CLAMPED AND SIDEBAND RESOLVED OPTOMECHANICAL CRYSTALS [1]

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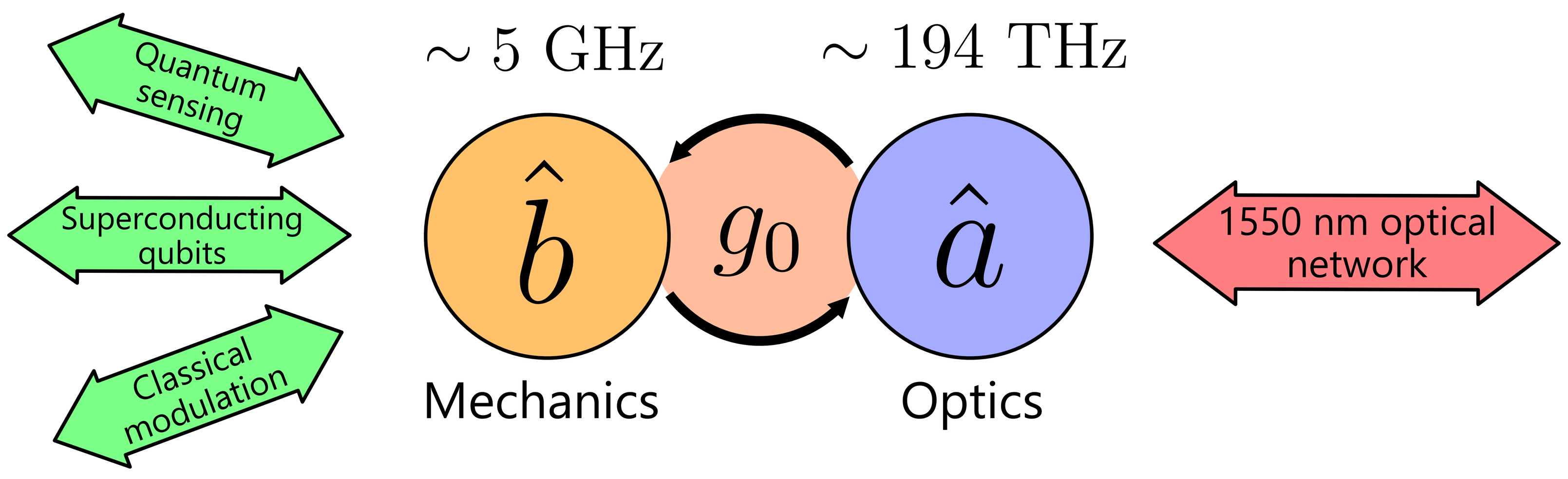
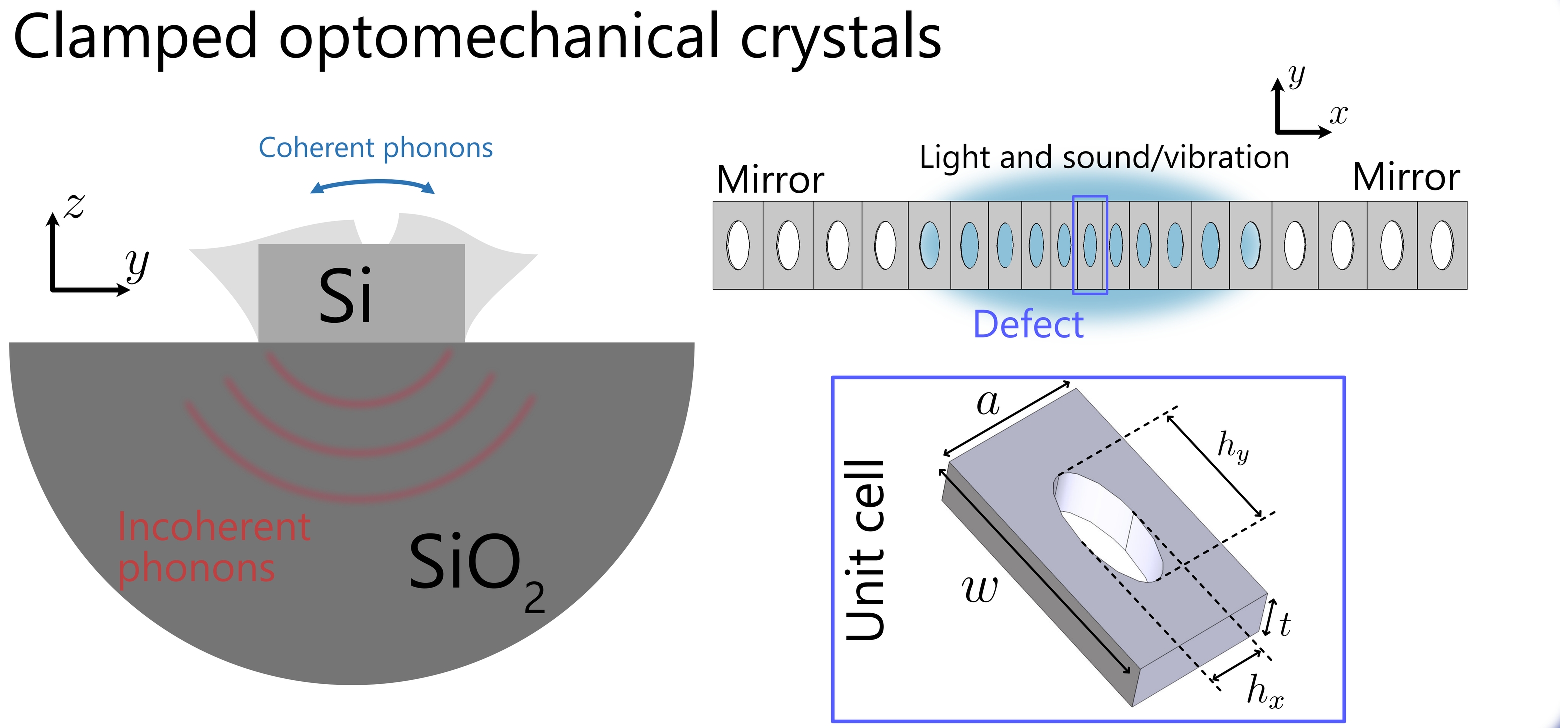
Goal - Signal transduction on classical and quantum level

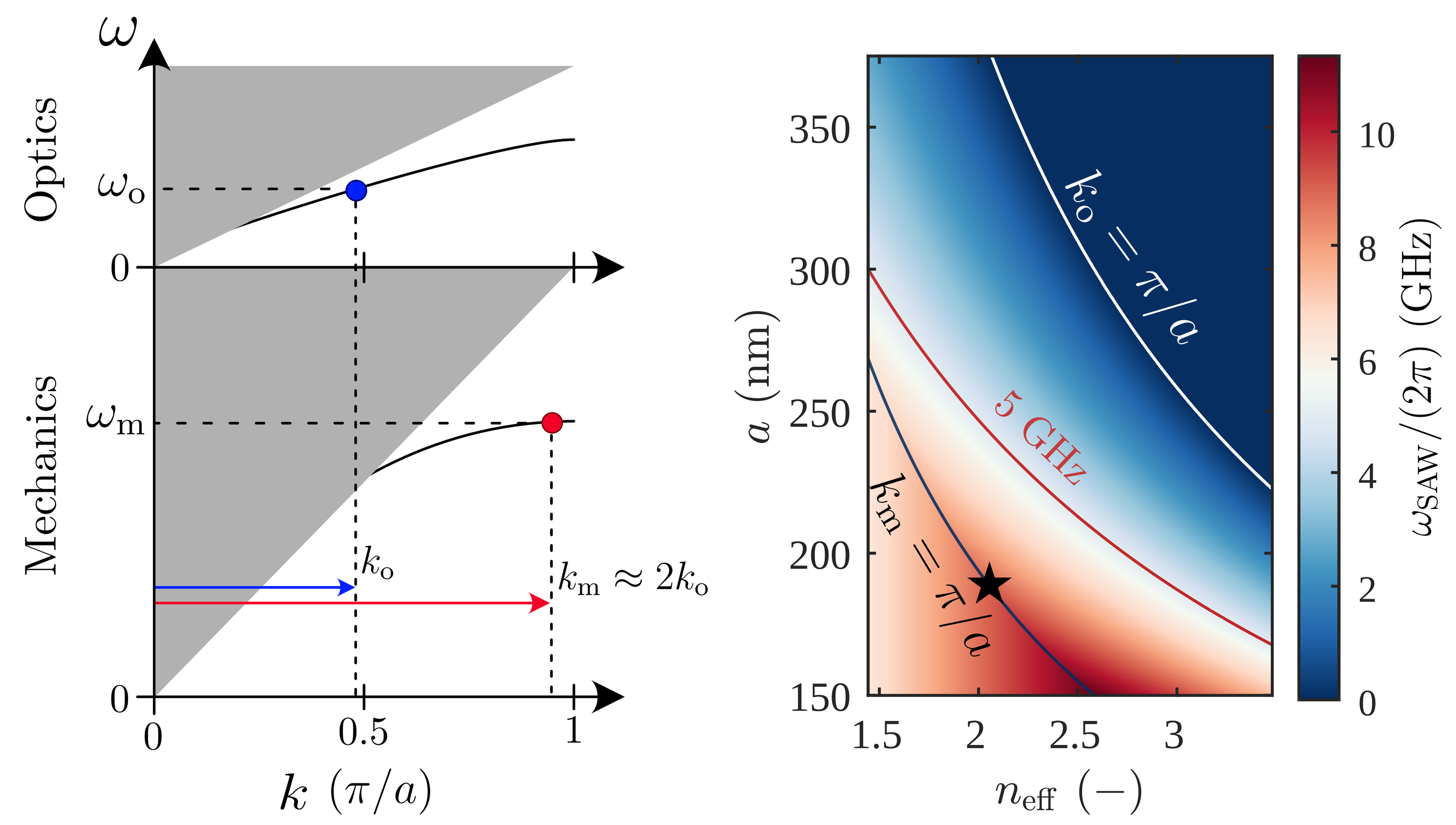


$$\mathcal{H}_{\text{int}} = \hbar g_0 \hat{a}^\dagger \hat{a} (\hat{b}^\dagger + \hat{b})$$

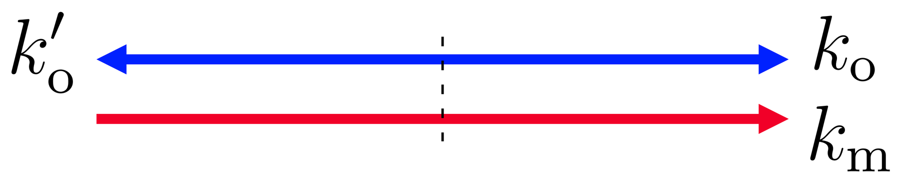
Clamped optomechanical crystals



Strong field confinement for clamped optomechanics



Phase matching for counter-propagating mechanical and optical fields

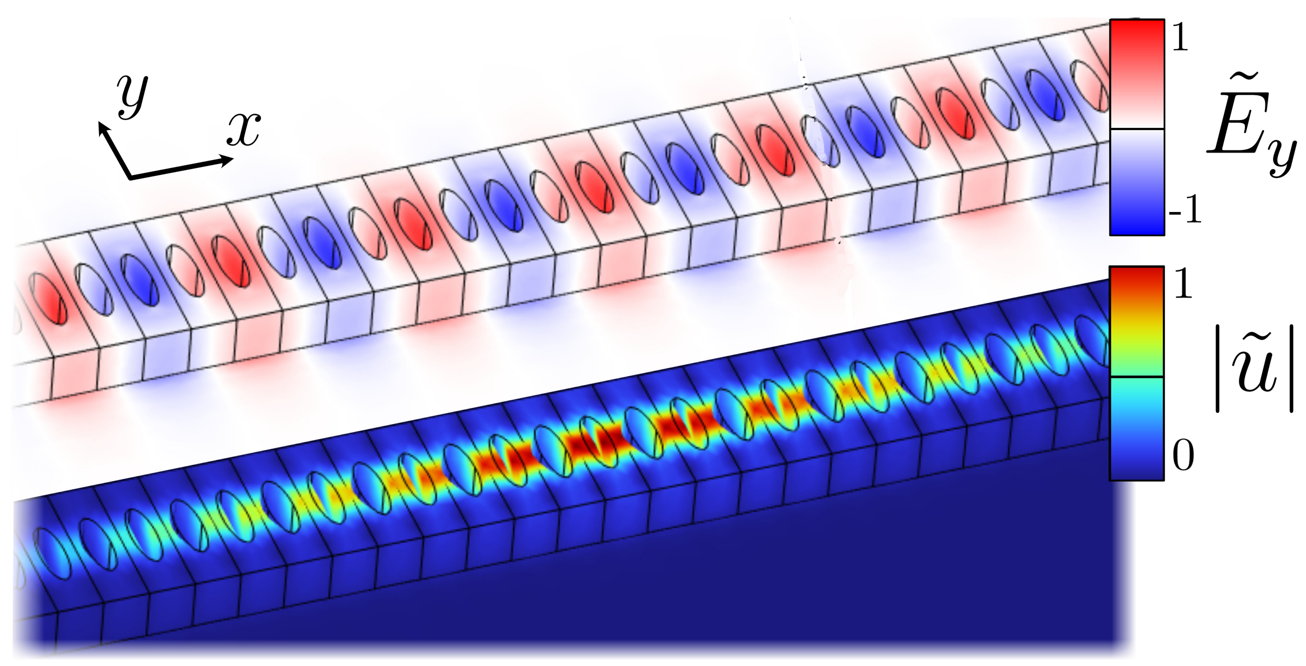


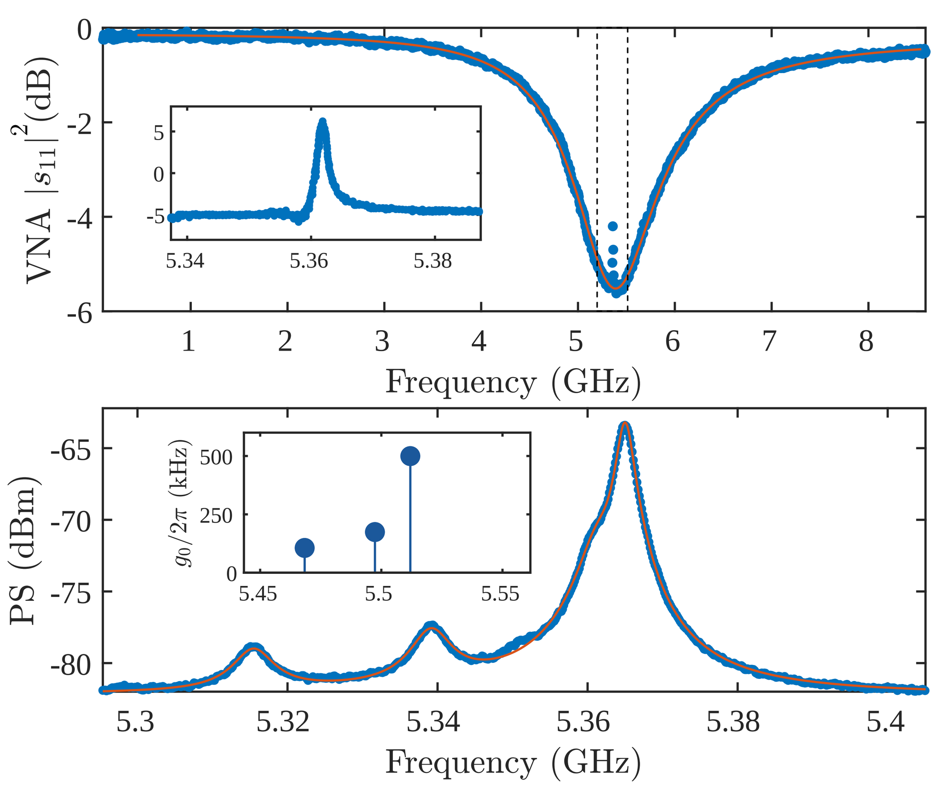
$$k_m \approx 2k_o$$

Requirements for clamped optomechanics

- No leakage to continuum
- Modes at desired frequencies
- Modes strongly coupled

Optical and mechanical resonances





Optical spectrum

$\omega_o/(2\pi) = 193.1$ THz

$\kappa/(2\pi) = 1.5$ GHz

Mechanical spectrum

$\omega_m/(2\pi) = 5.37$ GHz

$Q_m = 852$

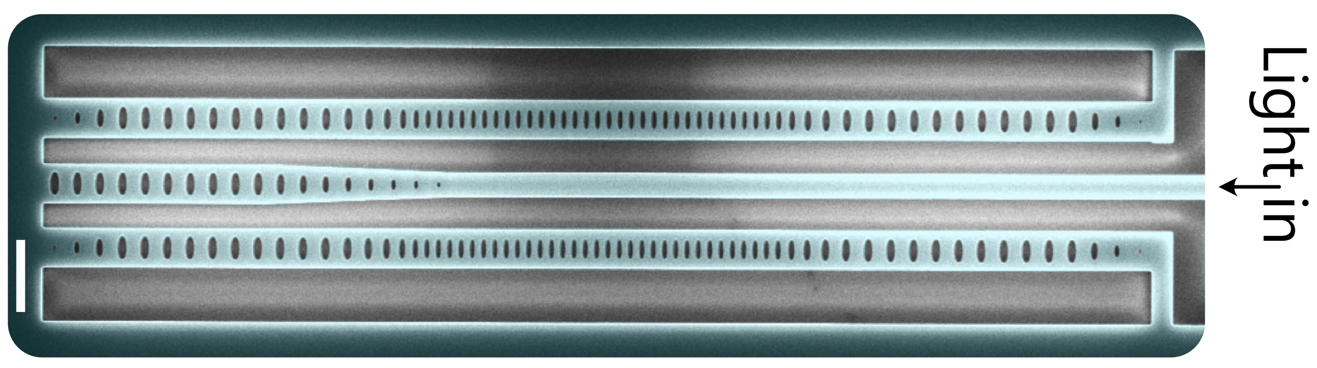
Sideband resloution

$\omega_m/\kappa = 3.6$

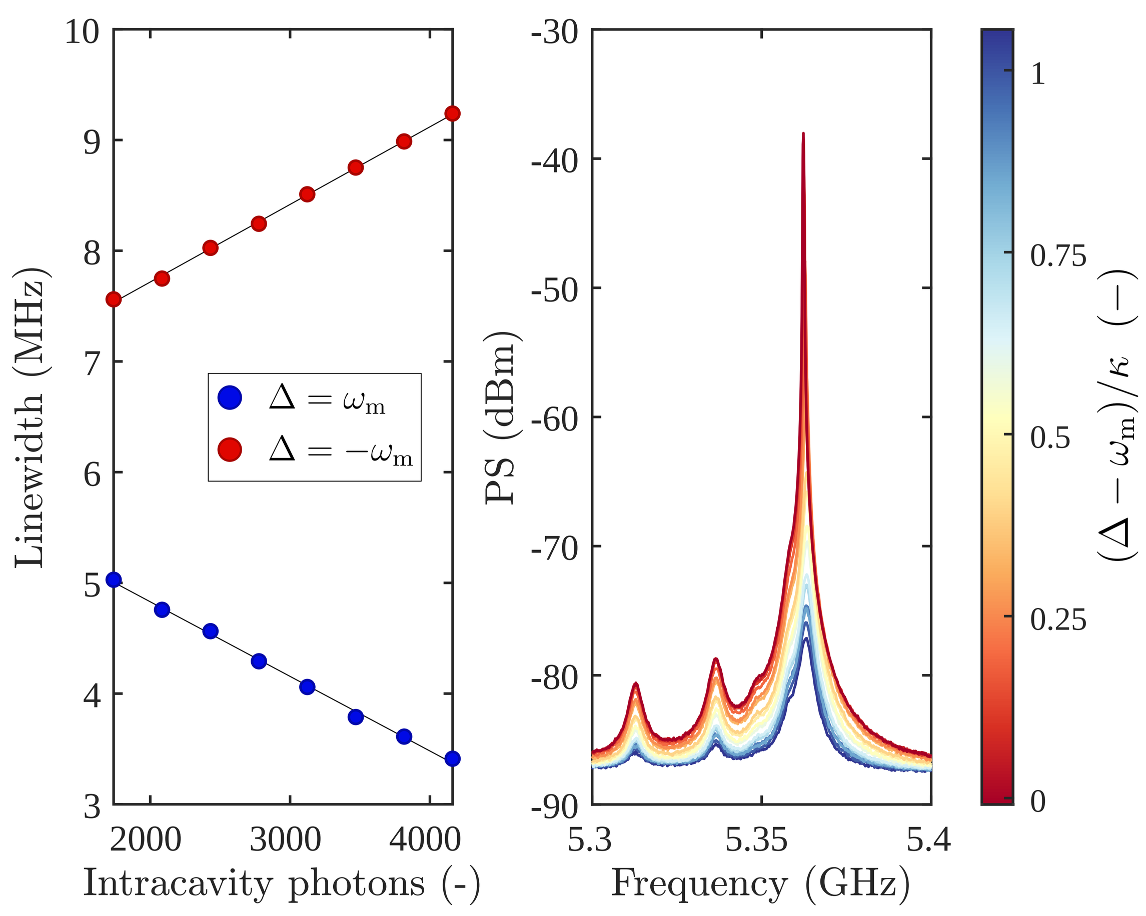
Resolved sideband regime!

Fabrication

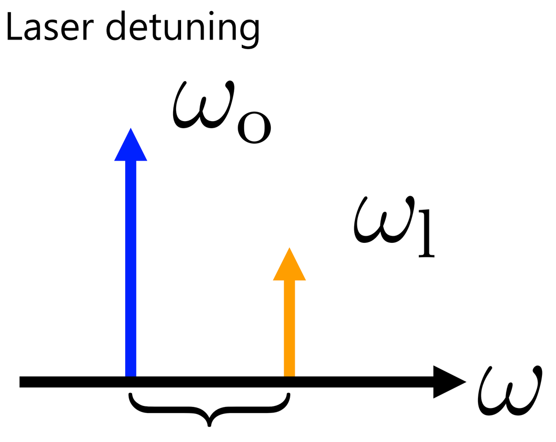
- 220 nm SOI
- ICP dry etch
- 3:1 Piranha clean



Optomechanical coupling



Laser detuning



$$\Delta = \omega_l - \omega_o$$

Measured optomechanical coupling rate

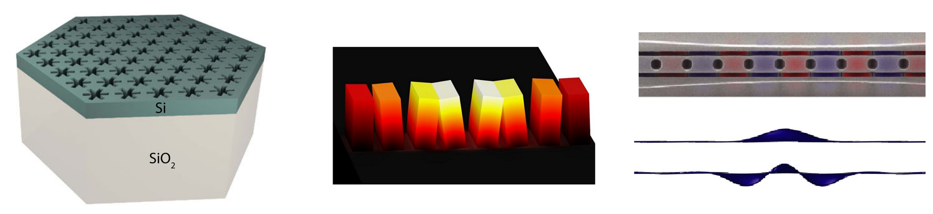
$$g_0/(2\pi) \approx 0.5 \text{ MHz}$$

Mechanical lasing observed for ~10^3 intracavity photons.

Conclusion

Clamped optomechanics comparison table

Reference	Liu et al. (est.) [2]	Zhang et al. [3]	Sarabalis et al. [4]	This work
$g_0/(2\pi)$ (kHz)	87	51	290	**500**
$\omega_m/(2\pi)$ (GHz)	**7.5**	0.66	0.48	**5.37**
$\kappa/(2\pi)$ (GHz)	9.7	4.9	8.2	**1.5**
$\gamma/(2\pi)$ (MHz)	16	**0.6**	2.6	6.3
ω_m/κ (-)	0.77	0.14	0.058	**3.6**
$\mathcal{C}_0 \equiv 4g_0^2/(\kappa\gamma)$ (-)	$2.0 \cdot 10^{-7}$	$3.5 \cdot 10^{-6}$	$1.6 \cdot 10^{-5}$	$\mathbf{1.1 \cdot 10^{-4}}$



The presented design shows leading performance when compared to previous efforts in clamped optomechanics. With strong coupling and sideband-resolved operation, there is potential for scalable optomechanical circuitry for both classical and quantum technology applications.

References

[1] J. Kolvik, P. Burger, J. Frey, R. Van Laer, arXiv:2303.18091 (2023).
[2] S. Liu, H. Tong, and K. Fang, Nat. Commun. 13 (2022).
[3] J. Zhang et al., ACS Photonics 9 (2022).
[4] C. J. Sarabalis et al., Optica 4 (2017).

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