

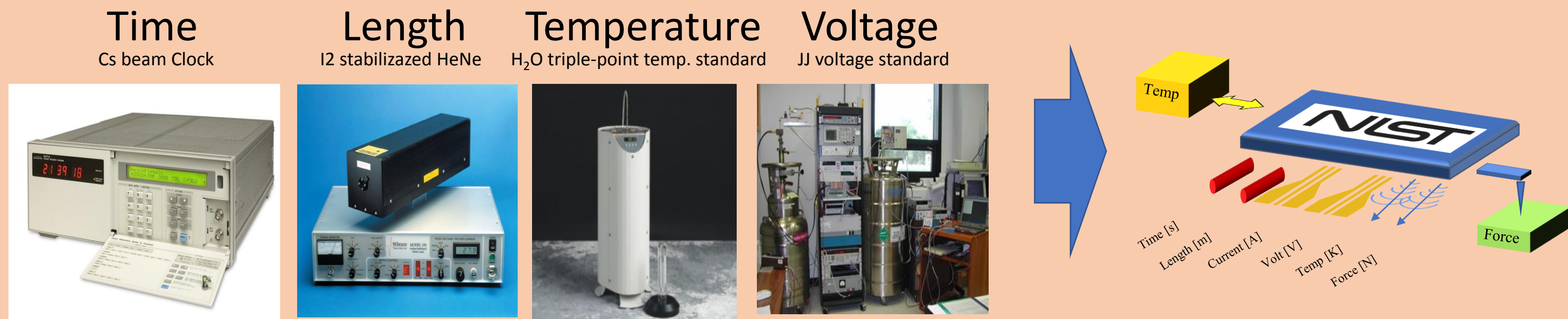
NIST on a Chip with Alkali Vapor Cells

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Concept

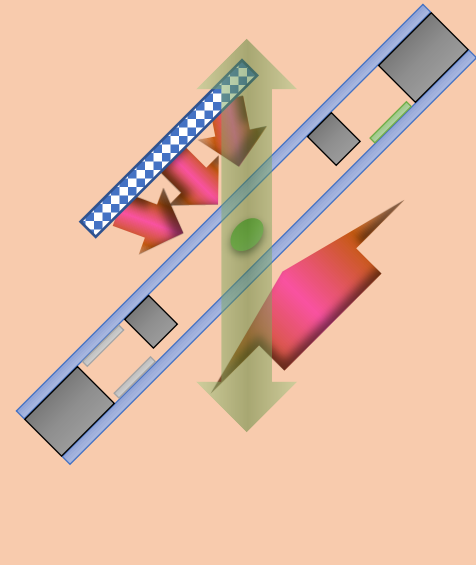
- Realize fundamental metrological units ([s], [m], [A], [K], etc.) in chip-scale instrument
- Goals: deployable, useable, flexible, manufacturable
- Ultimately: deploy in instruments to enable **in-situ** lifetime SI-traceable calibration



Realization of SI Units

Frequency

- Cold neutral atoms on a chip
 - Passively pumped MEMS cell
 - Grating MOT (Stimulated femission cooling)
 - $\Delta f \sim 10^{-10}$

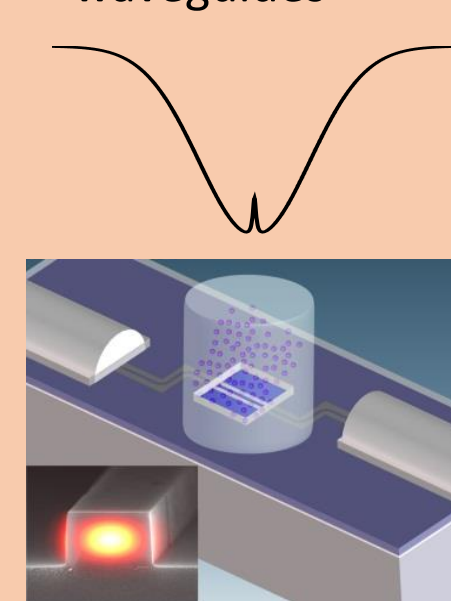


- Chip-scale Cs beam clocks?

Length

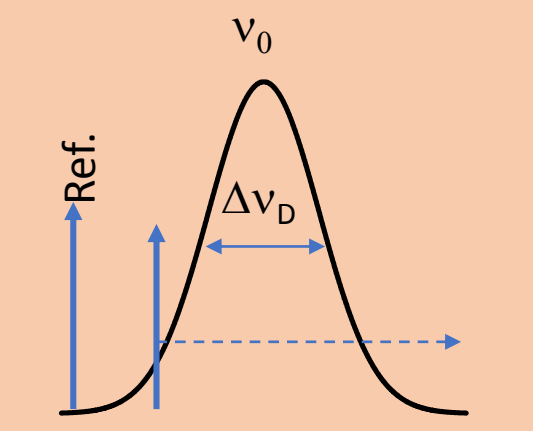
- Integration of vapor cells and single-mode photonics

- Sat. spec., 2-hv ?
- $\Delta f \sim 10^{-9}$
- Atomic cladding waveguides



Temperature

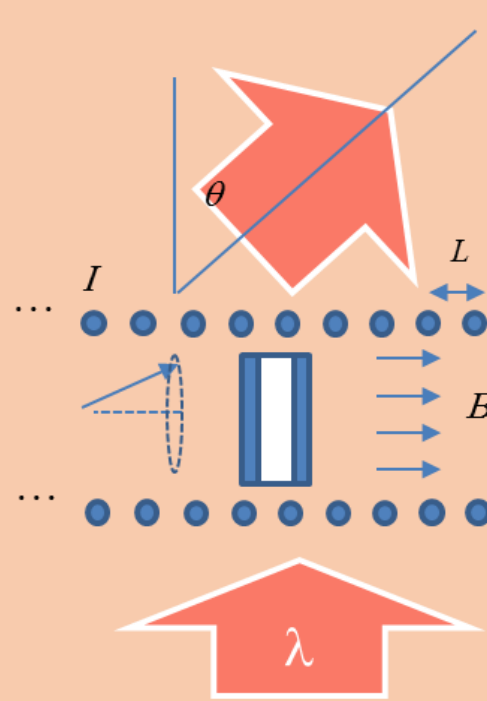
- Doppler thermometry
 - Measure Doppler-broadened lines spectroscopically
 - $k_B T = \frac{mc^2}{2} \left(\frac{\Delta \nu_D}{\nu_0} \right)^2$
 - Current expt's achieving $\sim 10^{-5}$ accuracy $\rightarrow 10^{-6}$



See: Borde (2005), Daussy (2007), Truong (2011)

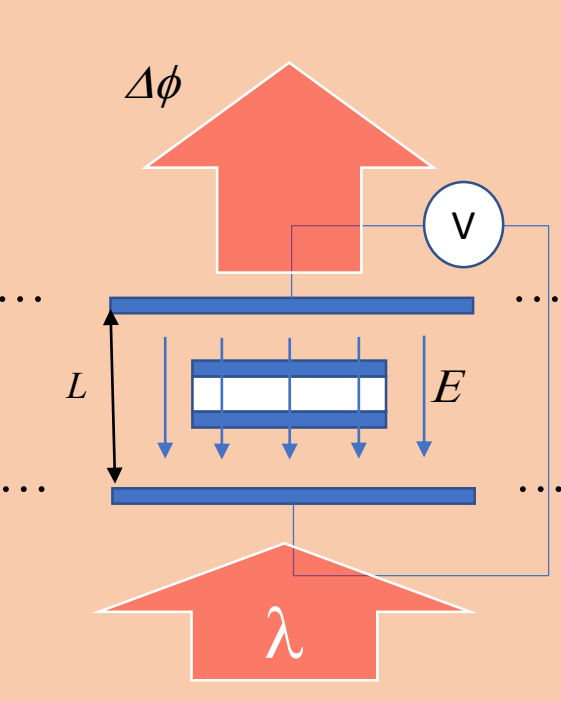
Current

- Larmor prec.
 - Many g-factors known to $\sim 10^{-8}$
 - $\frac{f_L}{\gamma} = B = \frac{\mu_0 I}{2L}$



Voltage

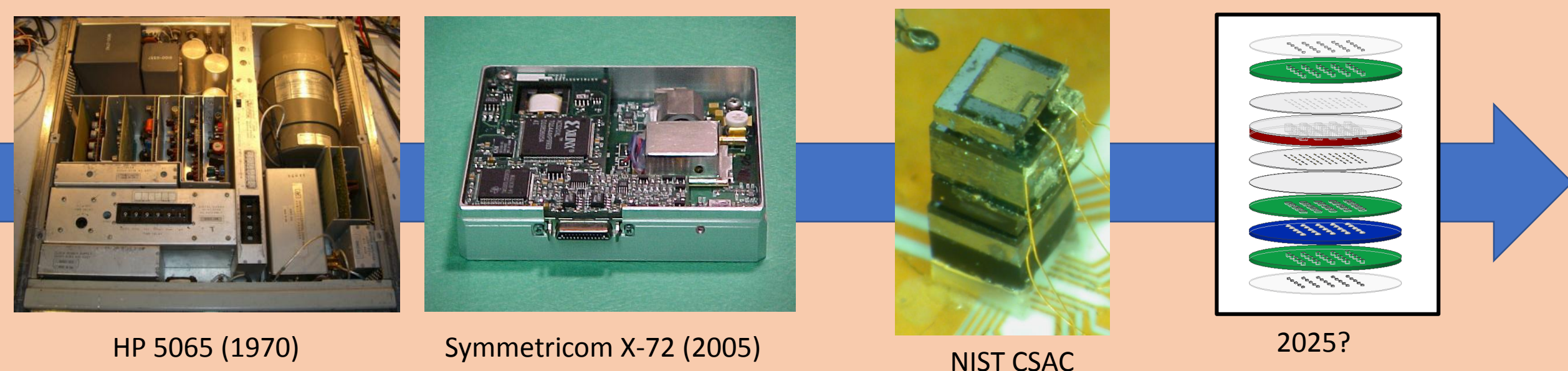
- DC Stark shifts
 - Rydberg atoms for large polarizability
 - $h\Delta f_S = -\frac{\alpha_0}{2} \left(\frac{V}{L} \right)^2$
 - For Yb, $\delta(\alpha_0) \sim 10^{-5}$



4+1 of 7 base SI units could be realized at chip-scale with microfabricated alkali vapor cells

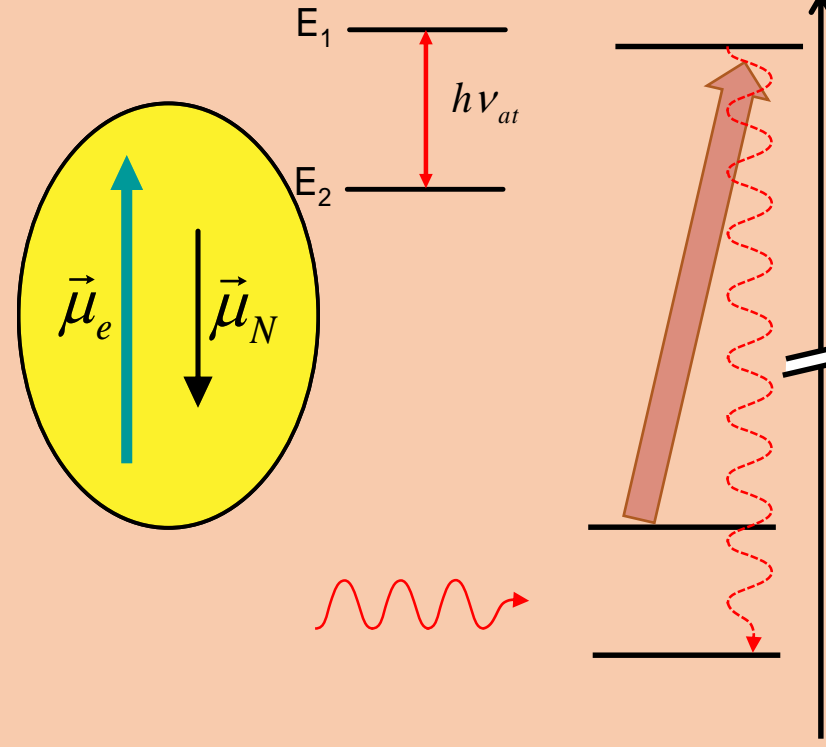
Manufacturing and Parallel Fabrication

- To what extent can precision SI-traceable calibration tools be fabricated using low-cost processes similar to integrated circuits?
- Potential impact: an SI-traceable reference in every instrument

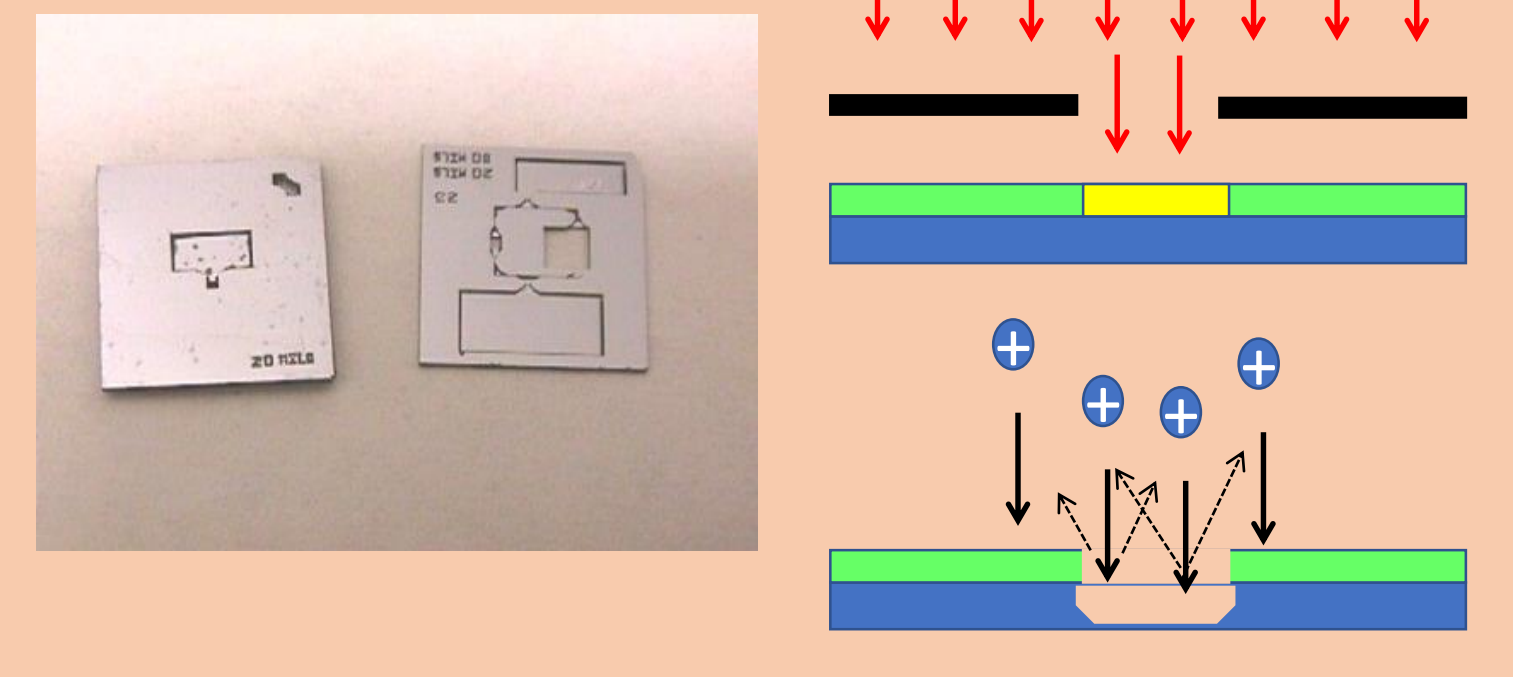


Core Technologies

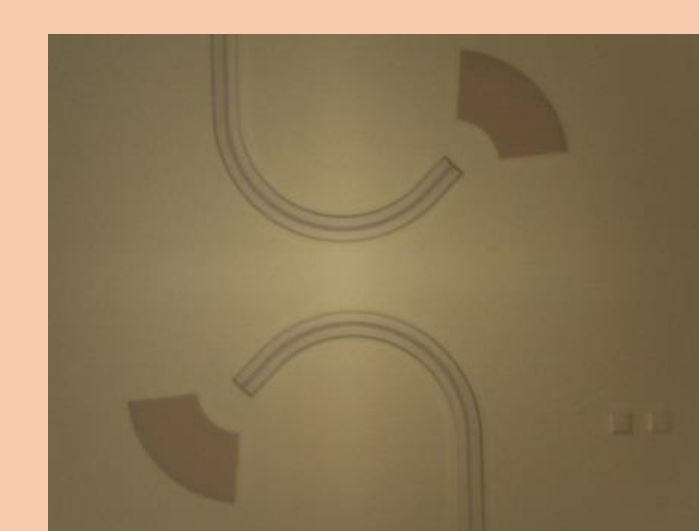
Atomic spectroscopy



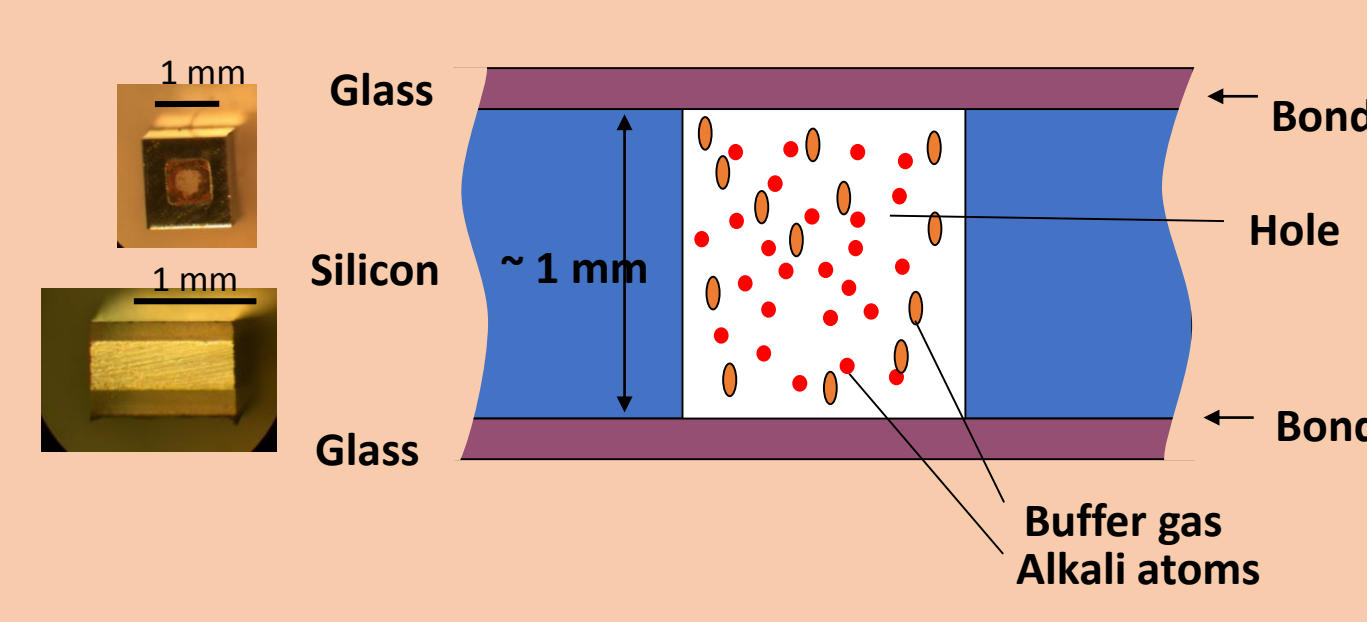
Silicon micromachining



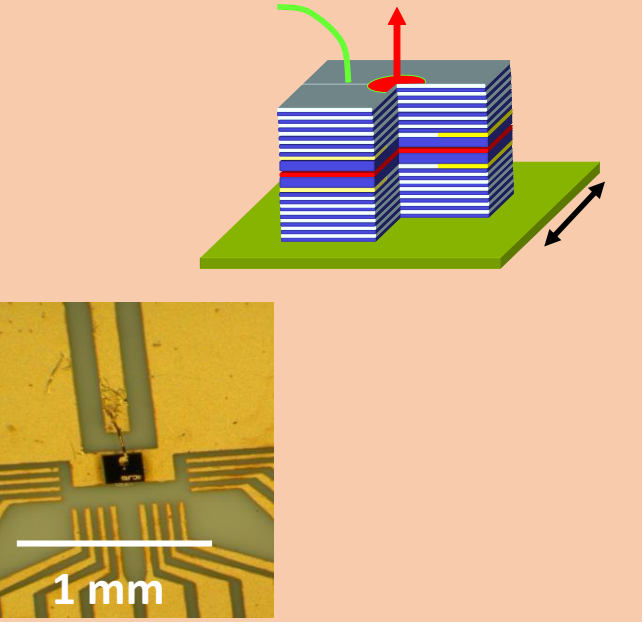
SiN Photonics



Alkali cell fabrication

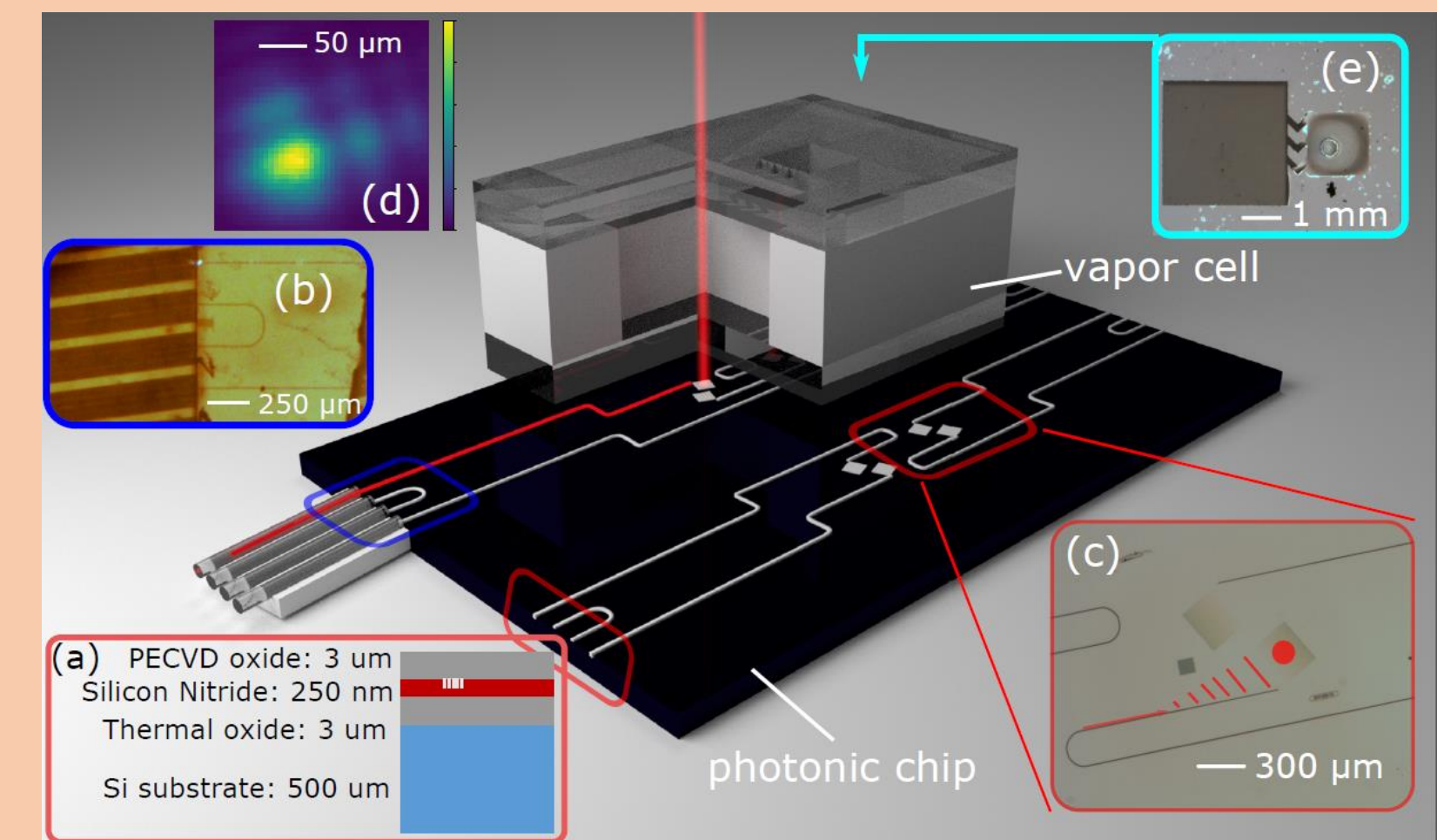
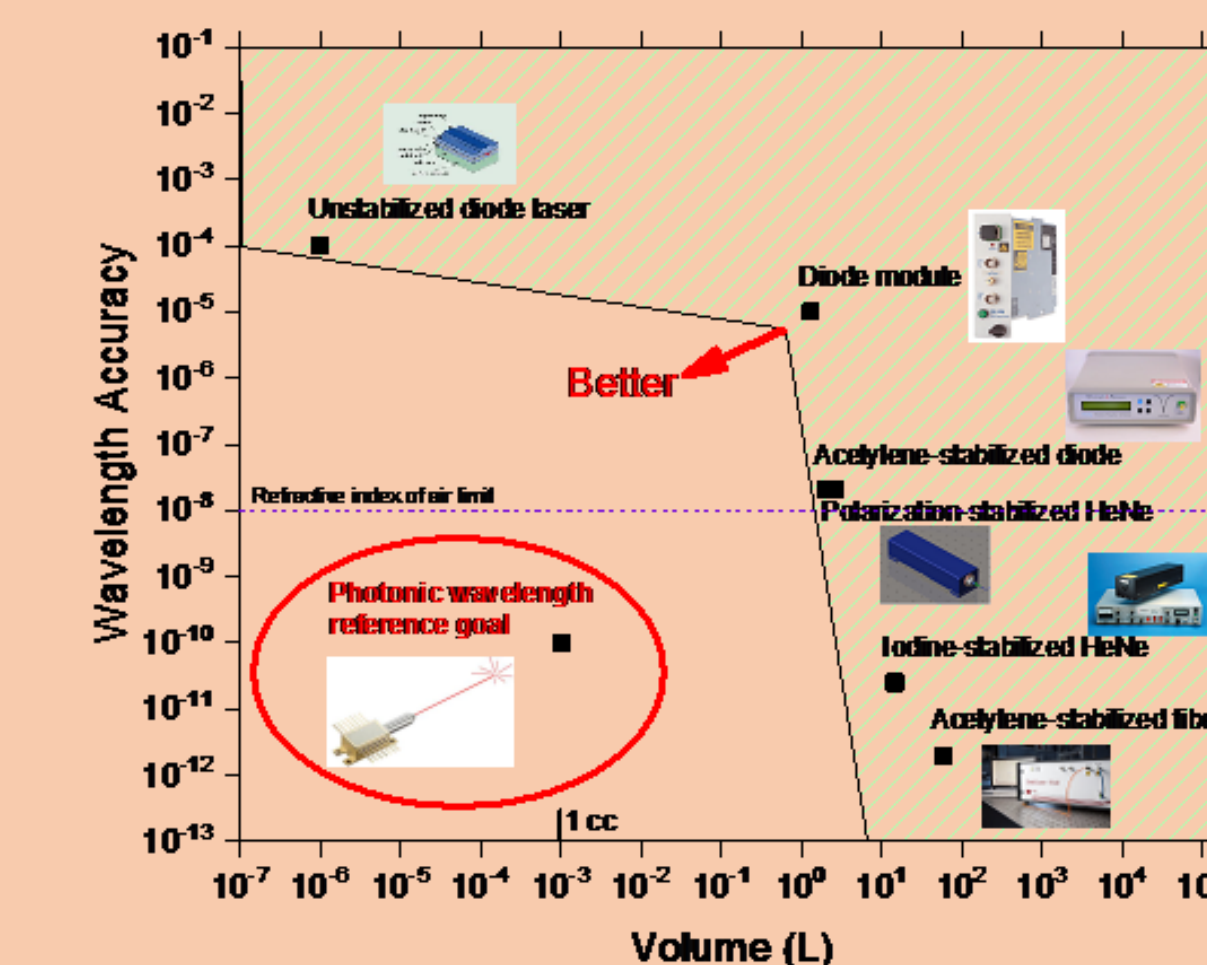


Advanced diode lasers

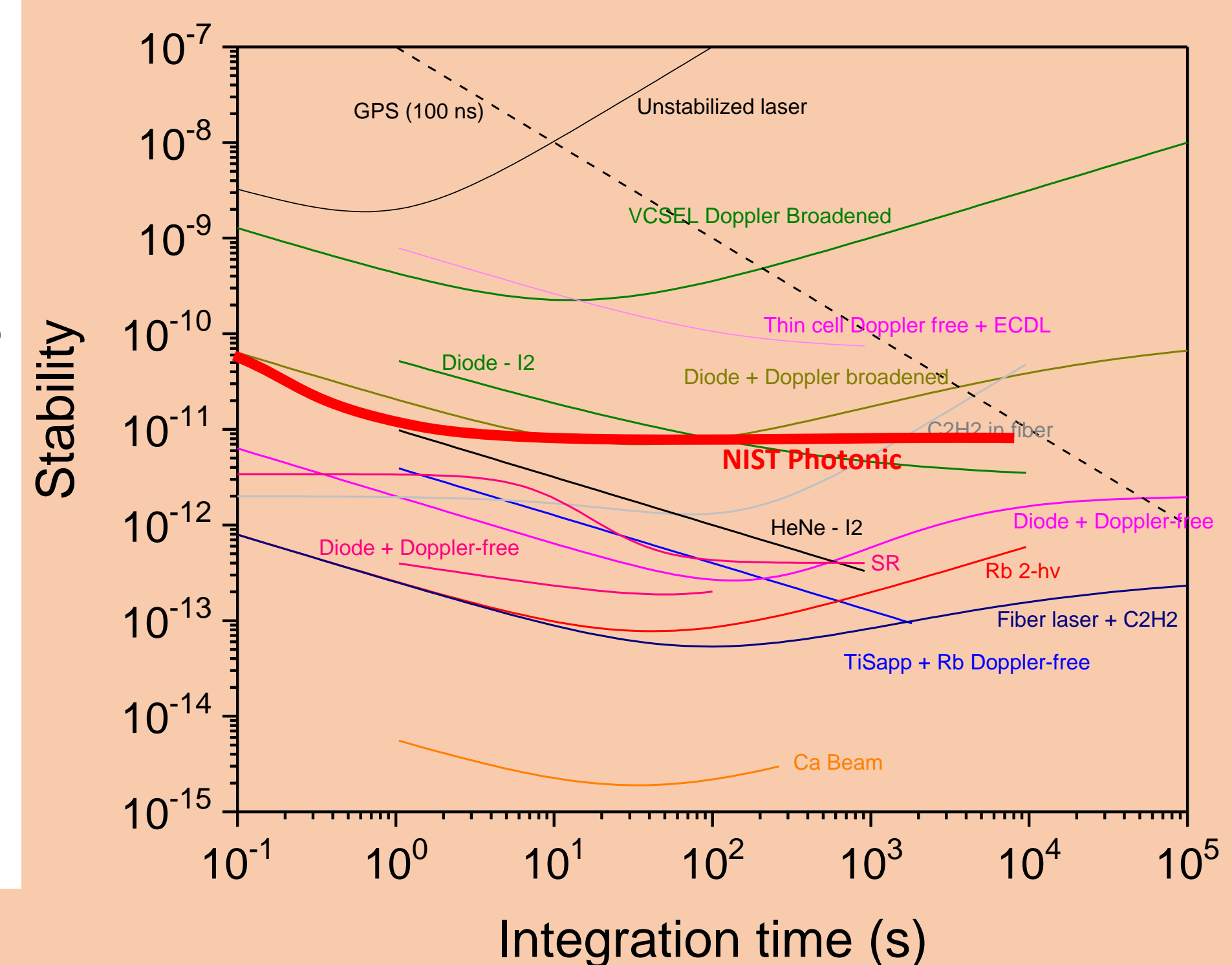
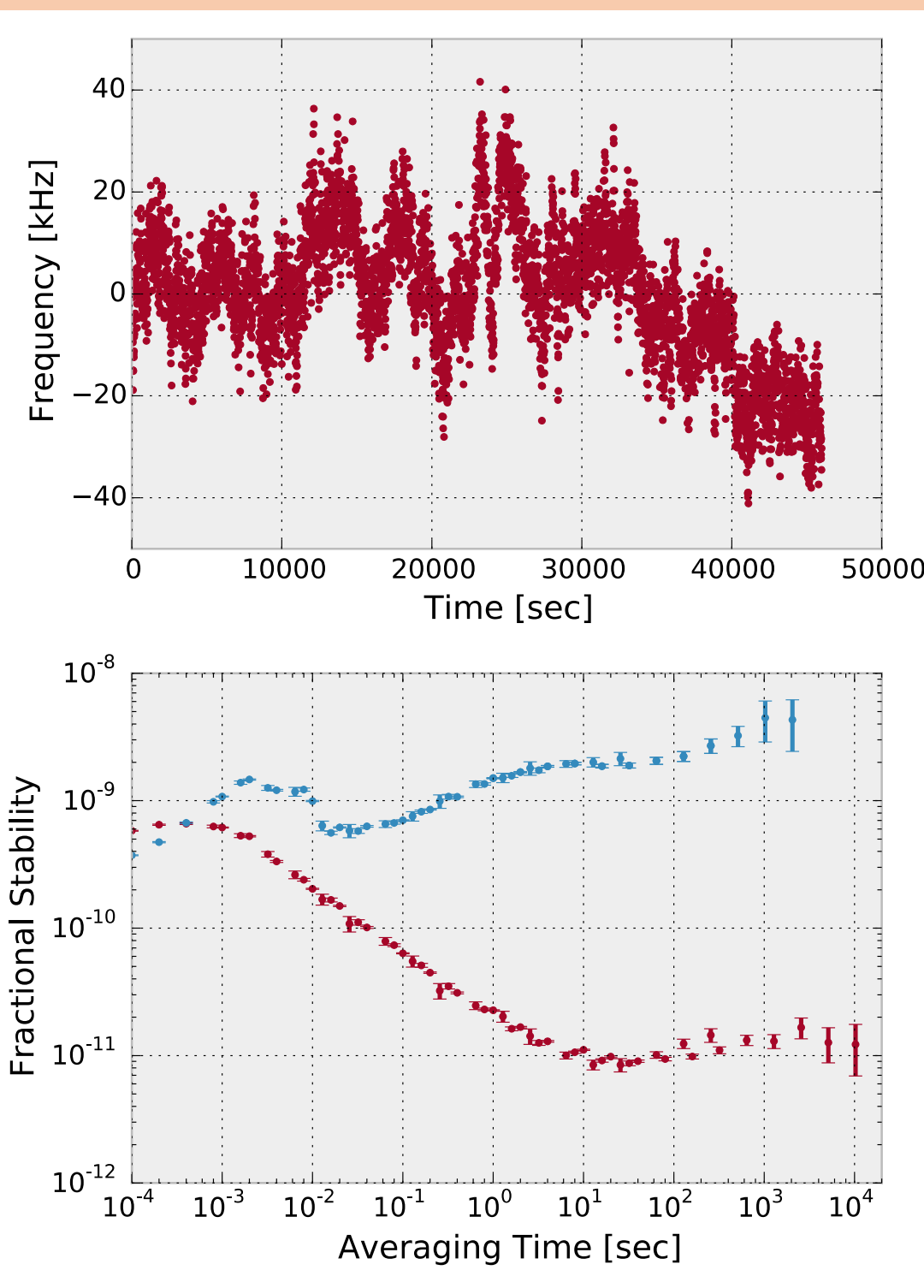


Photonic Integrated Alkali Vapor Cells

- Integrate microfabricated alkali vapor cells with single-mode photonics
- Ability to design atomic systems into photonic circuits: high non-linear coefficients, high accuracy, good signal-to-noise ratios



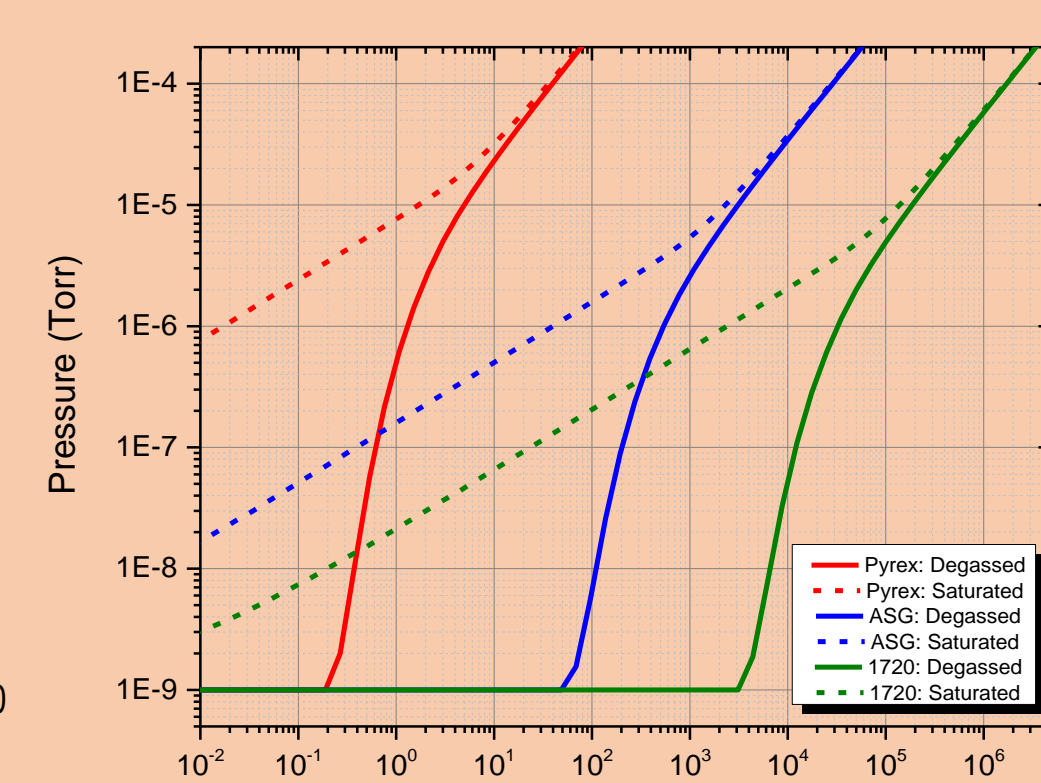
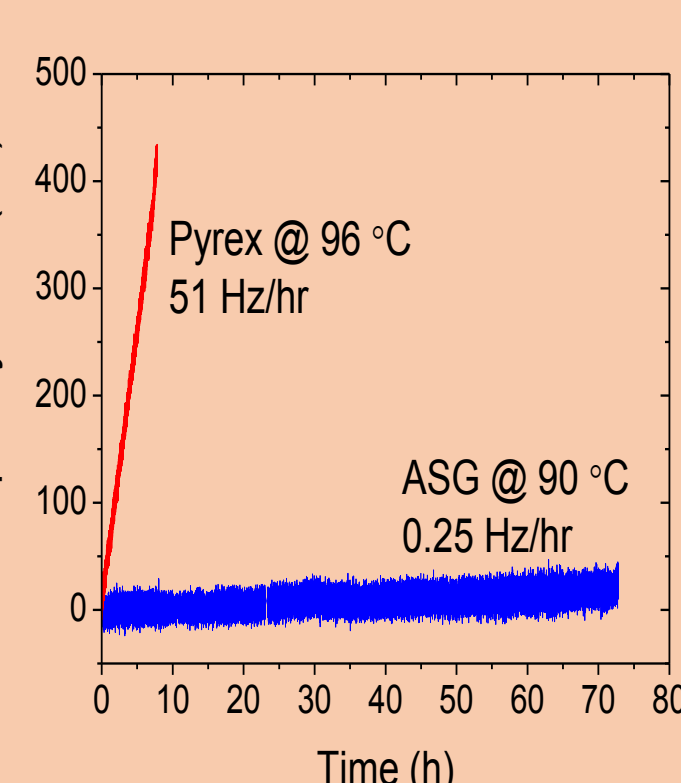
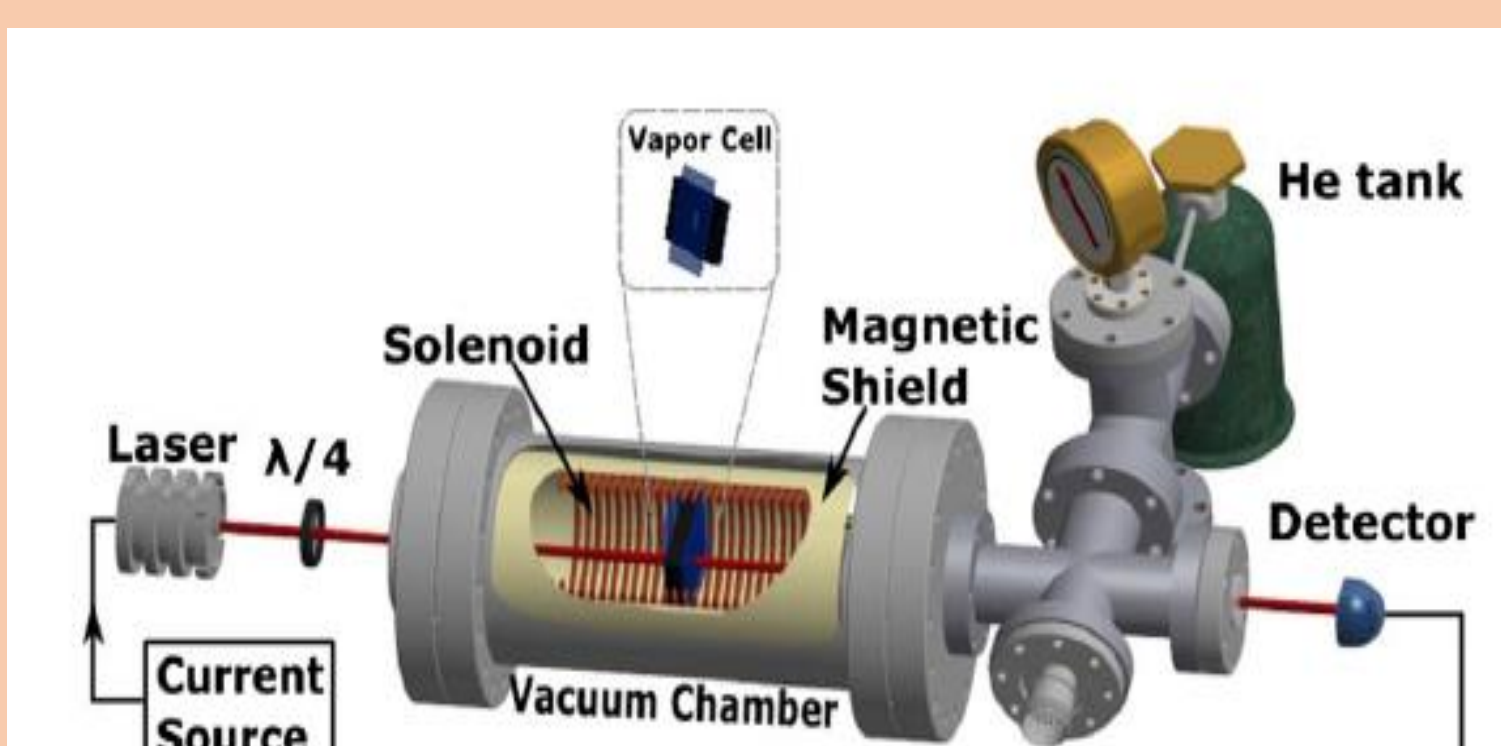
With Kartik Srinivasan, Vladimir Aksyuk, NIST



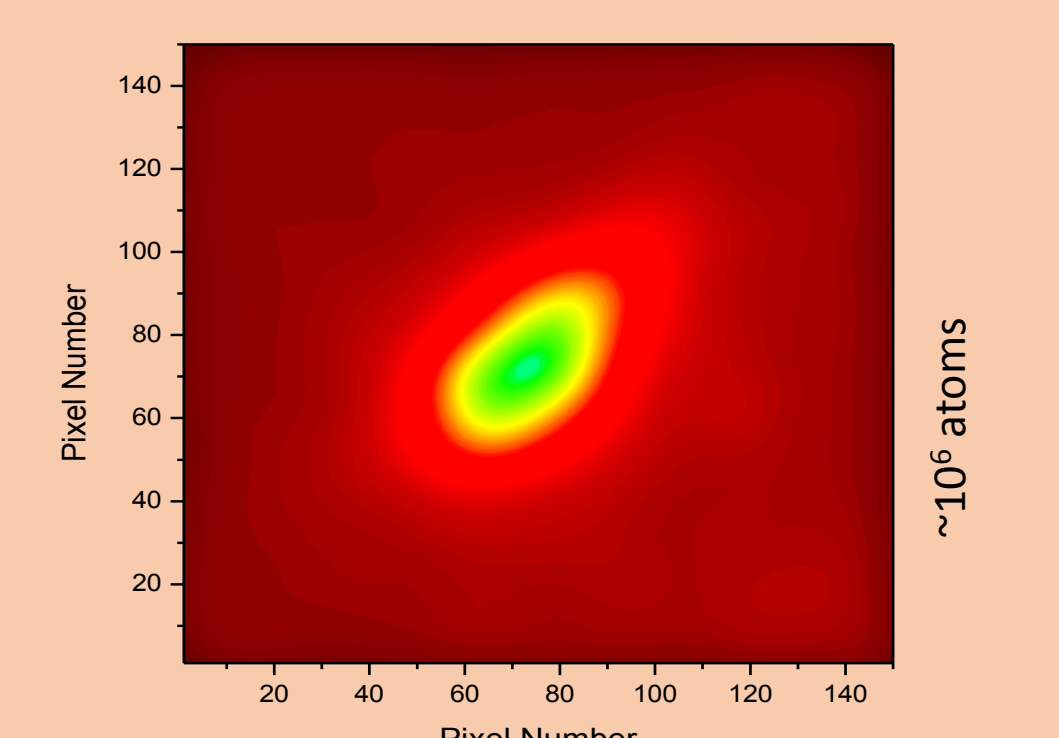
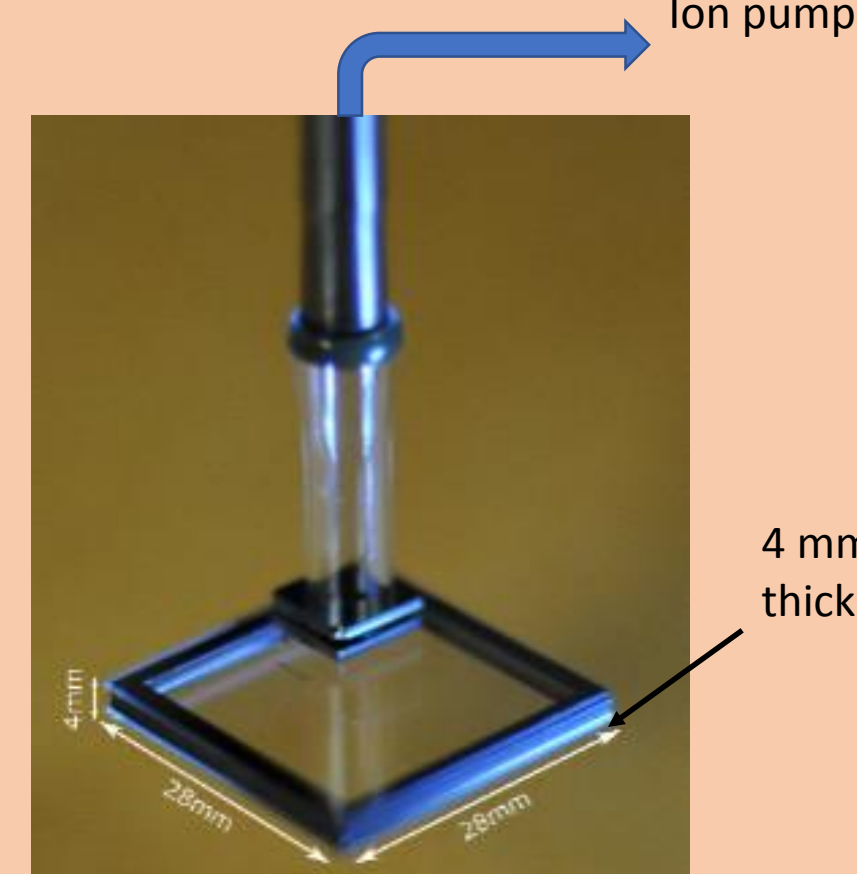
Toward Compact Cold Atom Systems

- All cold atom systems: most accurate clocks, sensors made so far require active pumping (ion pumps) for long-term operation
- Large, cumbersome, HV...

Cells with low He permeability

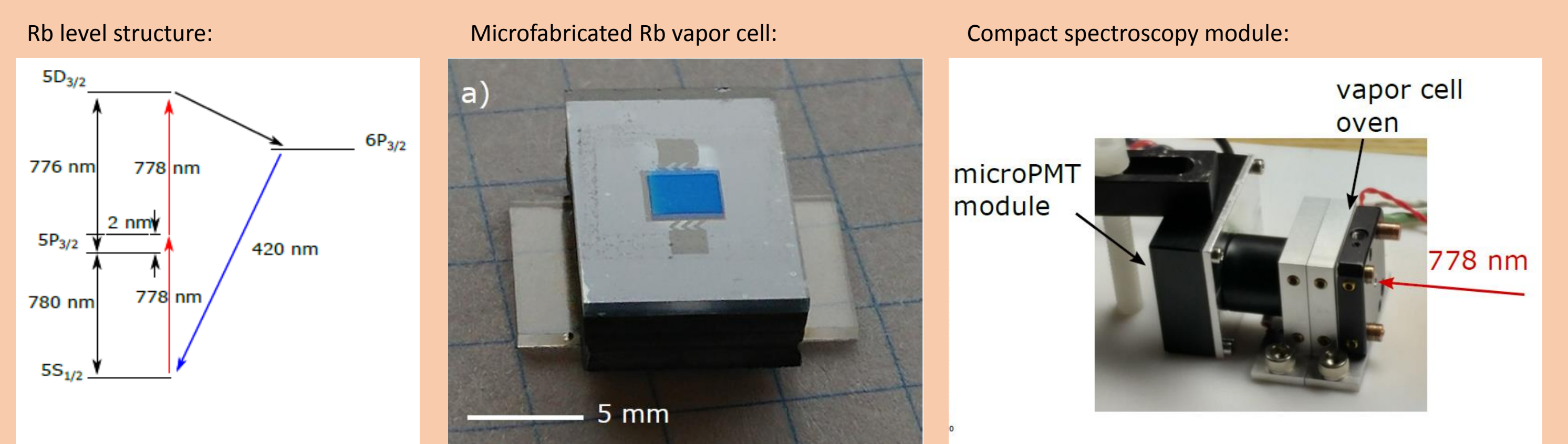


MOT in actively pumped MEMS cell

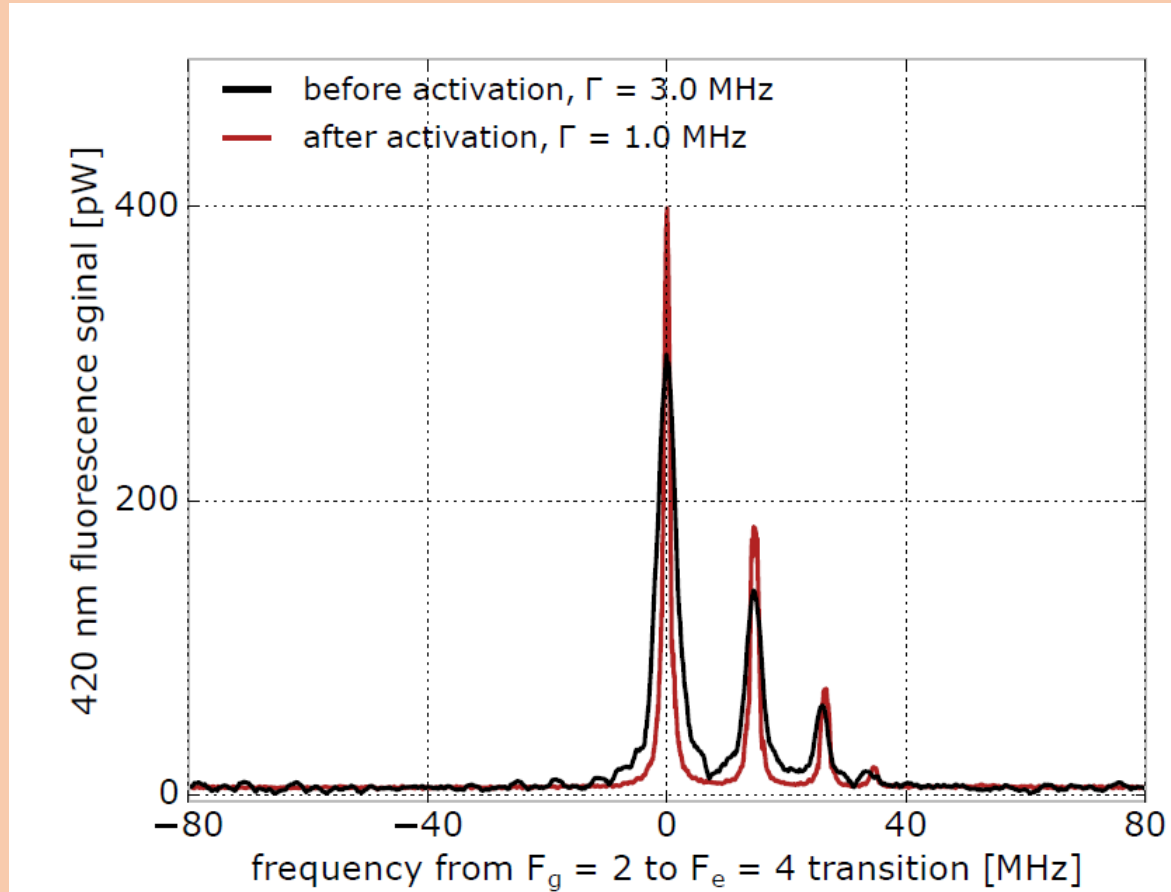


Two-photon spectroscopy in a MEMS cell

- 778 nm transition in Rb: high line Q (109) \Rightarrow better accuracy



Two-photon signals:



Stability of laser locked to transition

