

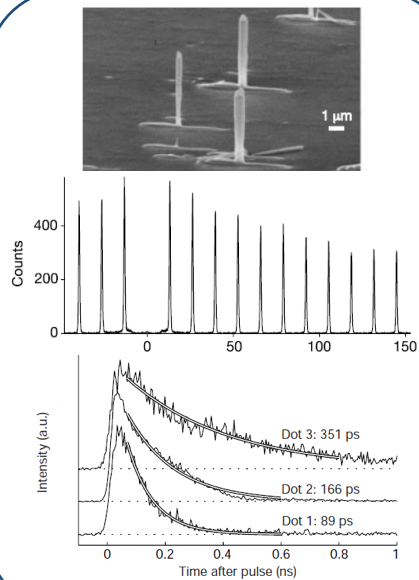
Rb-nano photonic hybrid systems

Hadiseh Alaeian, Michael Knudson, Teri Odom, & Brian Odom

MRSEC meeting, April 2017

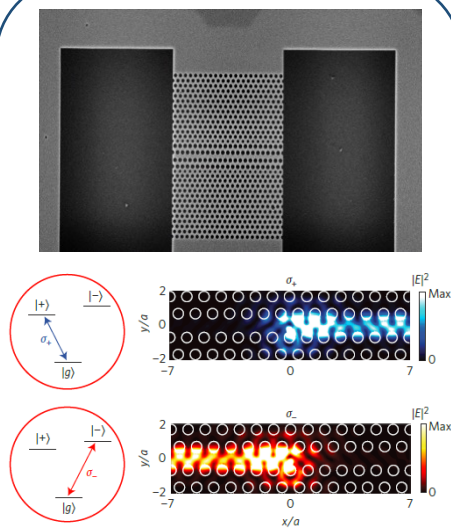
Development of Quantum Optics in Solid-State Systems

Single photon source



C. Santori, et. al., *Nature* **419**, 594 (2002)

Chiral quantum optics



Söllner, et. al., *Nat. Nano* **10**, 775 (2015)
H. Alaeian, et. al., *to be submitted*

Pros:

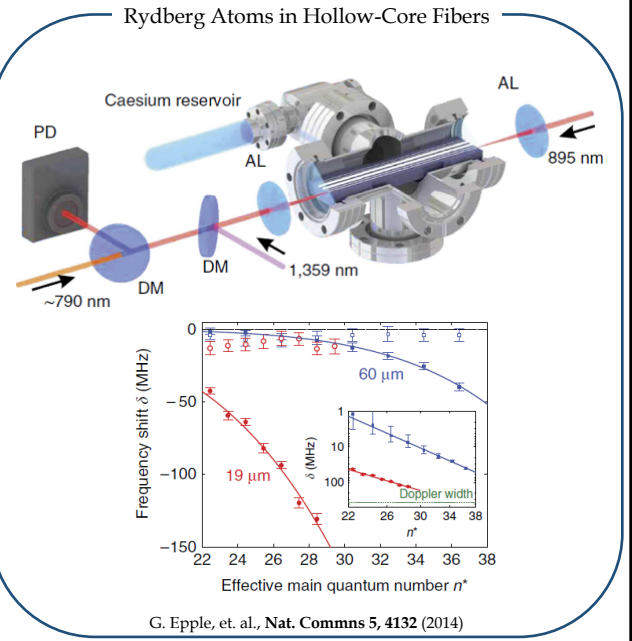
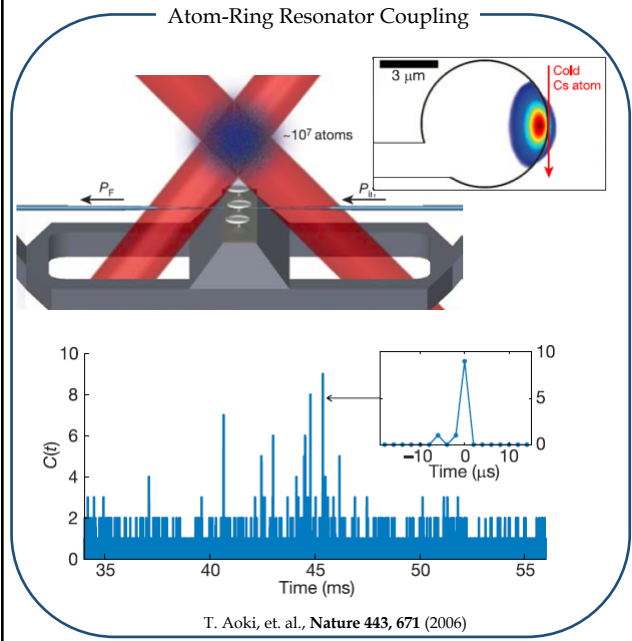
- Monolithic modules
- Suitable for integration
- Compatible with existing fabrication procedures

Cons:

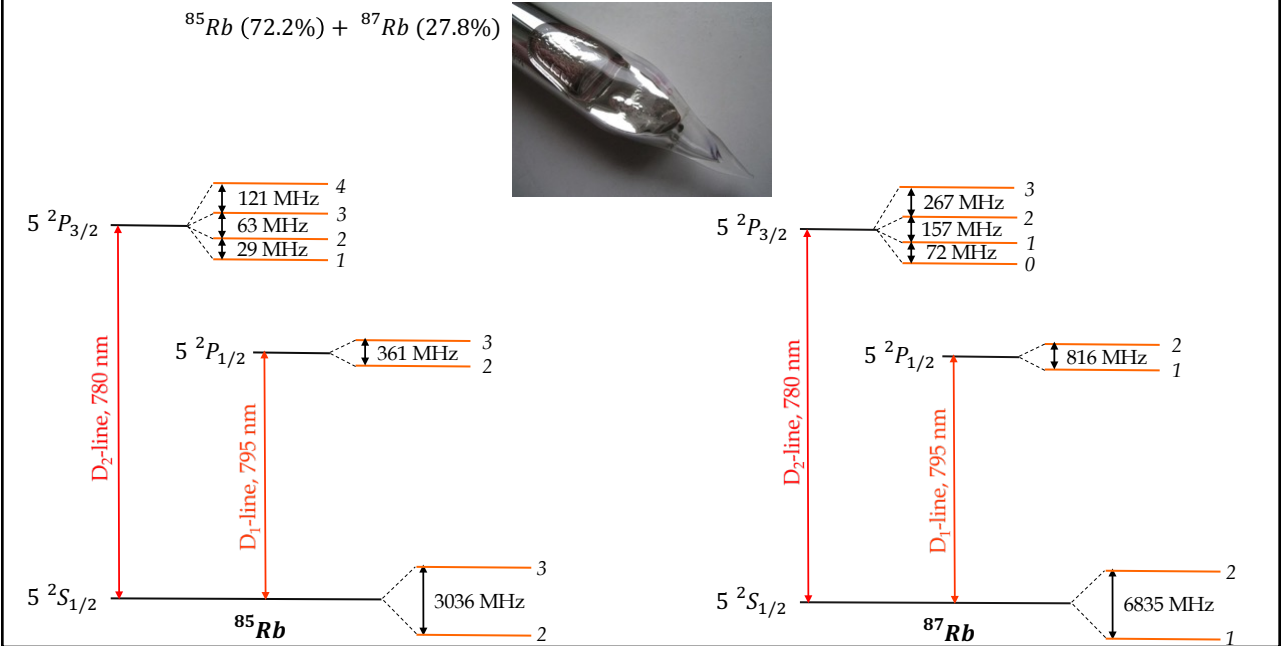
- Crystal field broadening (~THz)
- Heterogeneous quantum emitters
- Short coherence time and coherence length
- Not suitable for entanglement & collective behavior studies

Reviews by M. Lukin & P. Zoller

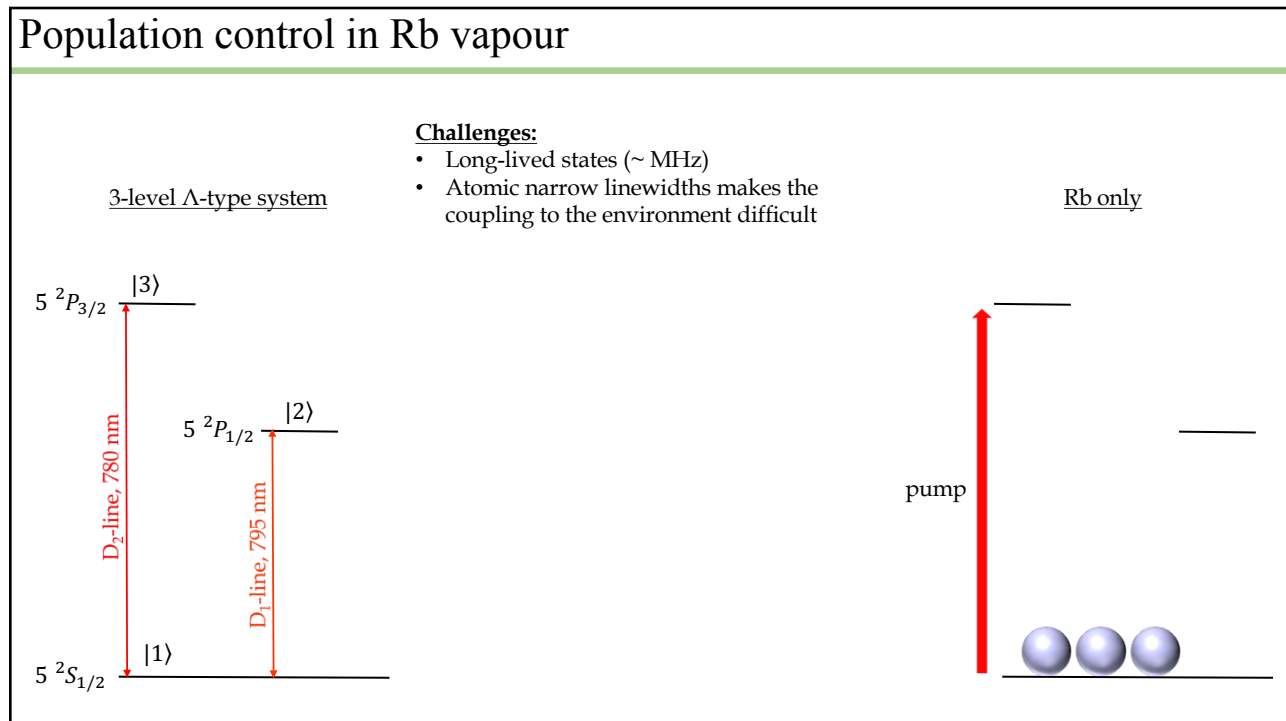
Atom-Photonics Hybrid Systems



Our Approach: Thermal gas + photonic systems



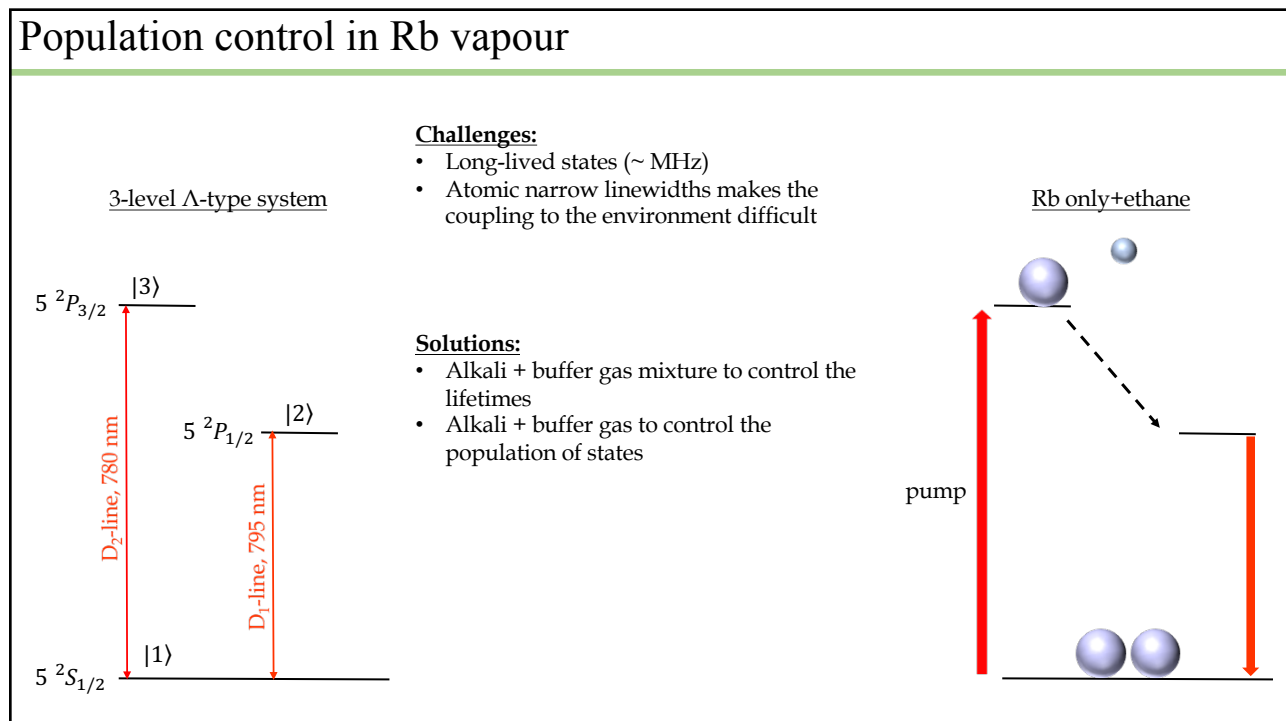
Population control in Rb vapour



Challenges:

- Long-lived states (\sim MHz)
- Atomic narrow linewidths makes the coupling to the environment difficult

Population control in Rb vapour



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Solutions:

- Alkali + buffer gas mixture to control the lifetimes
- Alkali + buffer gas to control the population of states

Experimental Setup

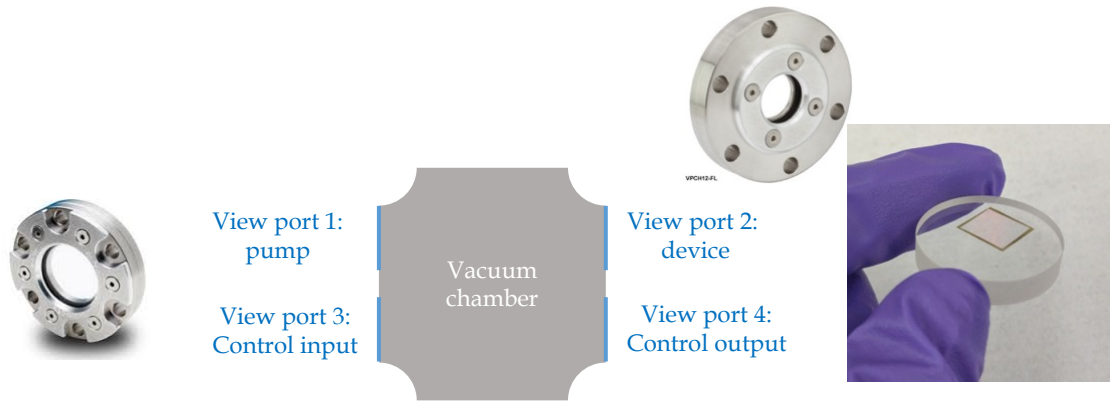
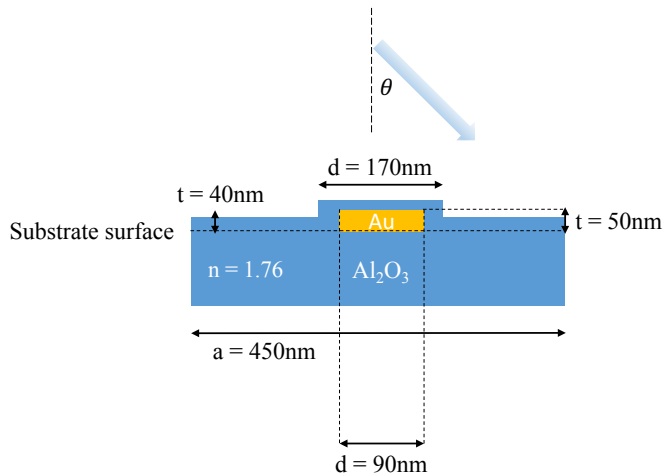
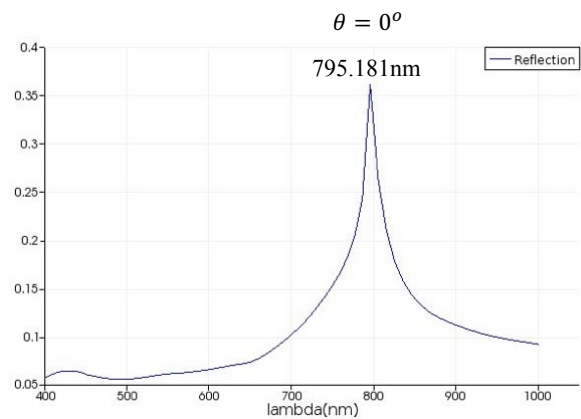


Image courtesy of Michael Knudson

Photonic device: Plasmonic Lattice



- A 2D periodic lattice with periodicity of 450nm
- Metallic NP of 90nm in diameter and 50nm in height
- A coating of 40nm in all directions



Photonic device: Plasmonic Lattice

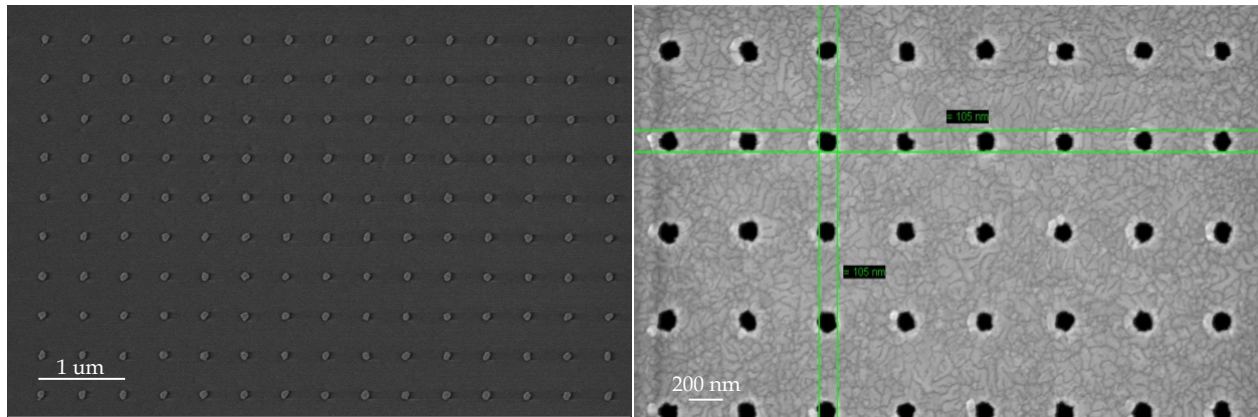


Image courtesy of Michael Knudson

Photonic device: Plasmonic Lattice

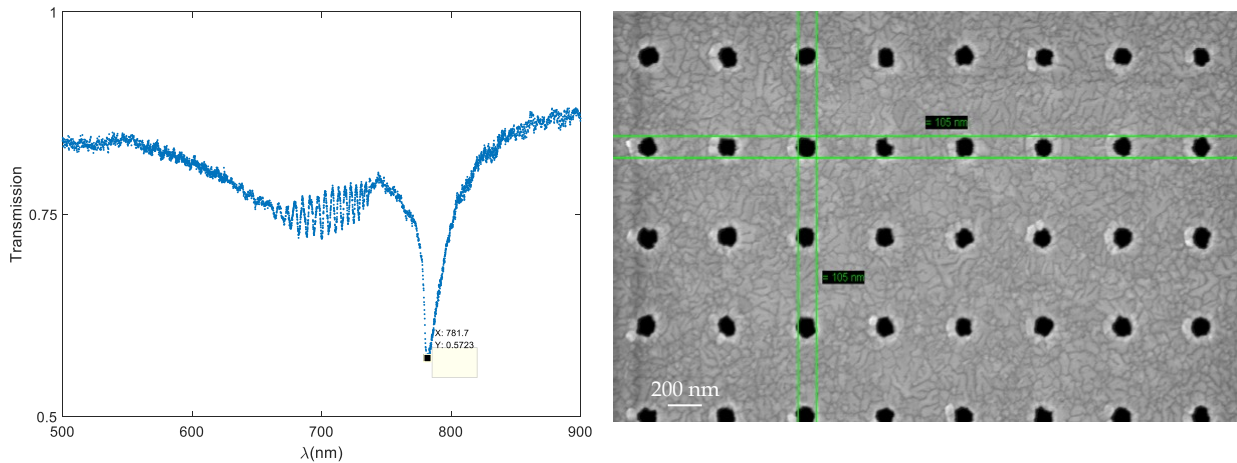
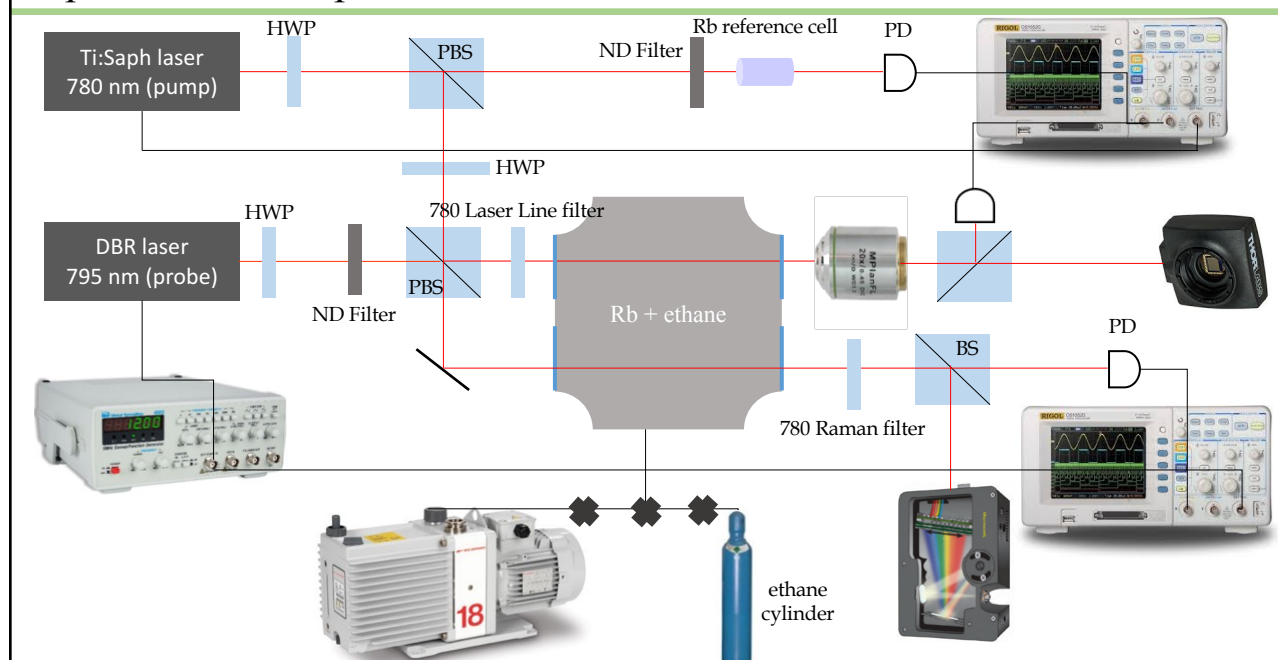
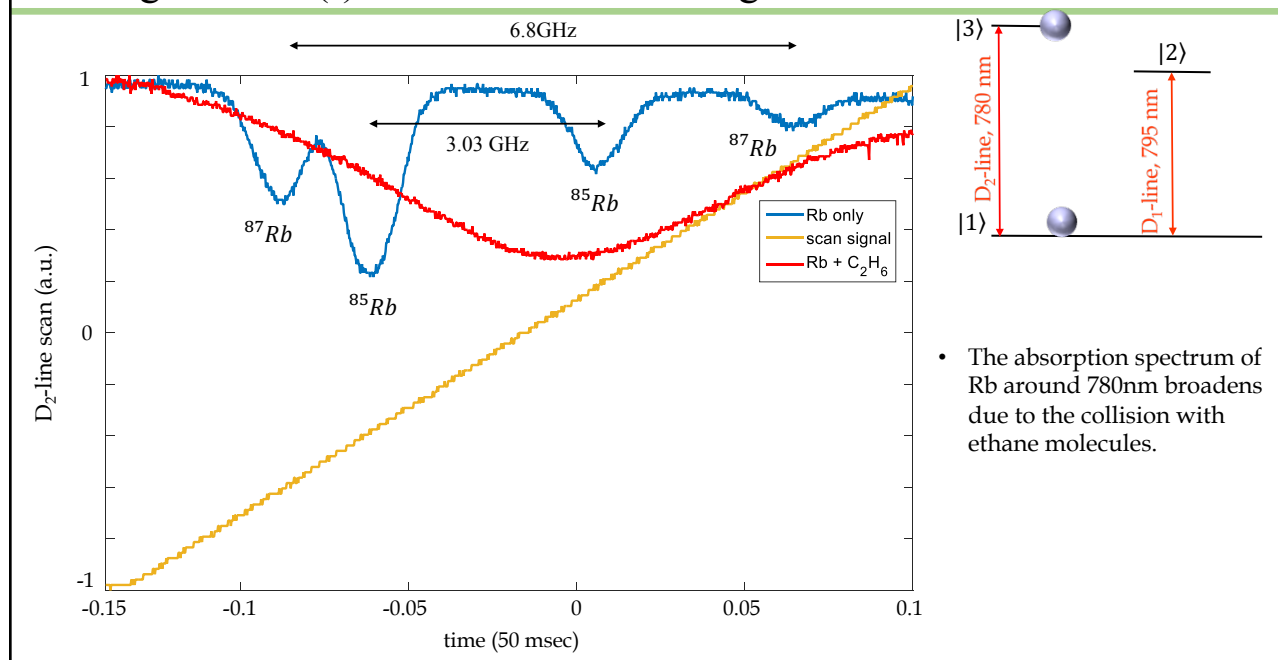


Image courtesy of Michael Knudson

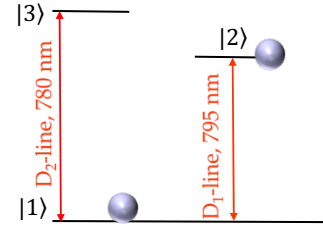
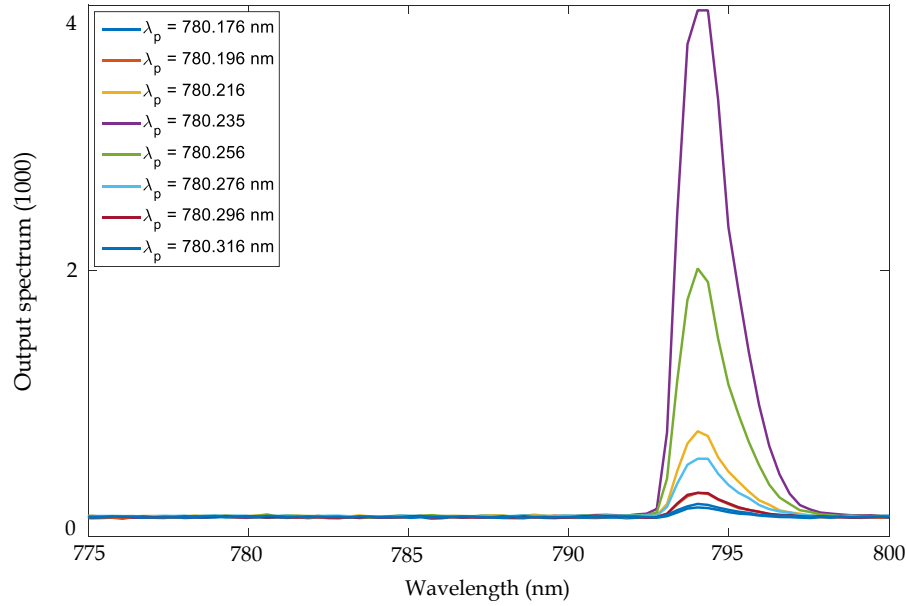
Experimental Setup



Buffer gas effect (I): collisional broadening

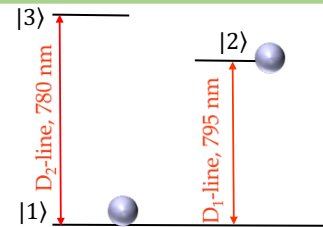
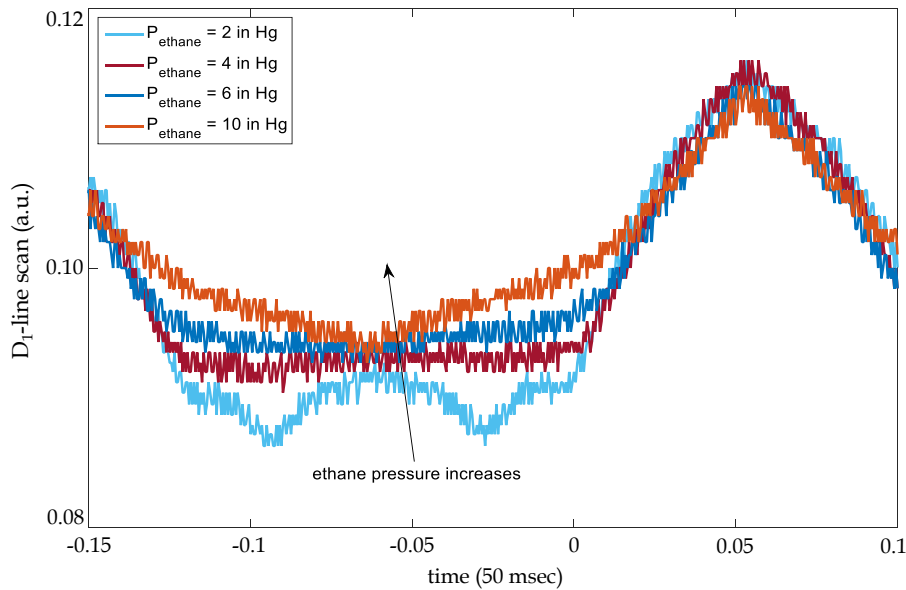


Buffer gas effect (II): Population Transfer



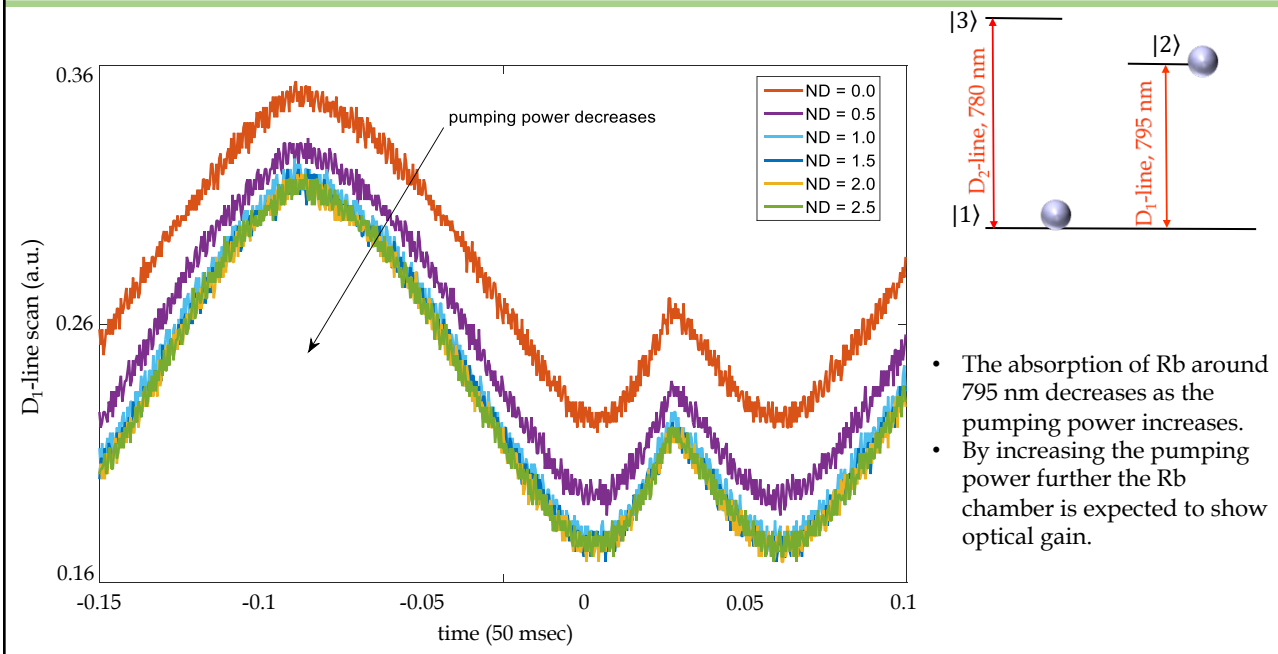
- Due to the collision some population is transferred from upper-P to lower-P state.
- The number of transferred Rb atoms is proportional to the pump wavelength around 780 nm.

Controlling the population difference ($\rho_{22} - \rho_{11}$): Buffer gas effect

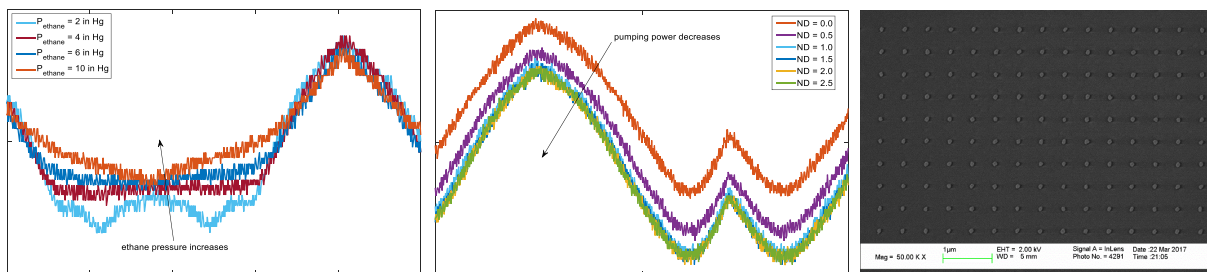


- The number of transferred Rb atoms can be controlled via the pressure of buffer gas as well.
- The absorption of Rb around 795 nm decreases due to the population transfer.

Controlling the population difference ($\rho_{22} - \rho_{11}$): Pumping power effect



Conclusion & Future works

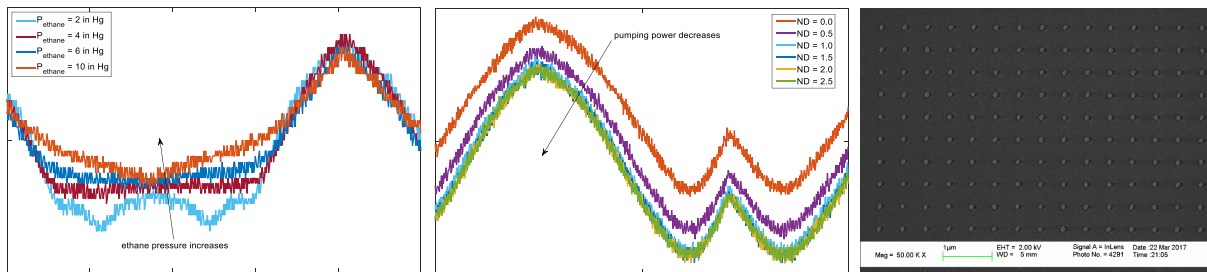


- The hybrid systems of atoms + nano-photonics would lead to integrable setups for cQED studies.
- Buffer gas can effectively broaden atomic linewidths for efficient interaction with engineered photon fields.
- Buffer gas & pumping power can control density of the levels from equilibrium all the way toward non-equilibrium.

Future works:

- Investigating the effect of photonic modes on manipulating atomic transitions.
- Fine tuning the gain of Rb and resonant mode coherence features toward a lasing action
- Using a properly designed photonic mode to make the forbidden atomic transitions possible → new tools for spectroscopy

Thank you for your attention!



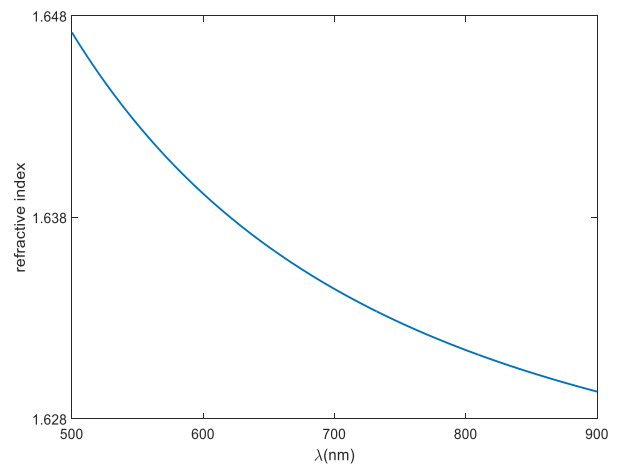
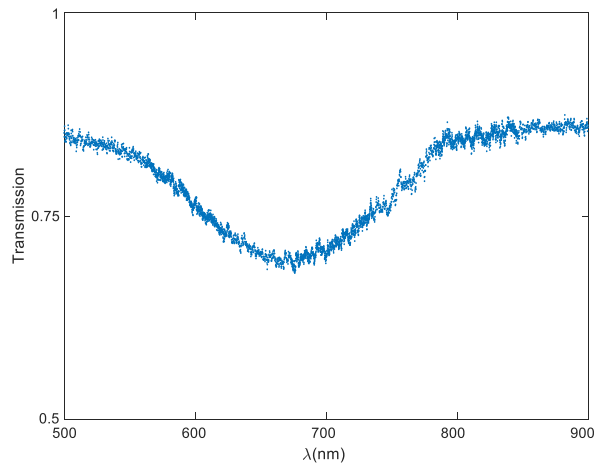
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Special thanks to:

- Prof. Teri Odom
- Prof. Brian Odom
- Michael Knudson
- Dr. Vincent Carrat
- Joshua Yablon

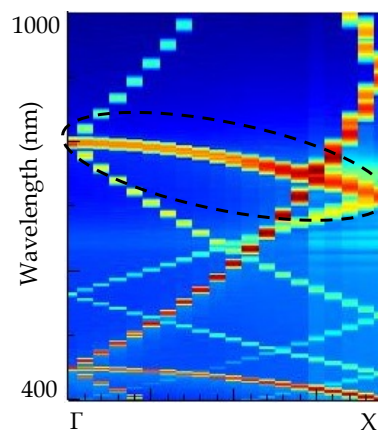
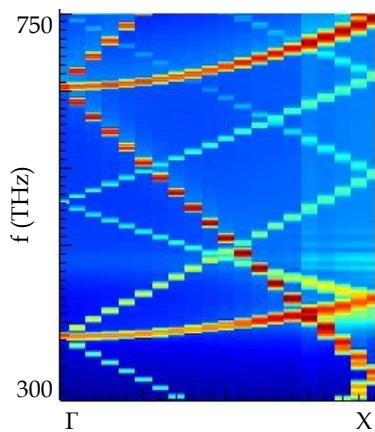
Supplementary slides

Device characterization & optical properties of alumina



- The refractive index of ALD Alumina is less than the bulk nominal value of 1.76

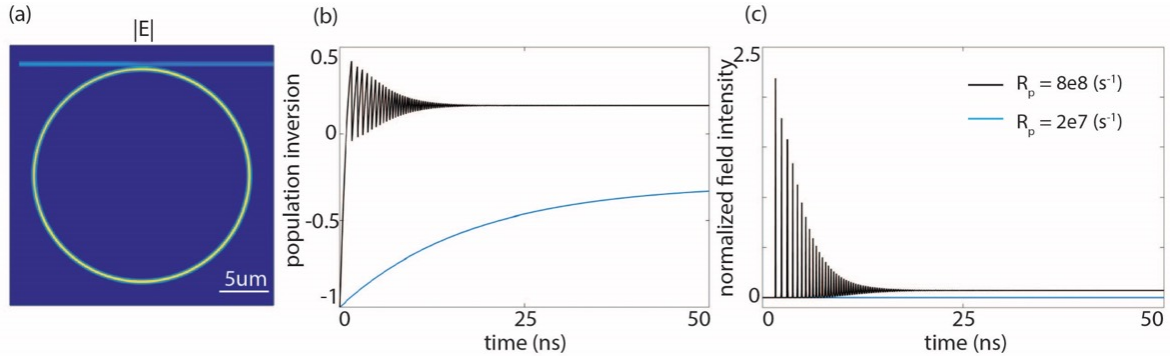
Device dispersion



H. Alaeian, et. al, to be submitted

Density matrix formulation

$$i\hbar\dot{\hat{\rho}} = [(\hat{H}_{atom} + \hat{H}_{int}), \hat{\rho}] + \text{Lindblad formulation of decoherence}$$



H. Alaeian, et. al, to be submitted