Subwavelength Grating based Microcavity for Polariton Study

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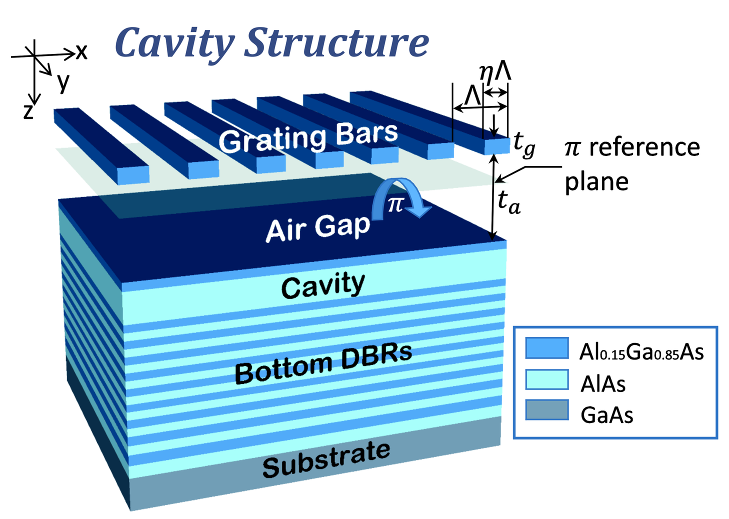
Introduction

Exciton-polaritons in semiconductors feature rich many-body quantum phases at high critical temperatures, even without thermal equilibrium [1]. On a solid-state platform, with a build-in photonic interface, quantum fluids of polaritons also promise diverse quantum photonic applications.

To create, understand and manipulate the quantum phases and their applications require lower-dimensional polariton system with desired properties. We establish a new cavity architecture for polaritons that uniquely allows flexible control of the polariton properties by design of the cavity mirror.

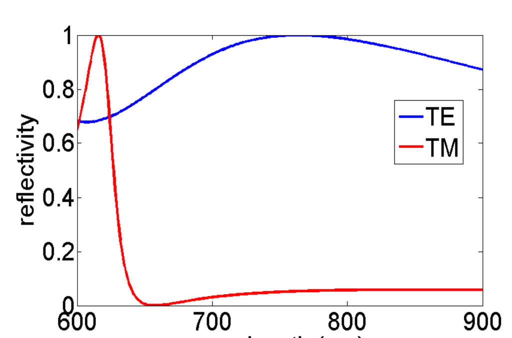
Subwavelength Grating (SWG) based Cavity System

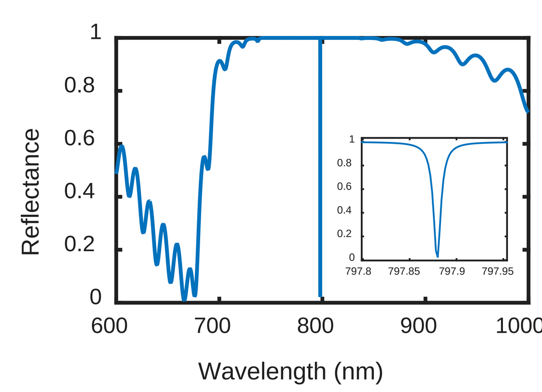


Suspended Photonic Crystal adds design flexibilities

- Polarization selectivity
- Dispersion engineering
- Lower dimensions & coupled systems

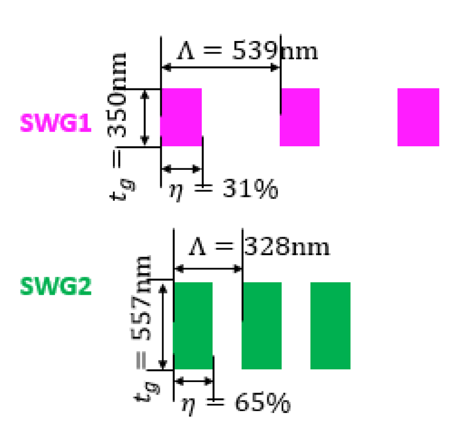
Broadband high-R & polarization selecvitiy

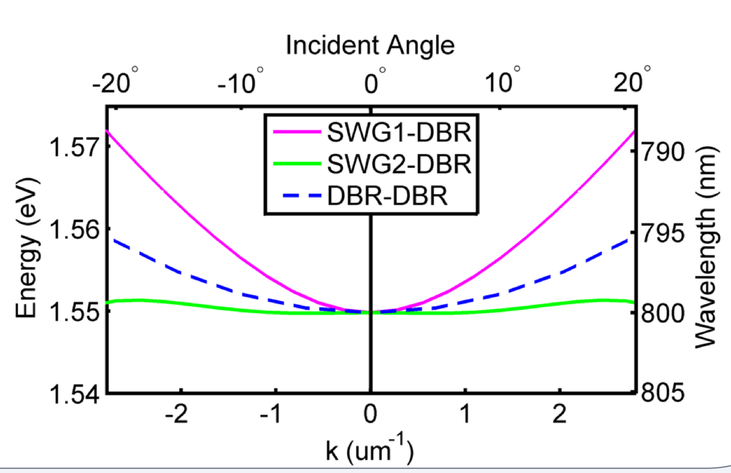




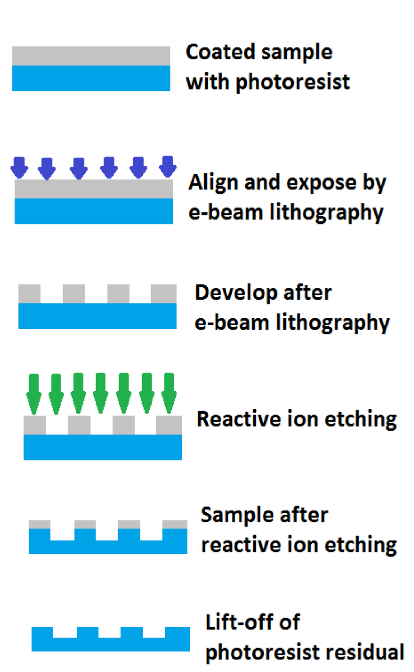
HighQ cavity resonance

Dispersion Engineering by Design [4]

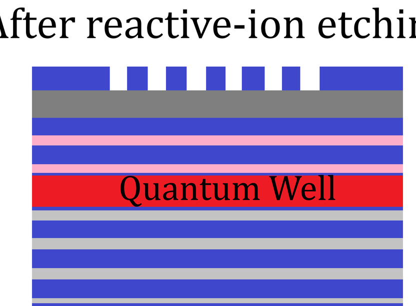




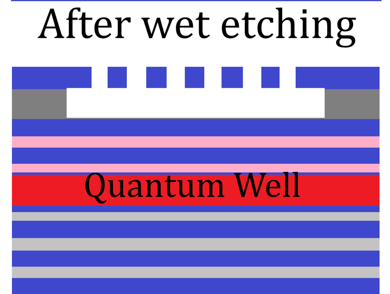
Sample Fabrication



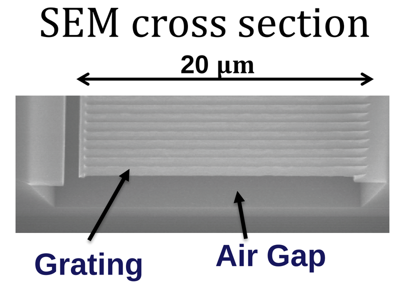
After reactive-ion etching



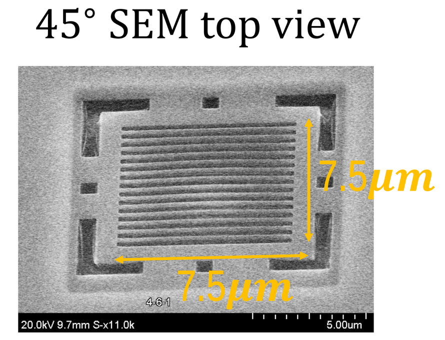
After wet etching



SEM cross section

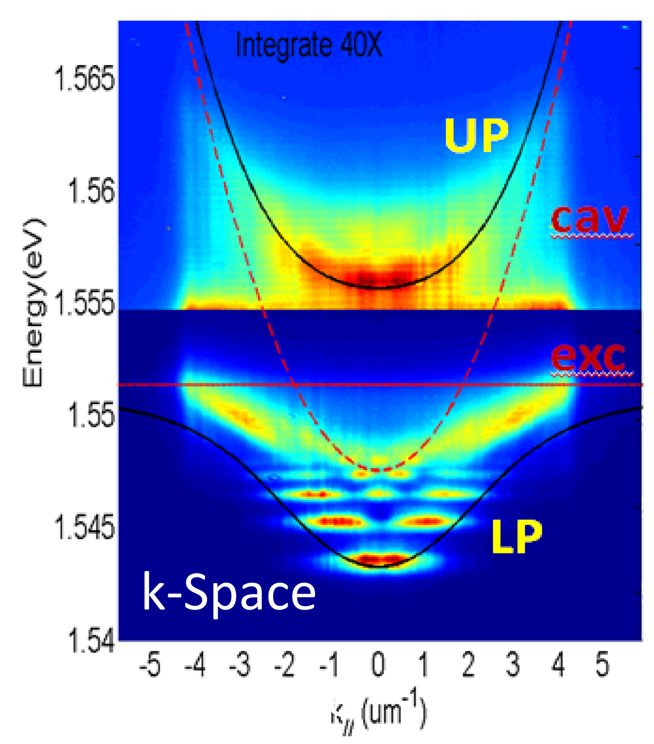


45° SEM top view



Polariton Mode Structure [2]

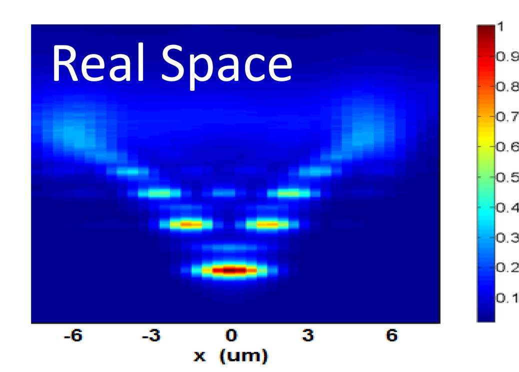
- Polariton modes measured by k-space and real-space spectroscopy.
- Strong lateral confinement and fully discrete modes by controlling the grating size.



Polariton Energies:

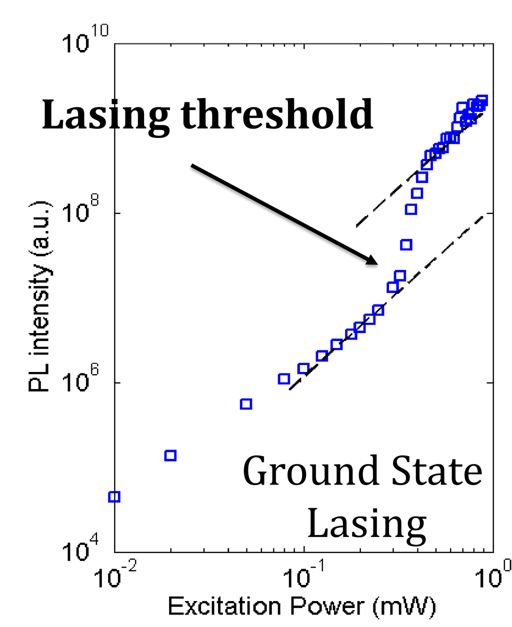
$$E_{LP,UP} = \frac{E_{cav} + E_{exc}}{2} \pm \frac{\sqrt{\Omega_0^2 + (E_{cav} - E_{exc})^2}}{2}$$

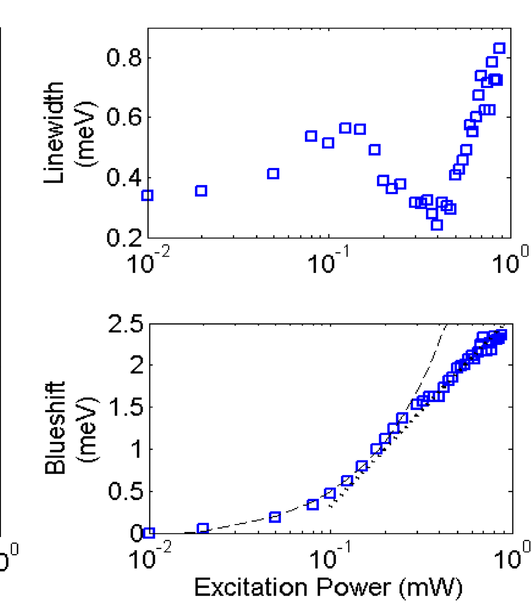
$\Omega_0 = 12\ meV$, is the Rabi splitting



UP: upper polariton **LP**: lower polariton **cav**: cavity photon **exc**: exciton

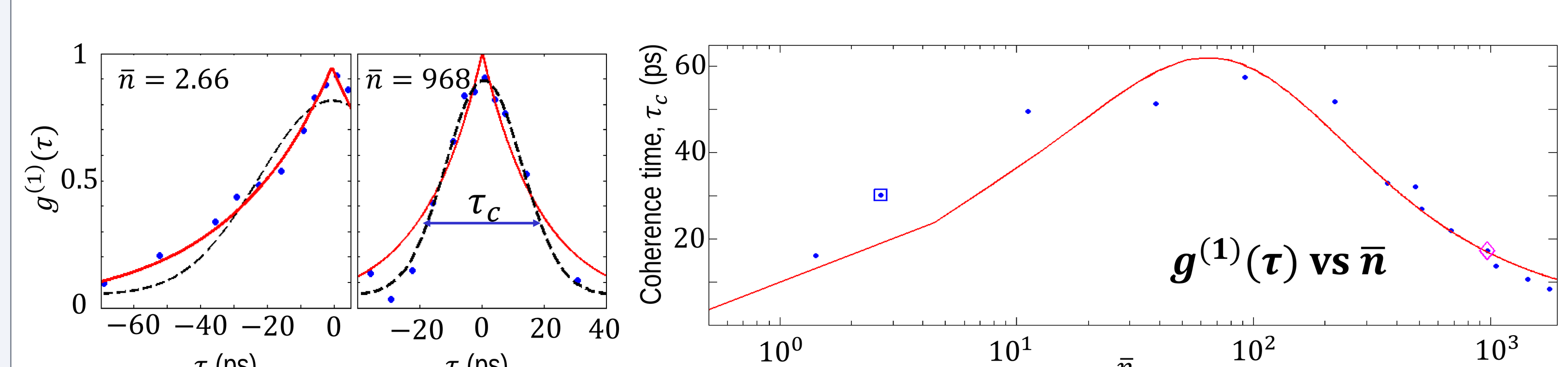
Single-mode Polariton Lasing & Coherence Properties [2,5]





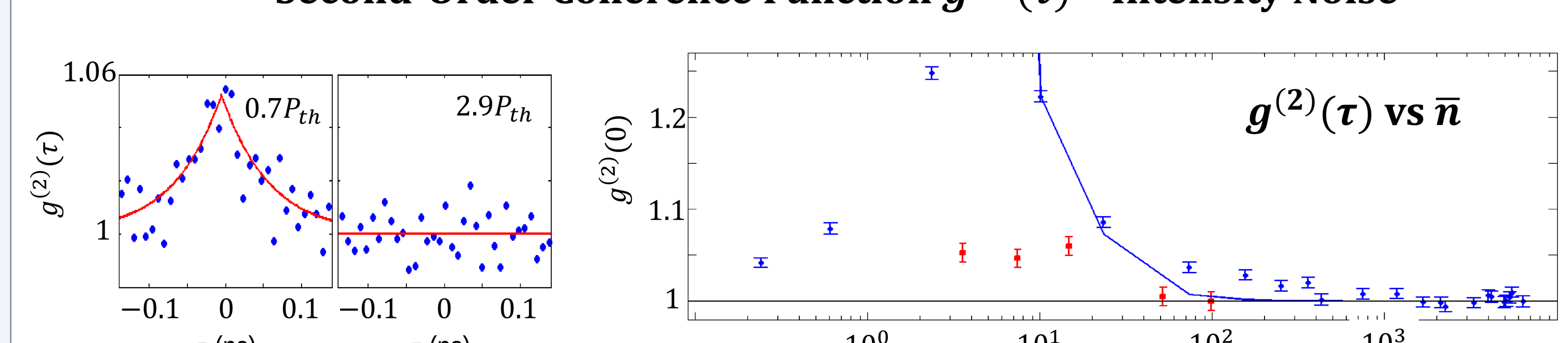
- Linewidth decrease due to coherent population
- Linewidth increase due to polariton interactions
- Large blue shift due to exciton interactions and saturation of oscillator strength

First-Order Coherence Function $g^{(1)}(\tau)$ – Phase Noise



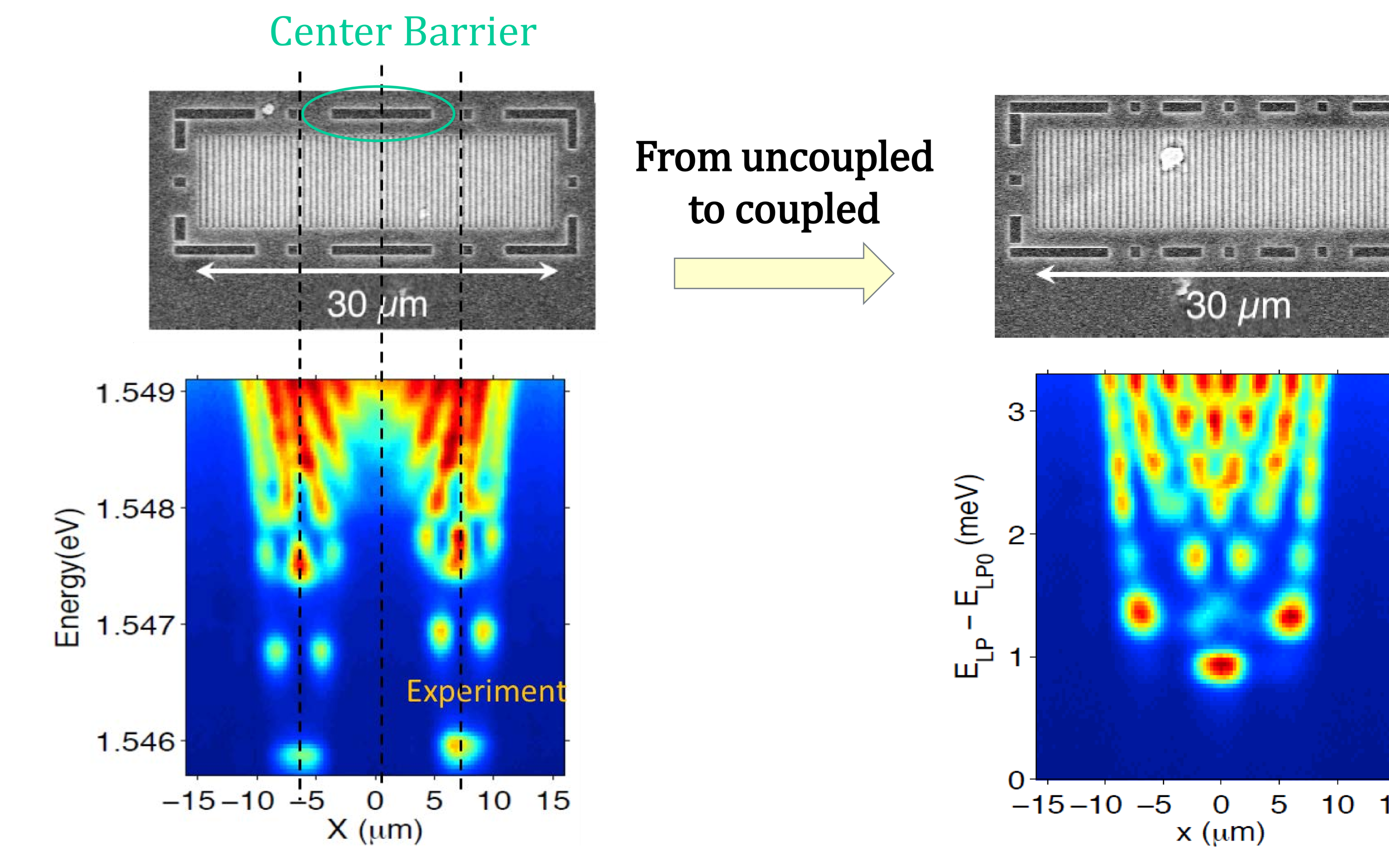
- Small $\bar{n}$: Schawlow-Townes formula -> Exponential line shape & increase in τ_c
- Large $\bar{n}$: Strong interaction -> Gaussian line shape & decrease in τ_c

Second-Order Coherence Function $g^{(2)}(\tau)$ – Intensity Noise

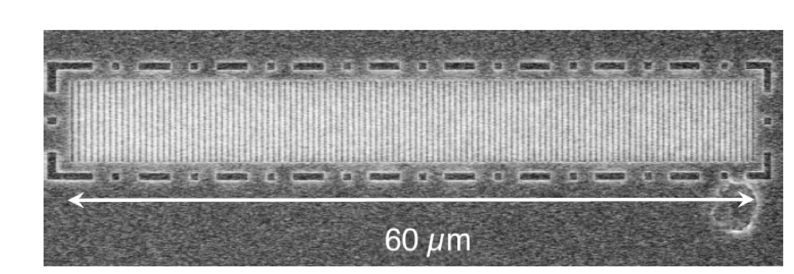


- Poisson noise limit ($g^{(2)}(0) = 1$) above the lasing threshold

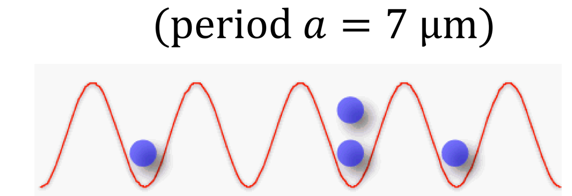
Coupled & Lattice Systems [3]



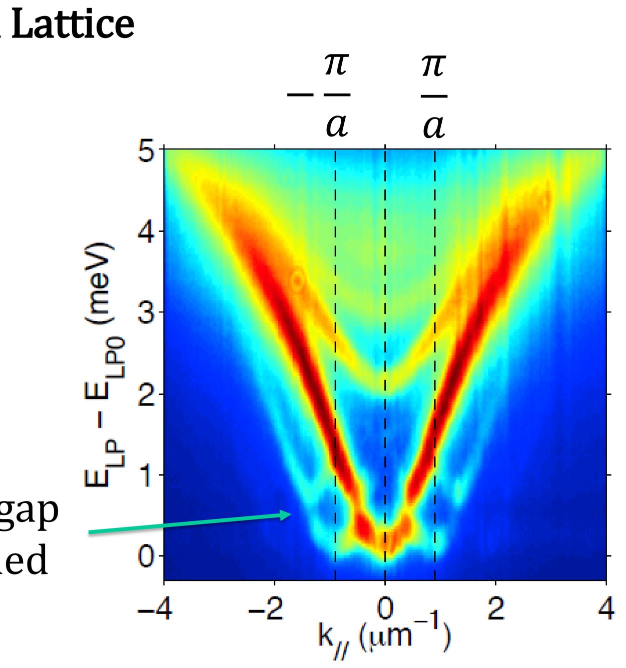
Quasi-1D Polariton Lattice



Polaritons modulated by periodic potentials (period $a = 7$ μm)



bandgap opened



Conclusion

We have demonstrated strong coupling in a designable cavity with an SWG as a cavity mirror. Using this cavity system, we illustrated unusual energy-momentum dispersions by design, we demonstrated a single-mode polariton laser with full intensity stability, we revealed intrinsic phase coherence properties of a polariton laser stemming from its matter-wave origin, and we created coupled and lattice polariton systems.

Acknowledgement

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References

[1] H. Deng, H. Haug, and Y. Yamamoto, Rev. Mod. Phys. **82**, 1489 (2010)
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[4] Z. Wang, B. Zhang, H. Deng, Phys. Rev. Lett., **114**, 073601 (2015)
[5] S. Kim, B. Zhang, Z. Wang, J. Fischer, S. Brodbeck, M. Kamp, C. Schneider, S. Höfling,, and H. Deng, "A coherent Single-mode Polariton Laser", in preparation