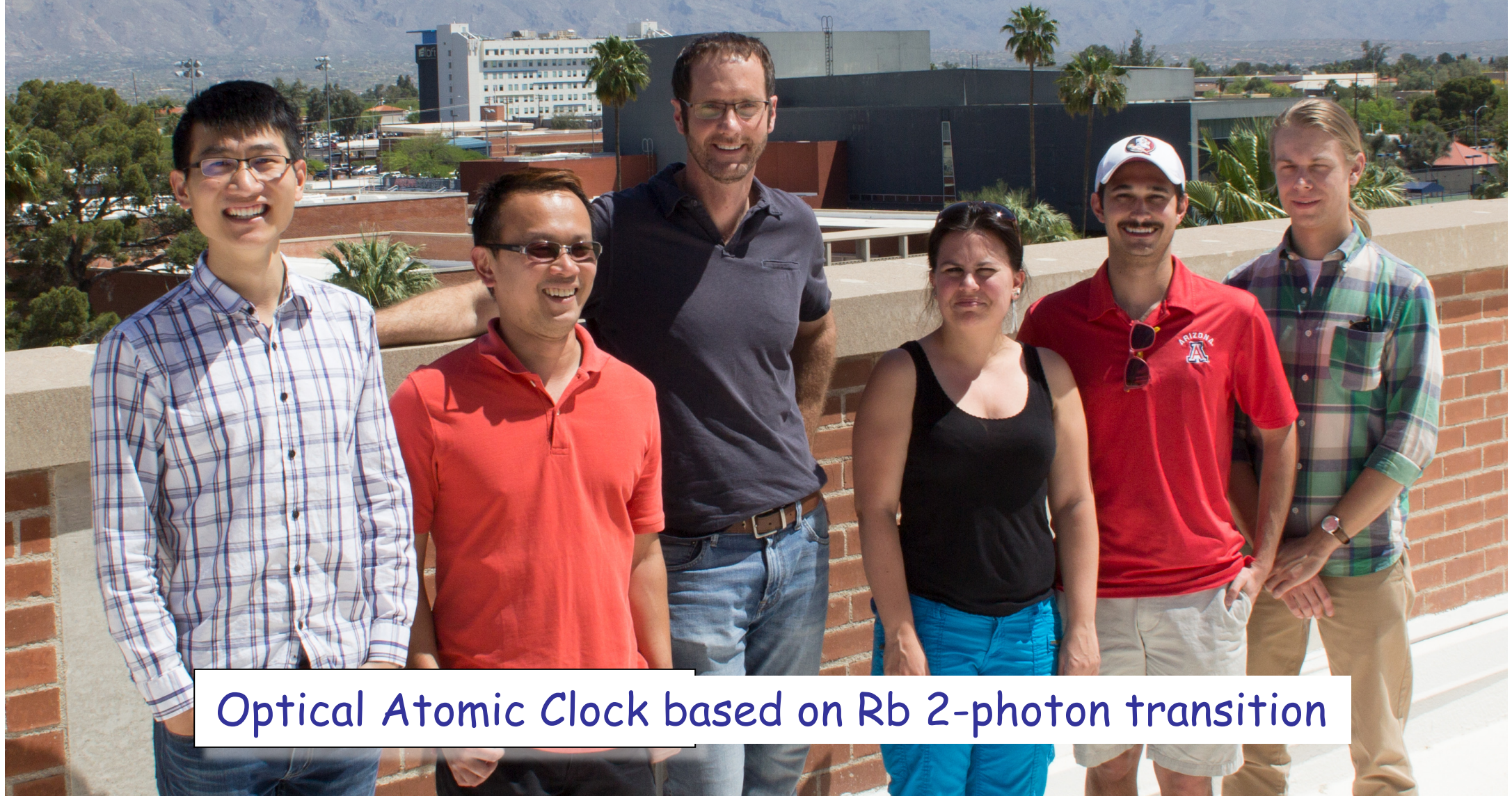


Jones Research Group



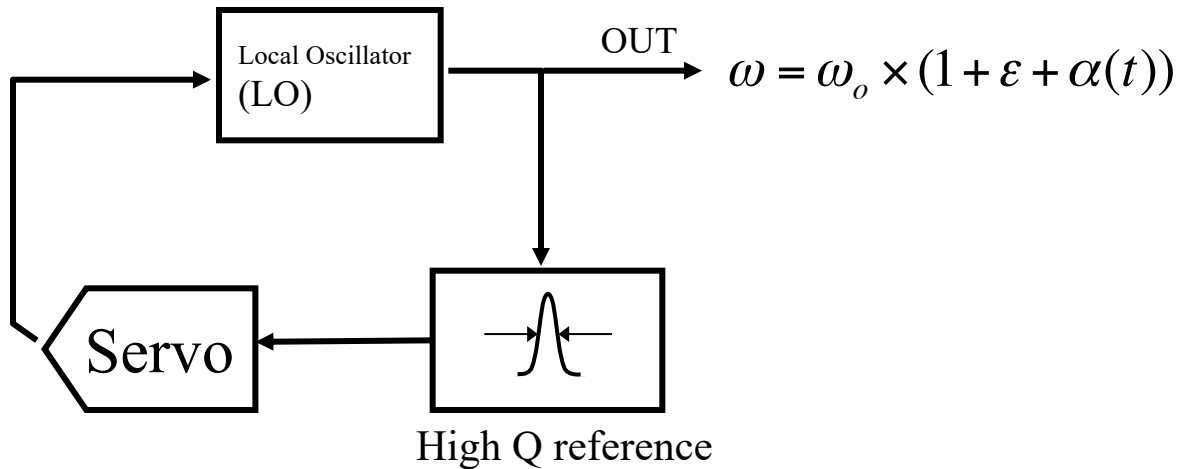
THE UNIVERSITY OF ARIZONA
James C. Wyant
College of Optical Sciences

College of Optical Sciences

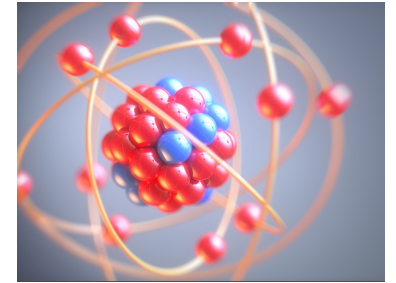
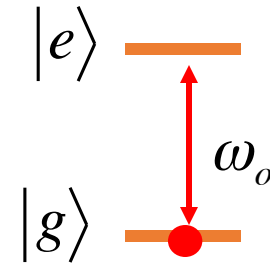


Optical Atomic Clock based on Rb 2-photon transition

Atomic clock basics



Unperturbed atom



• Fractional frequency stability:

$$\sigma(\tau) = \frac{1}{Q} \frac{1}{S/N} \frac{1}{\sqrt{\tau}}$$

where, $Q \equiv \frac{\omega_0}{\Delta\omega}$

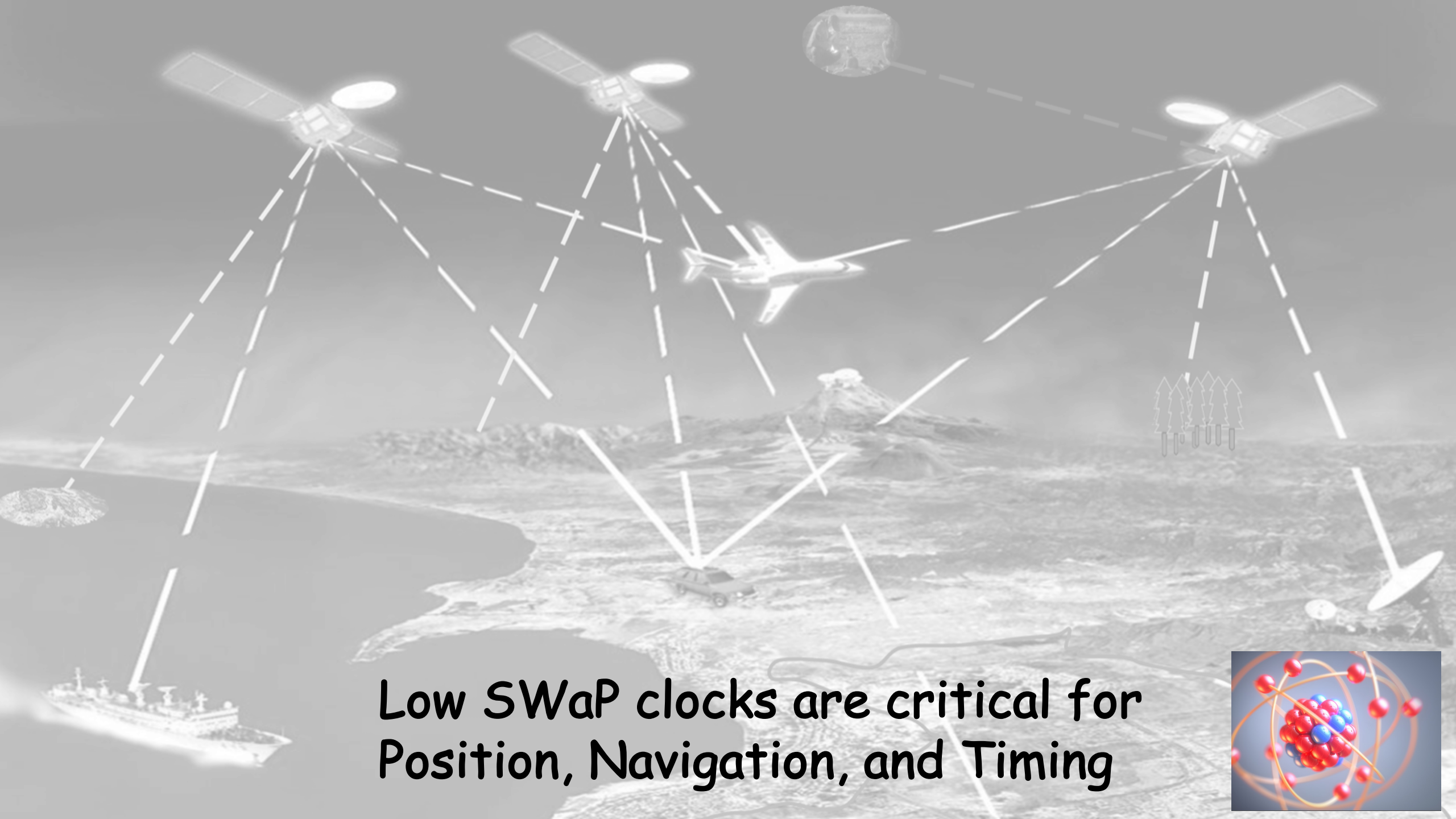
Ex: Cs microwave fountain

$$\sigma(\tau) \sim 10^{-14} \tau^{-1/2}$$

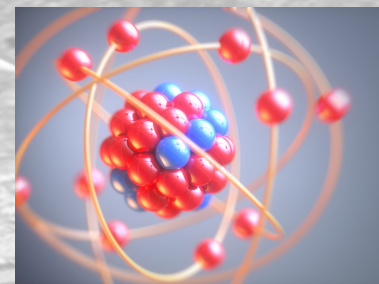
quantum limit: $\sigma(\tau) = \frac{1}{Q} \frac{1}{\sqrt{N_{atoms}}} \frac{1}{\sqrt{\tau}}$

Optical transitions $\sigma(\tau) \sim 10^{-18} \tau^{-1/2}$

-higher Q's
-many shifts independent of frequency (ie zeeman, collisional...)



**Low SWaP clocks are critical for
Position, Navigation, and Timing**



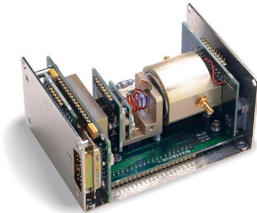
Clock comparisons

Performance



$$\sigma_y(1s) \sim 10^{-10}$$

Rb clock



$$\sigma_y(1s) \sim 10^{-12}$$

Cs beam tube



$$\sigma_y(\tau) \sim 10^{-12} \sqrt{\tau}$$

$$\sigma_y(\infty) \sim 10^{-14} \sqrt{\tau}$$

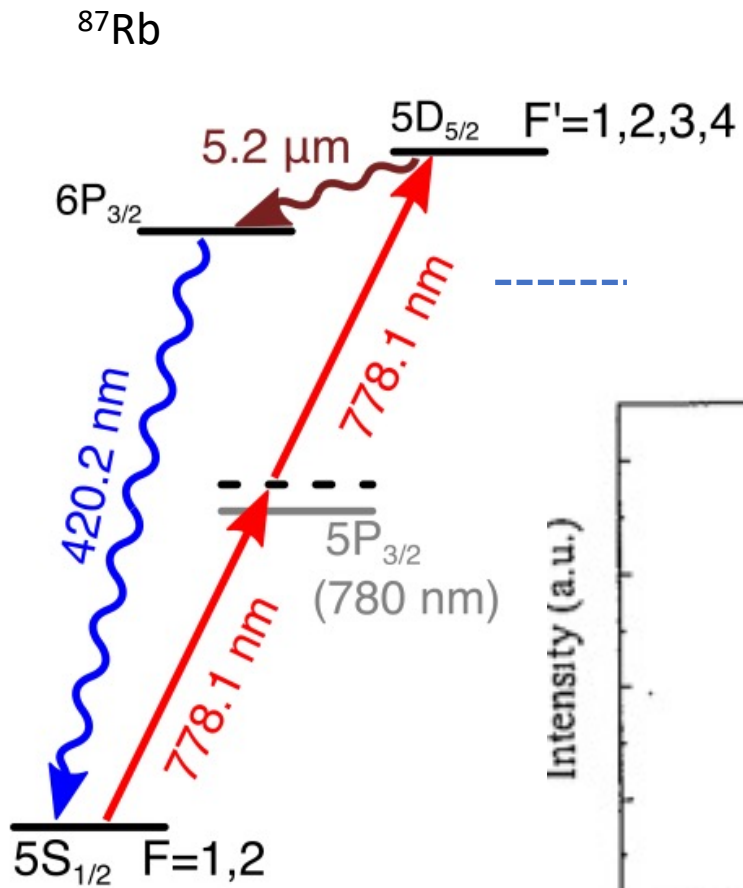
H maser



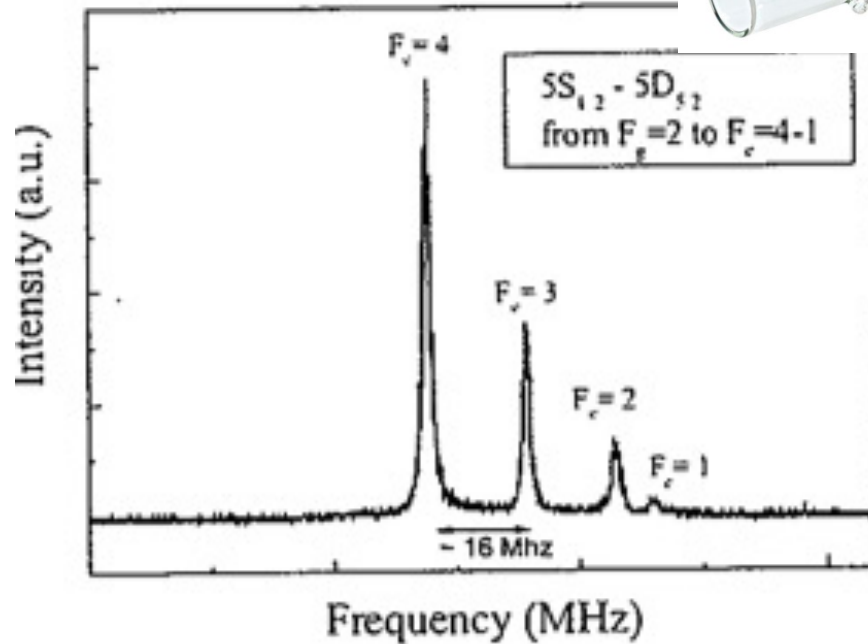
$$\sigma_y(\tau) \sim 10^{-13} \sqrt{\tau}$$
$$\sigma_y(\infty) \sim 10^{-15} \sqrt{\tau}$$

SWaP

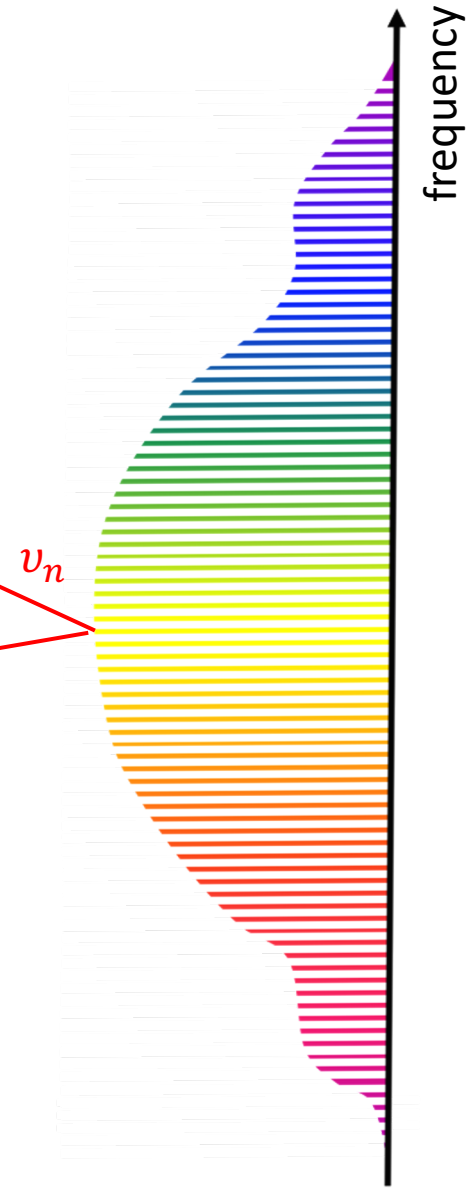
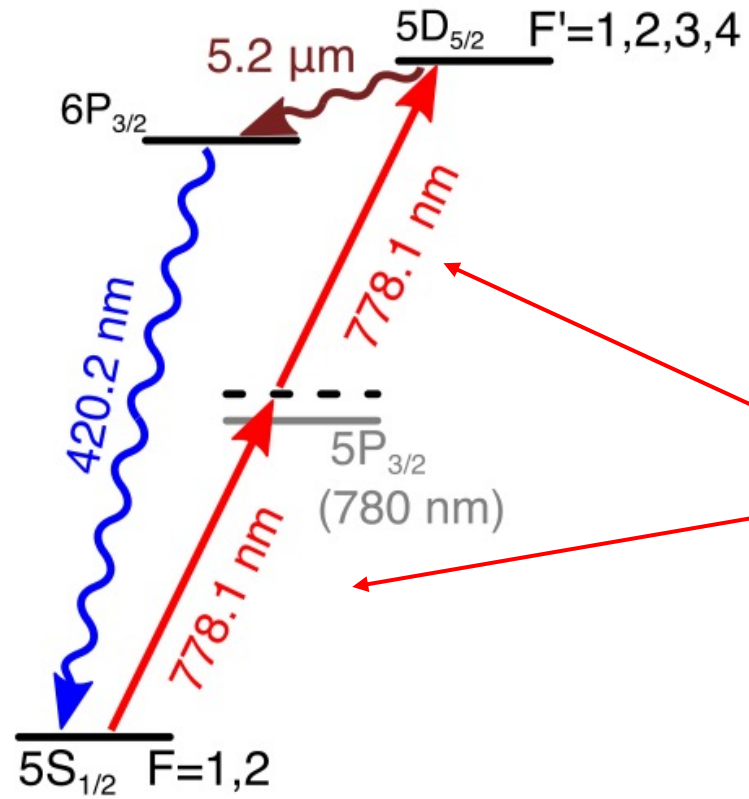
2-photon Rb clock transition



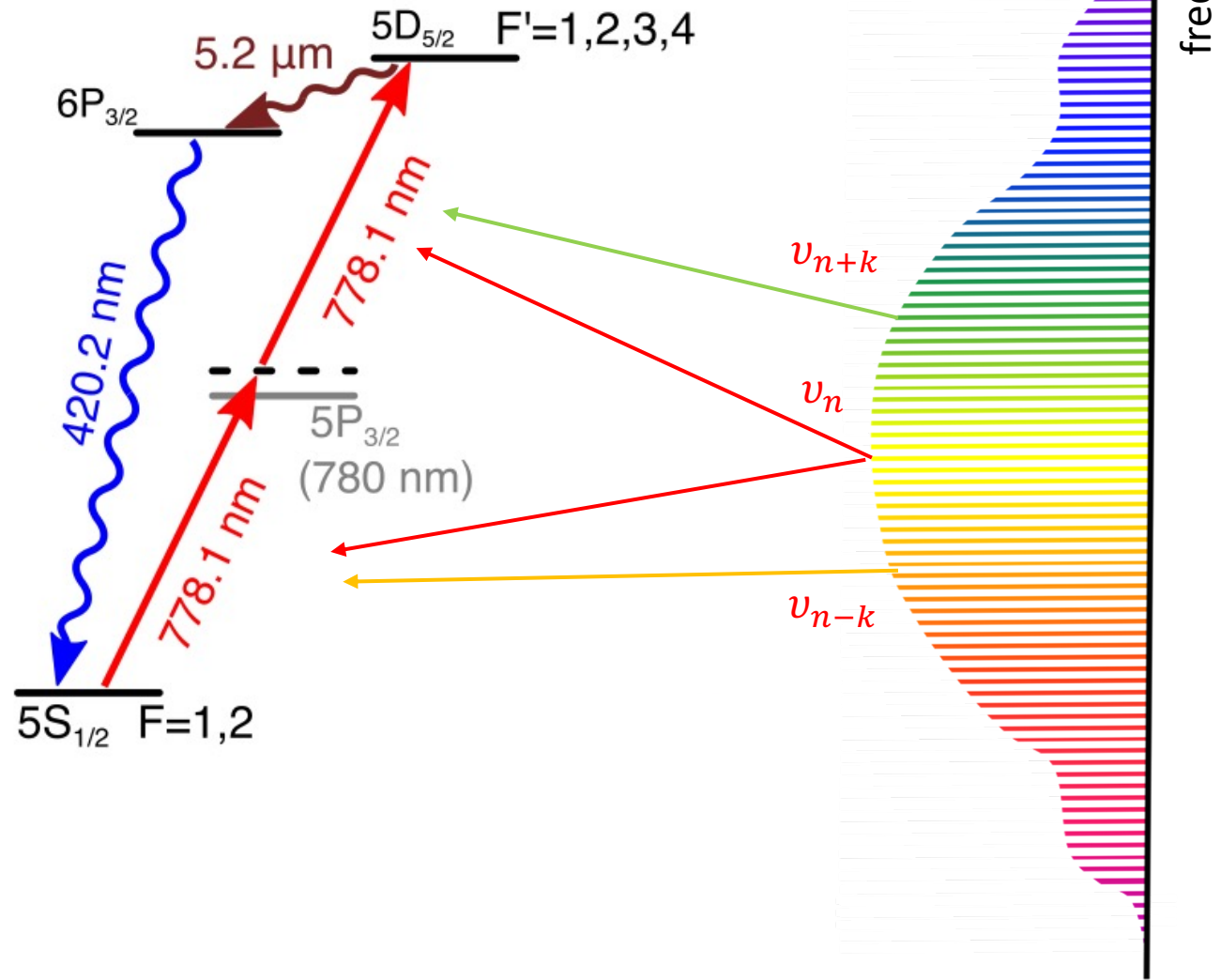
- Strong transition due to intermediate 5P_{3/2} state
- Narrow Doppler-free linewidth (~ 330 kHz)
- Utilizes simple room temperature gas cell



2-photon Rb clock transition

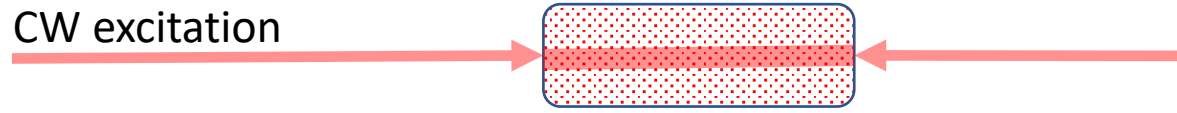


2-photon Rb clock transition



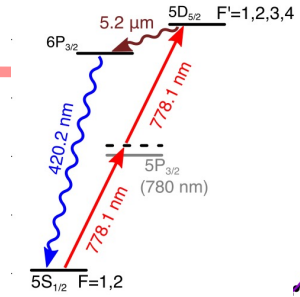
Coherent control of quantum excitation pathways

CW excitation



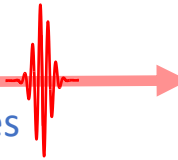
Doppler broaden background

Rb cell



Comb excitation

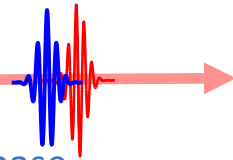
→ "chirp-free" pulses



Doppler free signal

Comb excitation

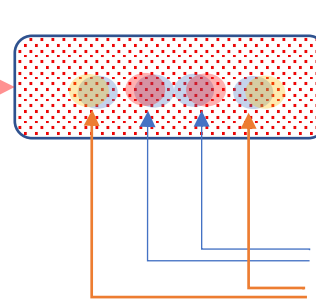
→ Spectral and phase control



Signal with no Doppler background

Comb excitation

→ Spectral and phase control



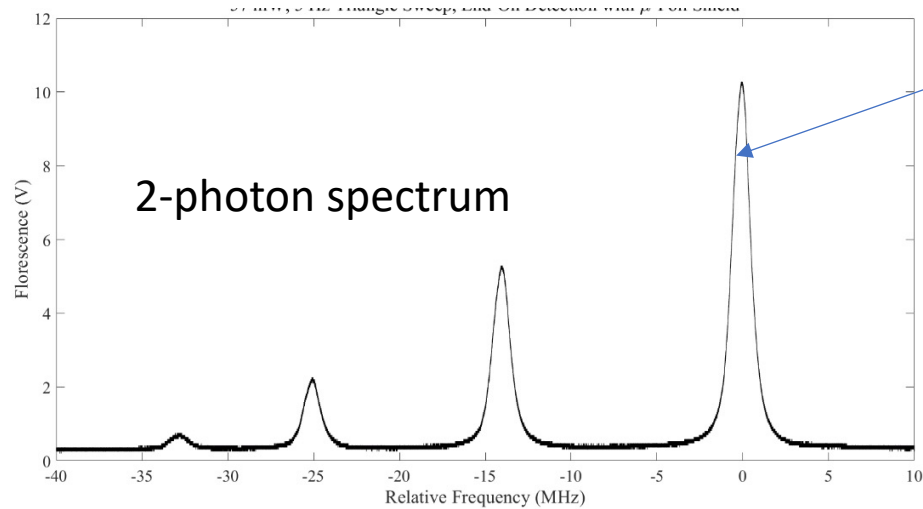
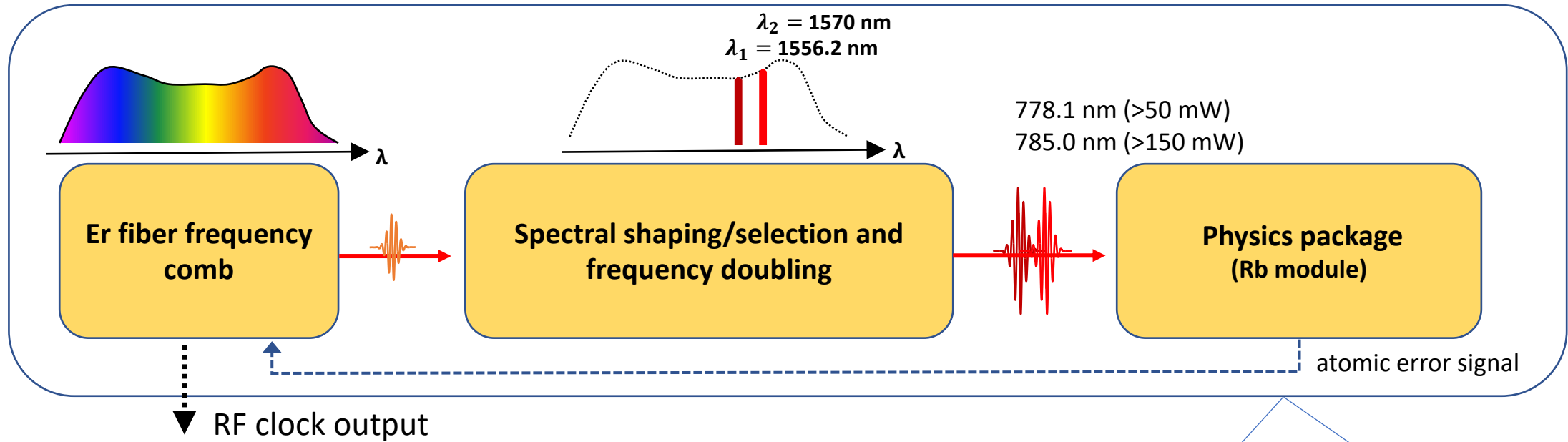
Multi-transition/ multi-species excitation

For example:

$5S_{1/2} \rightarrow 5D_{5/2}$ ^{87}Rb

$5S_{1/2} \rightarrow 7S_{1/2}$ ^{87}Rb

Our approach...



Clock transition

