Demonstration of the polaritonic Bardeen-Cooper-Schrieffer state
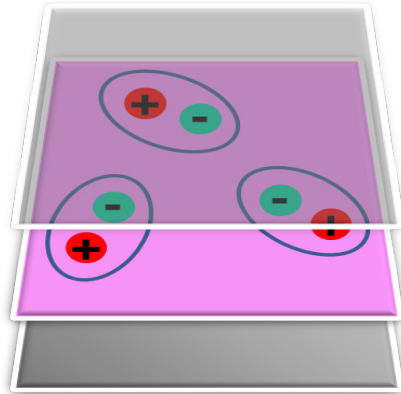
N.H. Kwong, R. Binder

University of Arizona
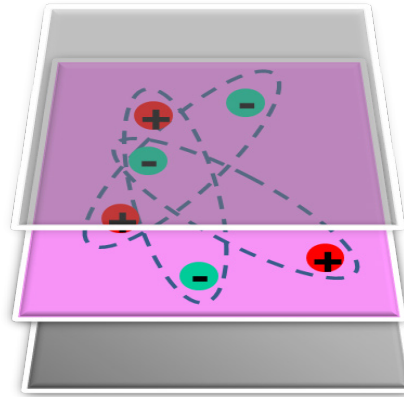
In collaboration with Hui Deng, University of Michigan

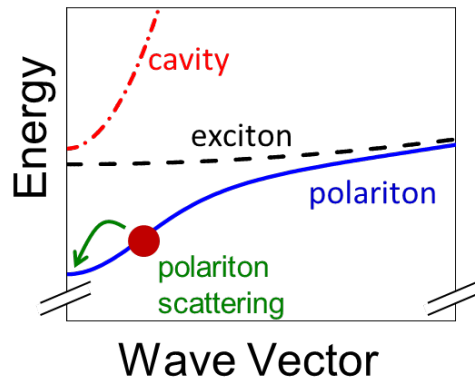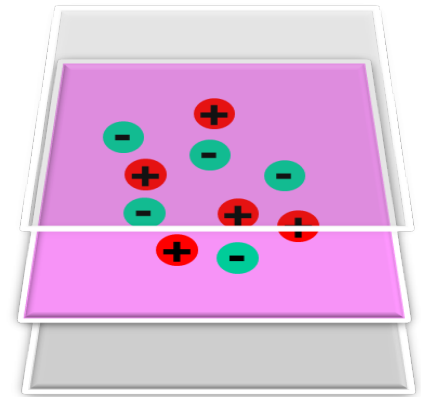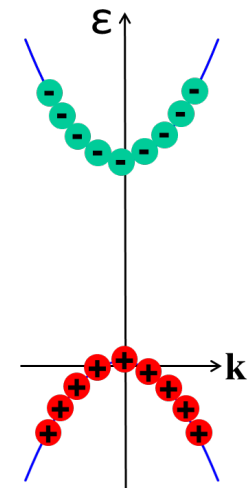# Polariton BEC*

Polariton BCS**

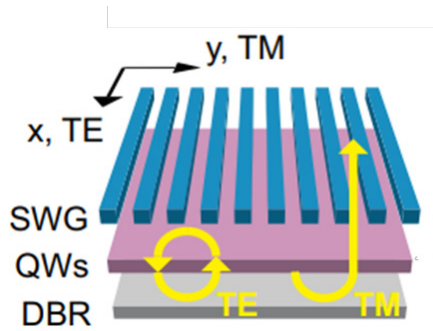# Photon Laser

well established
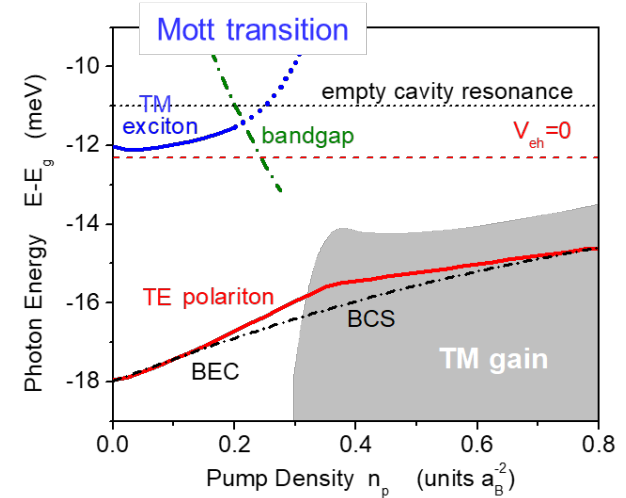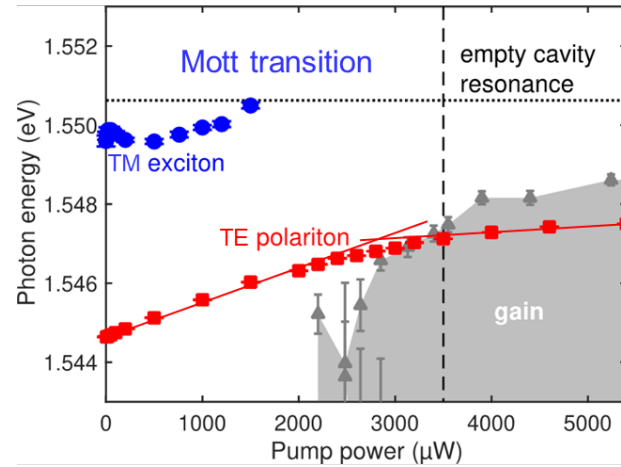(theory and experiment)

mostly theory well established

well established
(theory and experiment)

*BEC = Bose-Einstein condensate, **BCS = Bardeen, Cooper, Schrieffer

Comparison experiment vs. theory*

- lasing in TE
- no lasing in TM
- same carrier distributions

TM: - the 'usual', first Mott transitions, then optical gain

TE: - lasing threshold above Mott transitions inferred from TM, **rules out BEC**
         - no jump of emission frequency to cavity, **rules out photon laser**

*Hu, Wang, Kim, Hui Deng, Brodbeck, Schneider, Hofling, Kwong, Binder, Phys. Rev. X 11, 011018 (2021)

	Polariton BEC	**Polariton BCS**	**Photon Laser**
Transition	←→ smooth crossover	←→ smooth crossover	
Carrier density	$n \ll n_{Mott}$	$n \geq n_{Mott}$	$n > n_{Mott}$
e-h distribution	far below Fermi degeneracy, no inversion	below Fermi degeneracy, small inversion	Fermi degenerate, strong inversion
Gain type	bosonic	fermionic	fermionic
Quasi-particles	exciton-polariton with bound e-h pair	e-h-polariton with bound e-h pair	e-h plasma (unbound pairs)
Emission frequency	below cavity	below cavity	close to cavity resonance
Excitation spectrum	gap , by exciton binding & photon coupling	BCS-like gap by e-h pairing & photon coupling	gap possible (light-induced spectral hole)

Microscopic analysis: carrier distribution functions
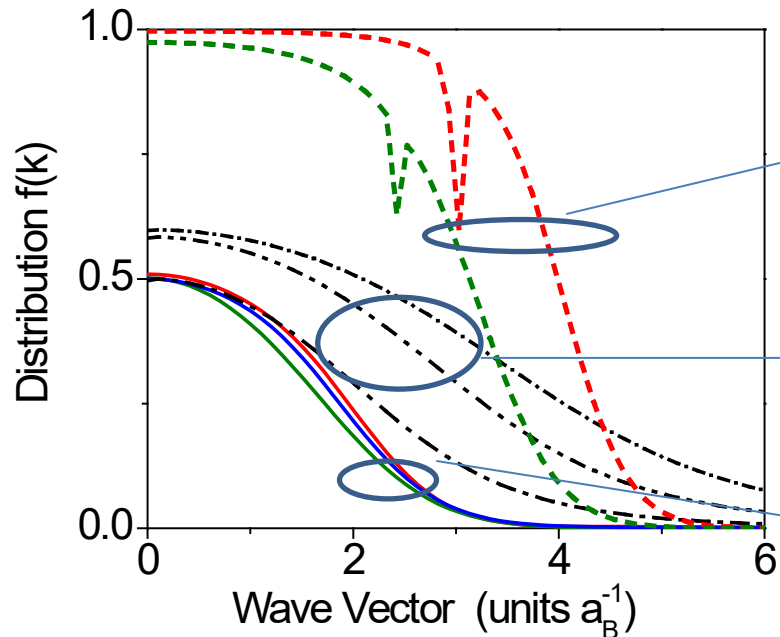
Photon laser model:
- Fermi degenerate distribution functions
- can exhibit spectral hole

Ideal polariton BCS:
- no Fermi degeneracy in distribution functions
- distribution functions not much larger than 0.5
- cannot exhibit spectral hole

Full calculation modeling experiment

Conclusion: distribution functions are open-dissipative
                system analog to ideal polariton BCS system