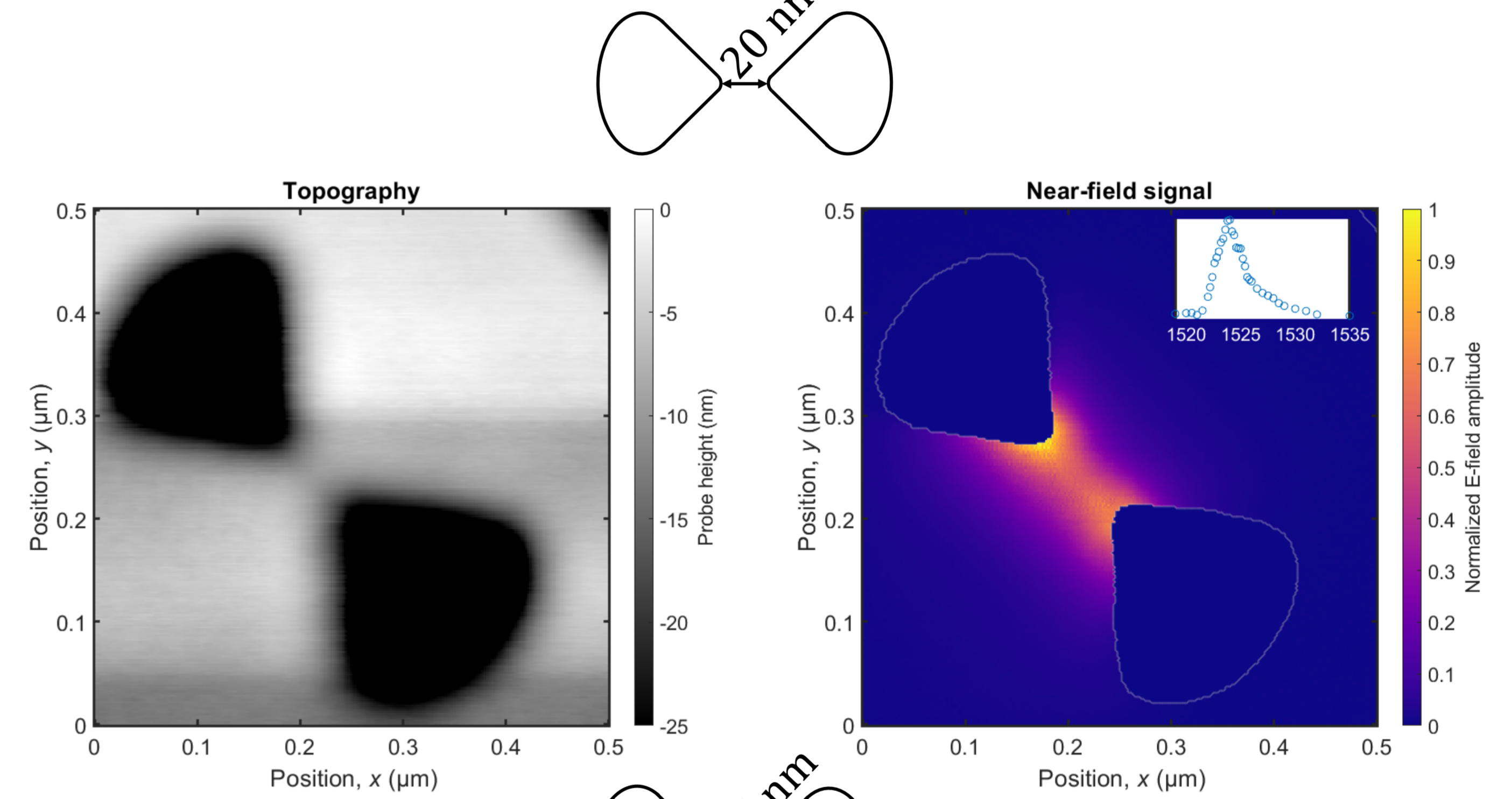
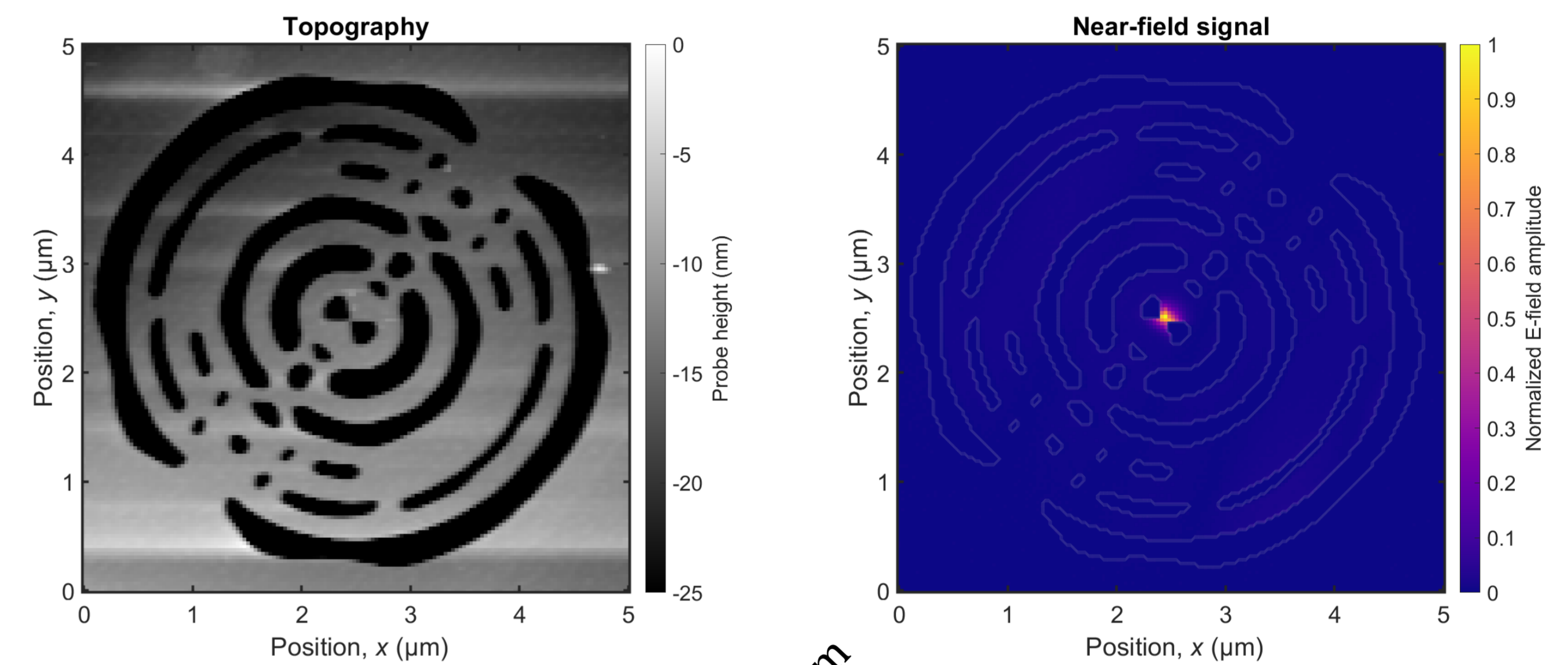
## Simulations



FDTD-simulations yield a Q-factor of  $\sim 1000$  and a mode volume of  $0.26 (\lambda/2n)^3$  for a bowtie spacing of 20 nm, which is significantly below the so-called diffraction limit. Moreover, when reducing the bowtie spacing to 15 nm, simulations reveal  $Q \sim 800$  and  $V \sim 0.19 (\lambda/2n)^3$ .

## Experimental Demonstration

### The electric field of the cavity is measured with the sSNOM:



→ Experimental demonstration of field confinement in the center of the bowtie cavity.

## References

- [1] M. Albrechtsen et al., *Nat. Commun.*, 13, 6281 (2022)
- [2] L. N. Casses et al., *Opt. Express*, 30, 11181 (2022)
- [3] R. E. Christiansen & O. Sigmund, *J. Opt. Soc. Am. B*, 38, 510 (2021)



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