





# Atom-photon interface

Peter Domokos

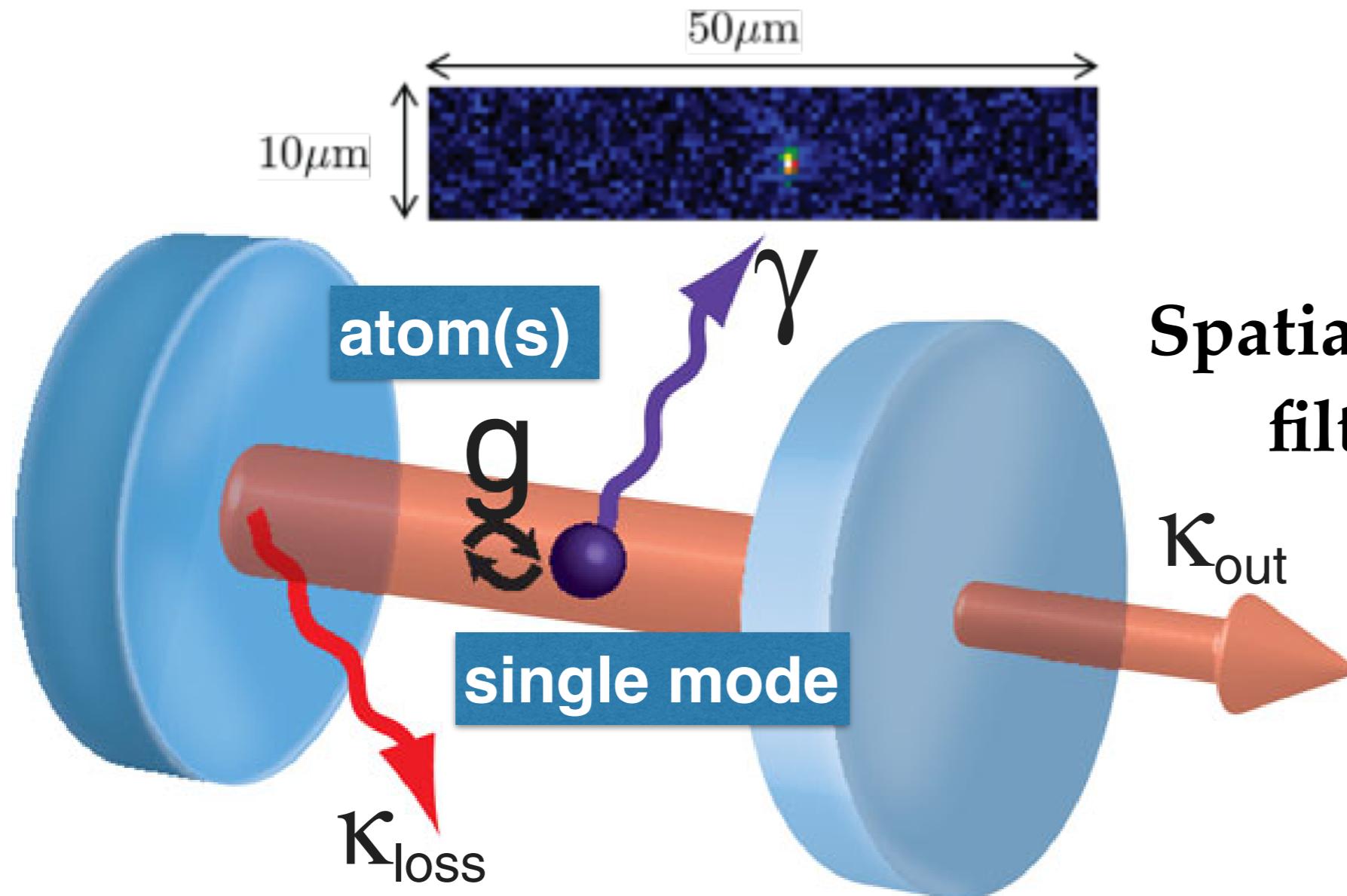
MTA Wigner Physics Research Centre



PROJECT  
FINANCED FROM  
THE NRDI FUND  
*MOMENTUM OF INNOVATION*

# Cavity Quantum Electrodynamics

Controlled interaction between light and matter

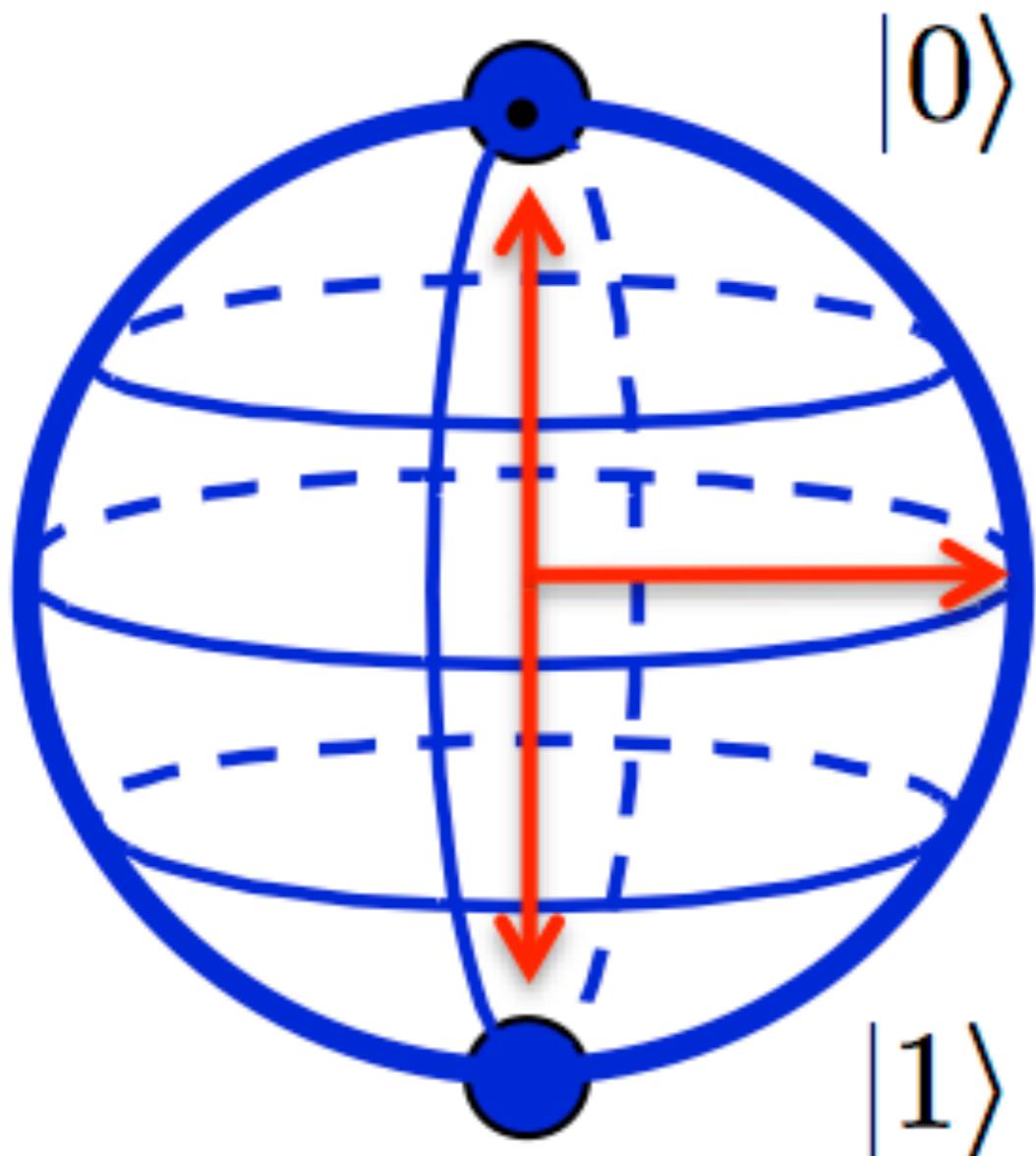


Spatially and spectrally  
filtered radiation

**MANIPULATE AT THE ULTIMATE QUANTUM NOISE LEVEL**

# Quantum information

bit → kvantumbit (Qubit)



$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

- COMMUNICATION
- COMPUTING

## Examples

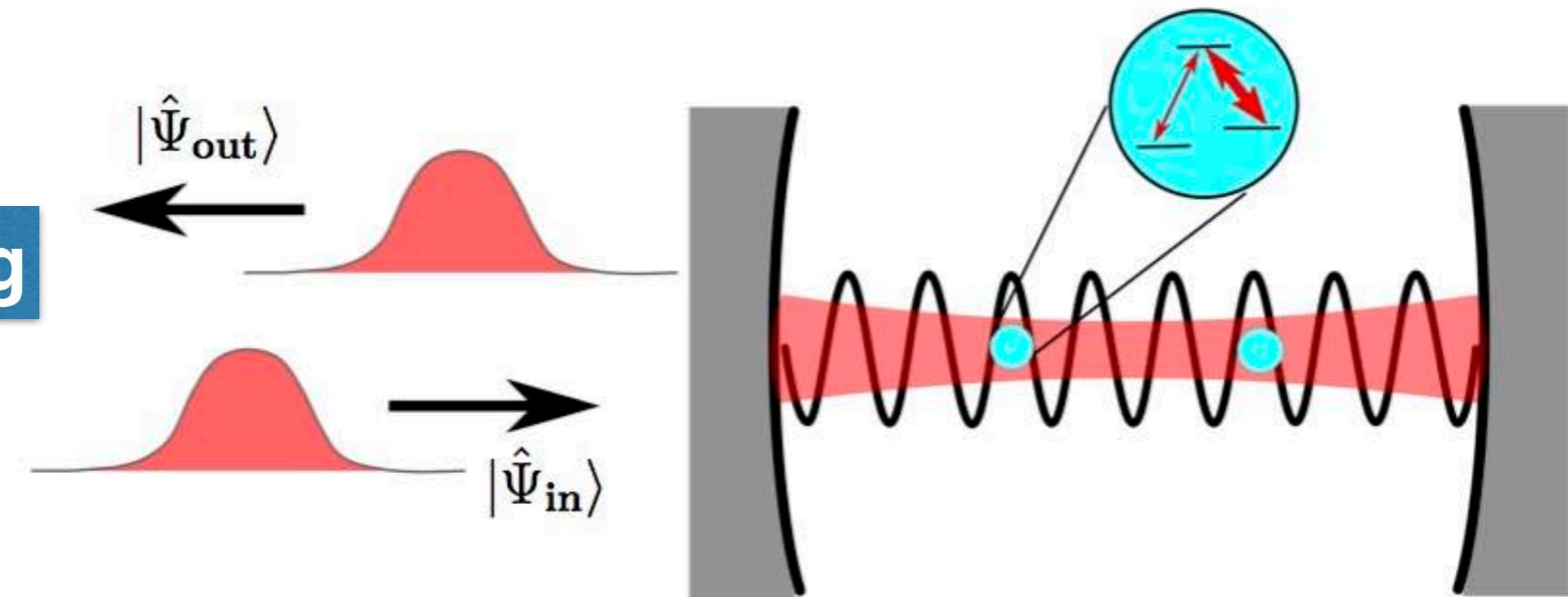
- photon + polarization
- atom ground- and excited state
- atom hyperfine states

CQED : INTERACTING QUANTUM BITS

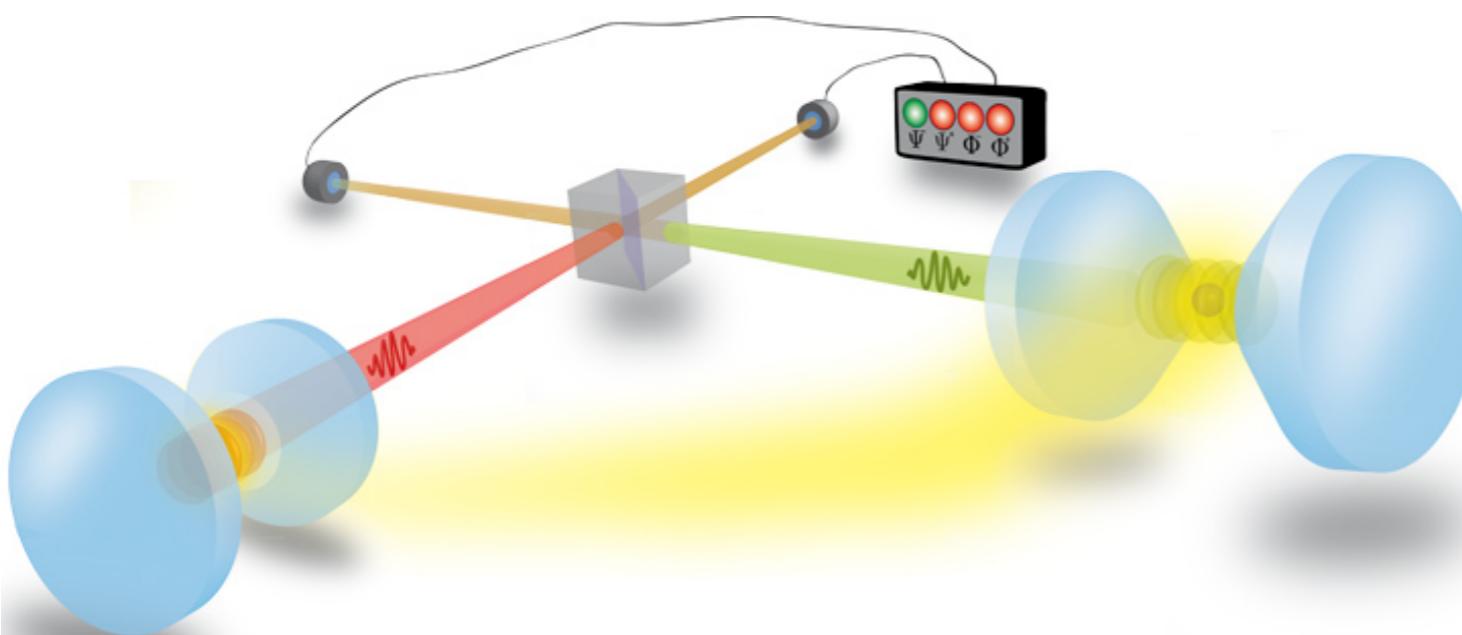
# Quantum memory

photon = flying qubit  $\longleftrightarrow$  atom = memory qubit

weakly interacting



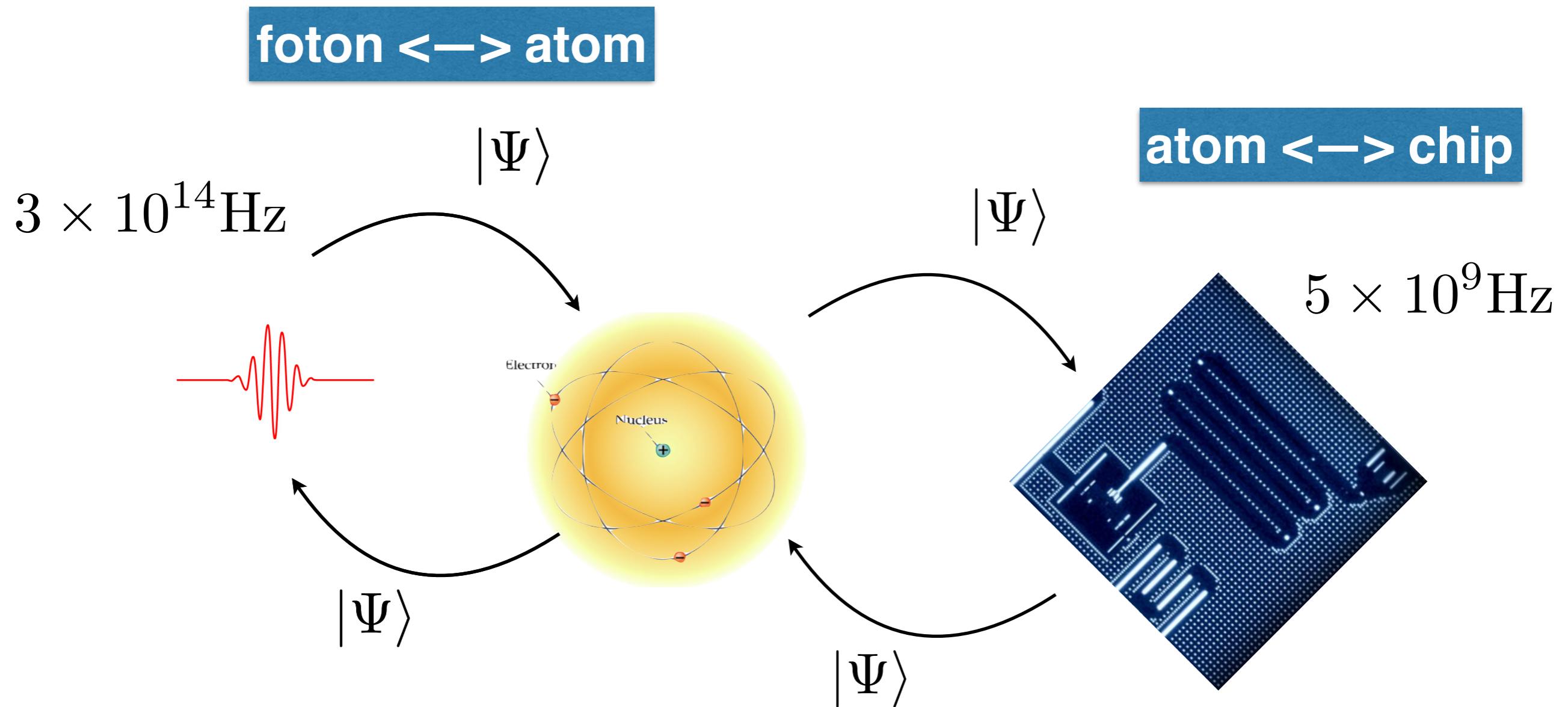
Quantum network



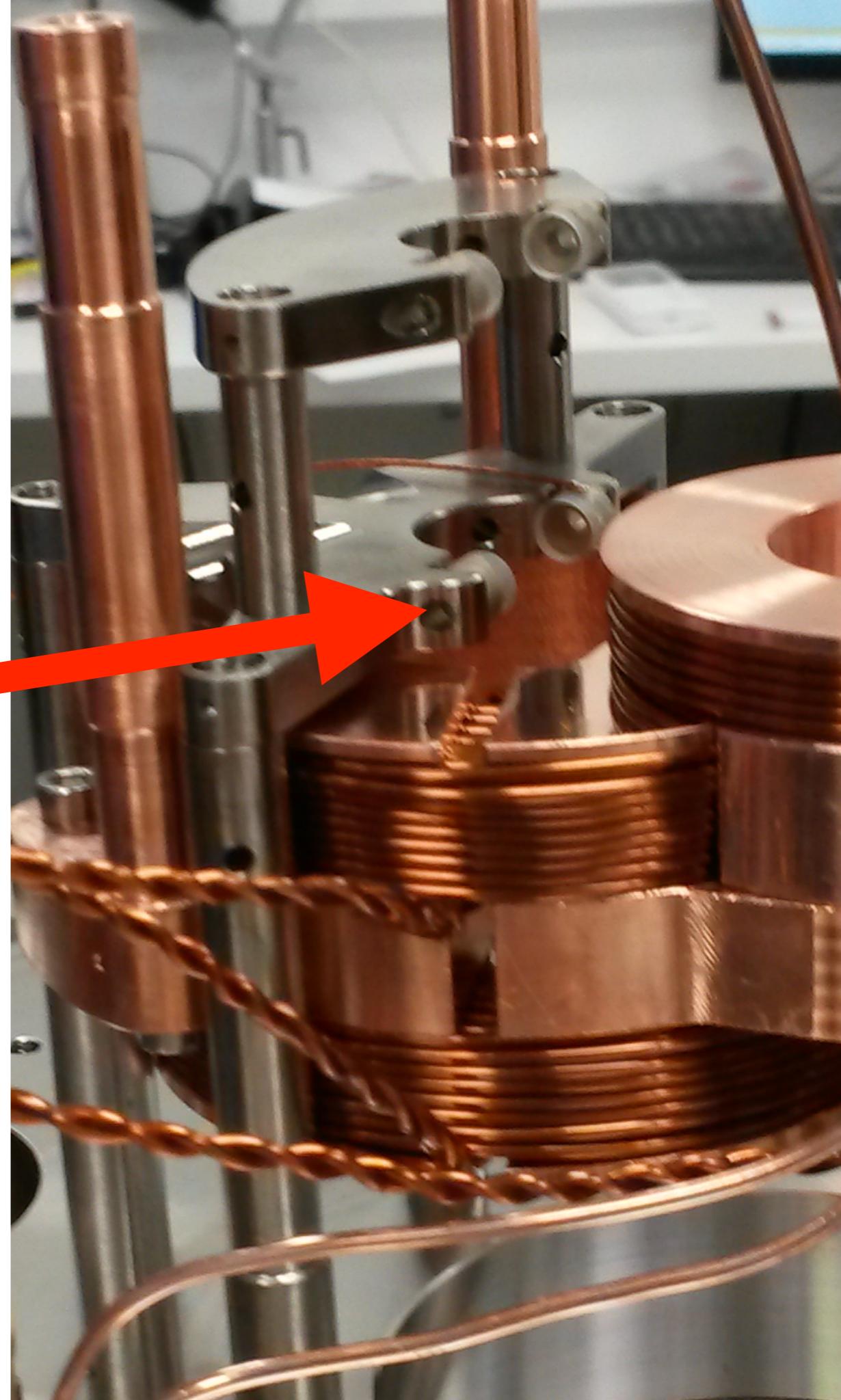
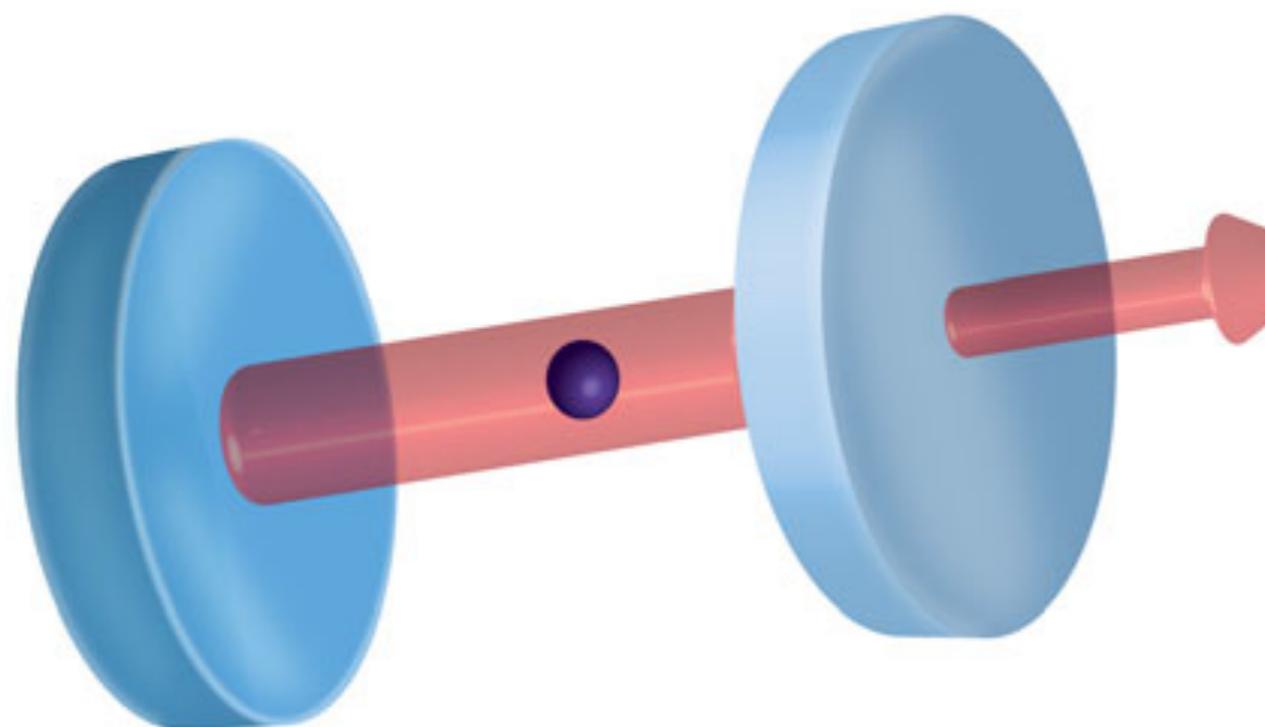
strong interaction,  
long coherence time

# Microwave — visible (NIR) conversion

Linking quantum computation to communication

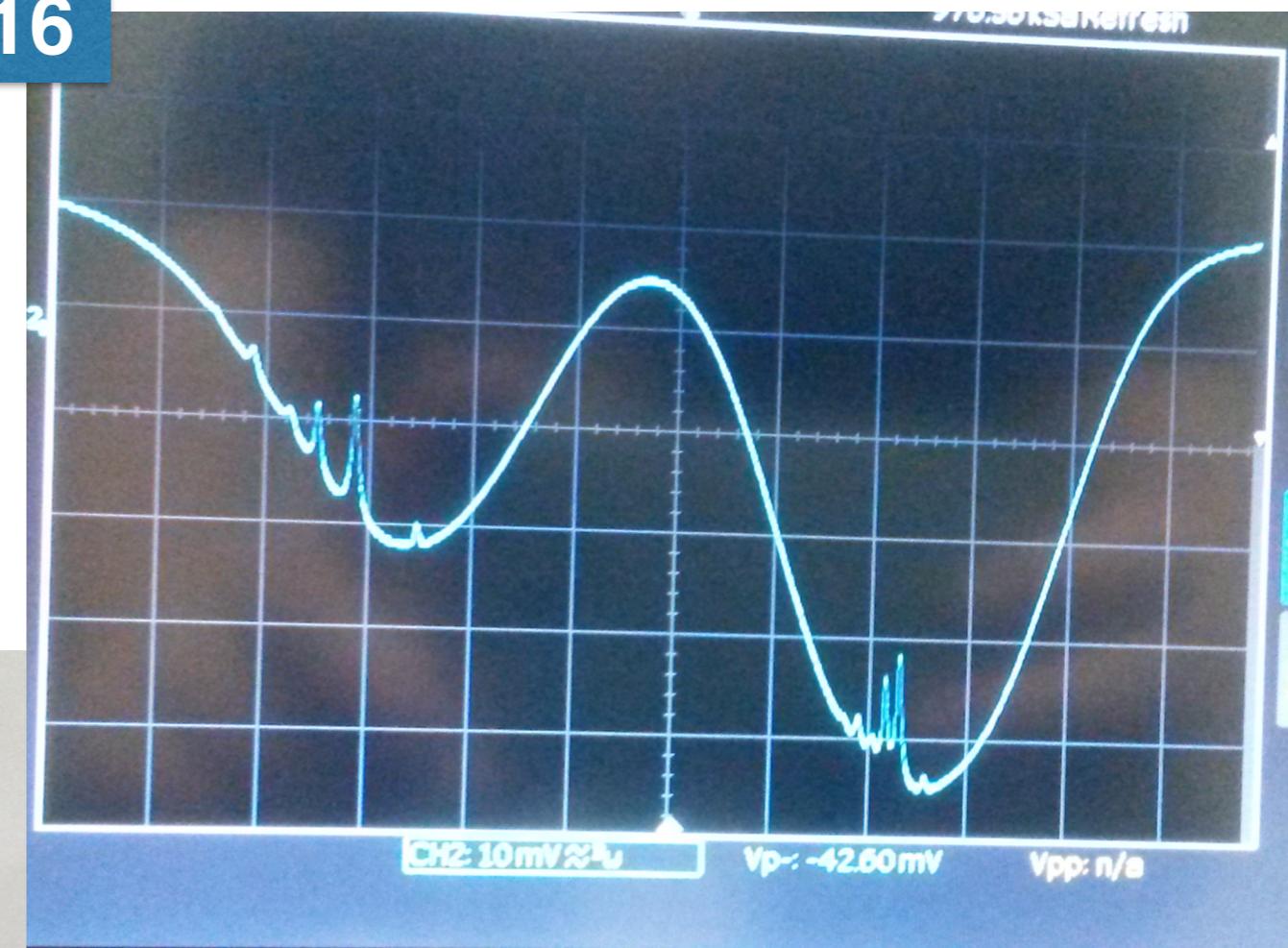
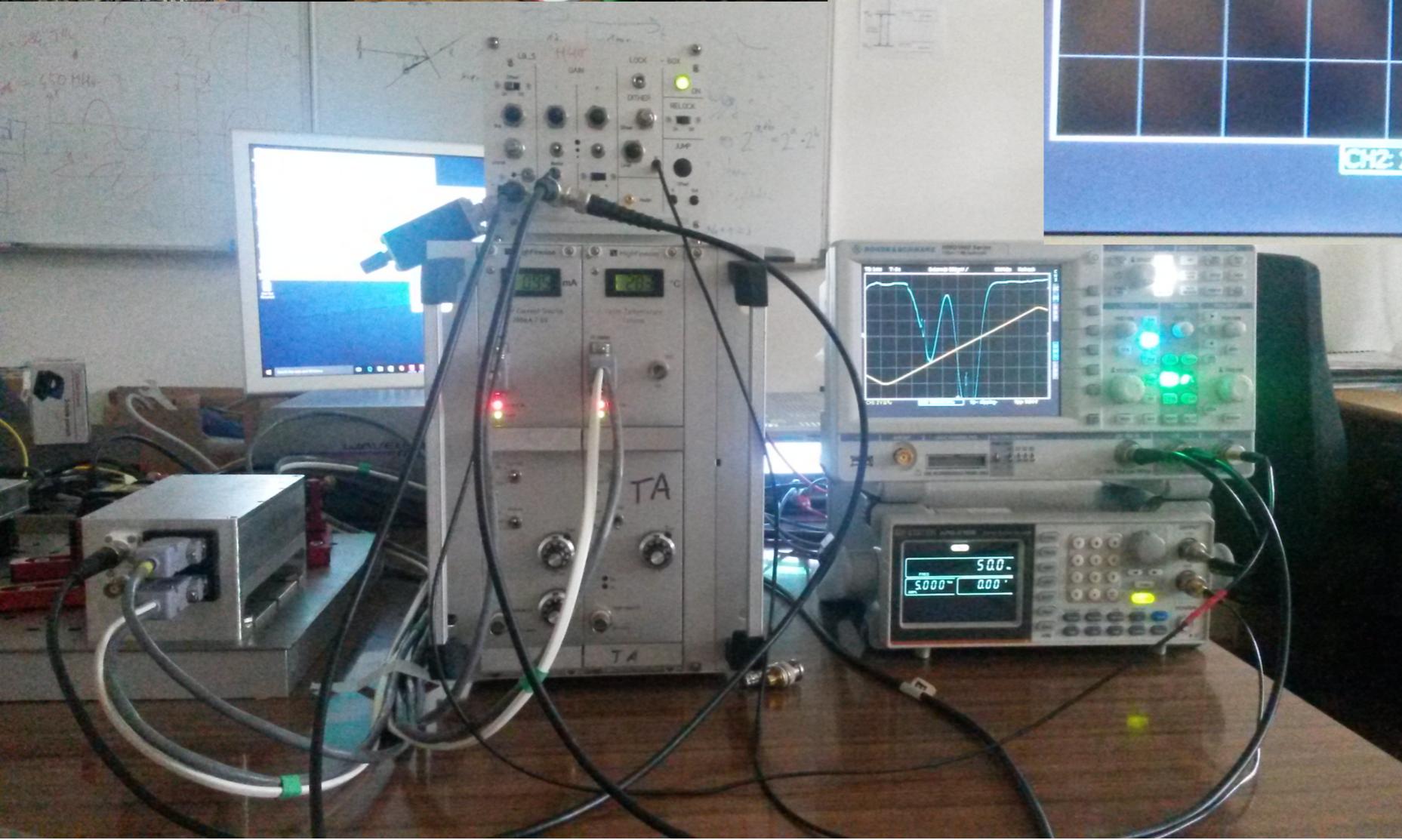
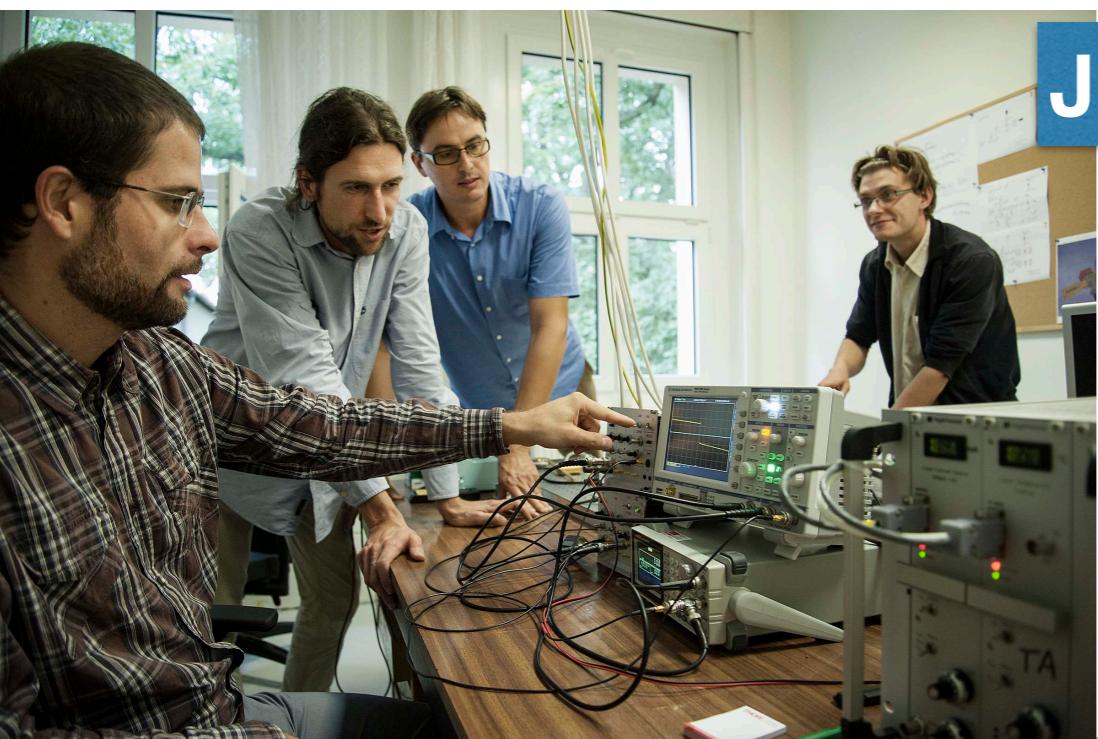


# From theory to experiment



# The beginnings

July 2016



nonlinear  
saturated-absorption  
spectroscopy of Rb

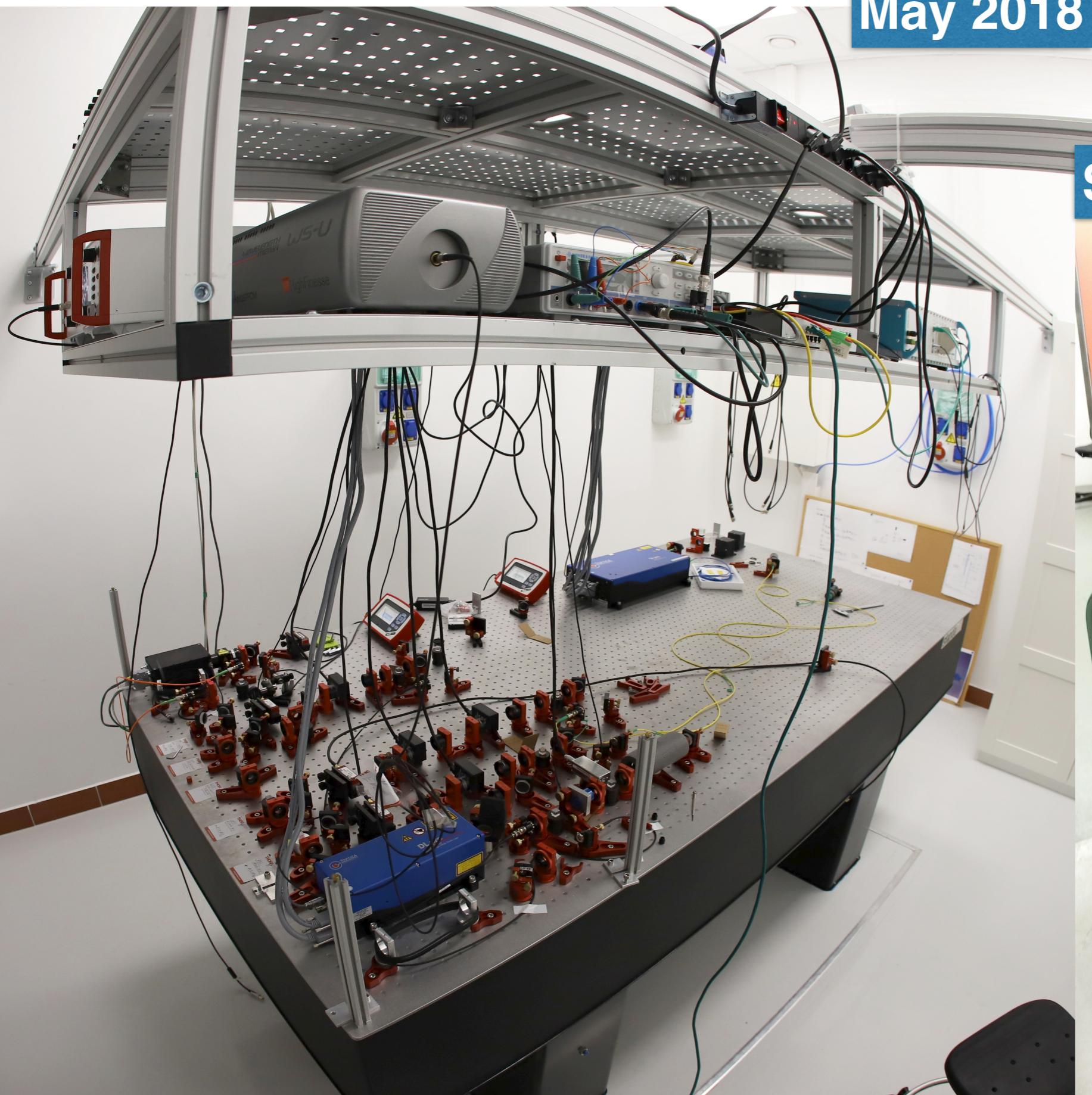
# The new laboratory space

January 2017



# The progress

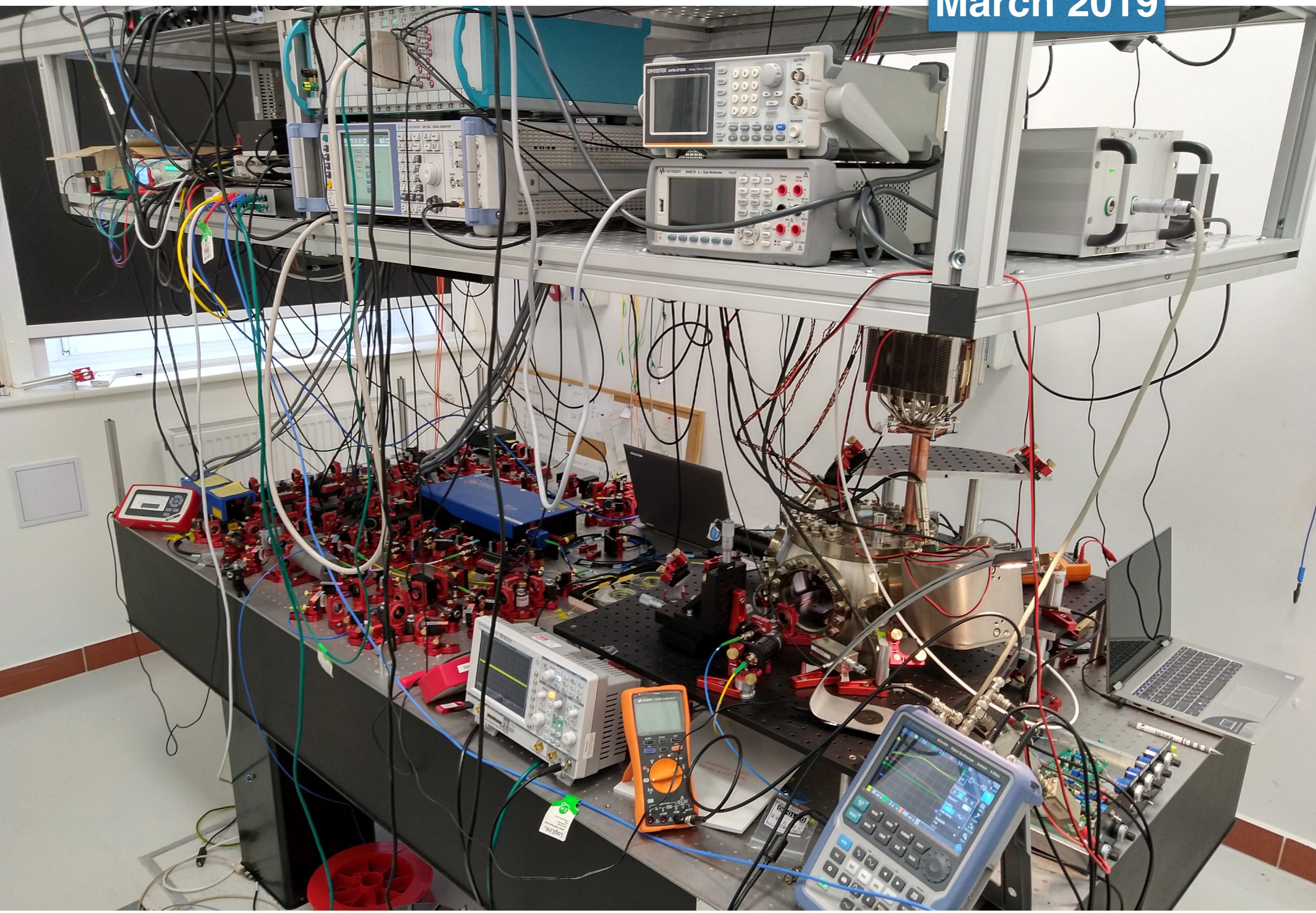
May 2018



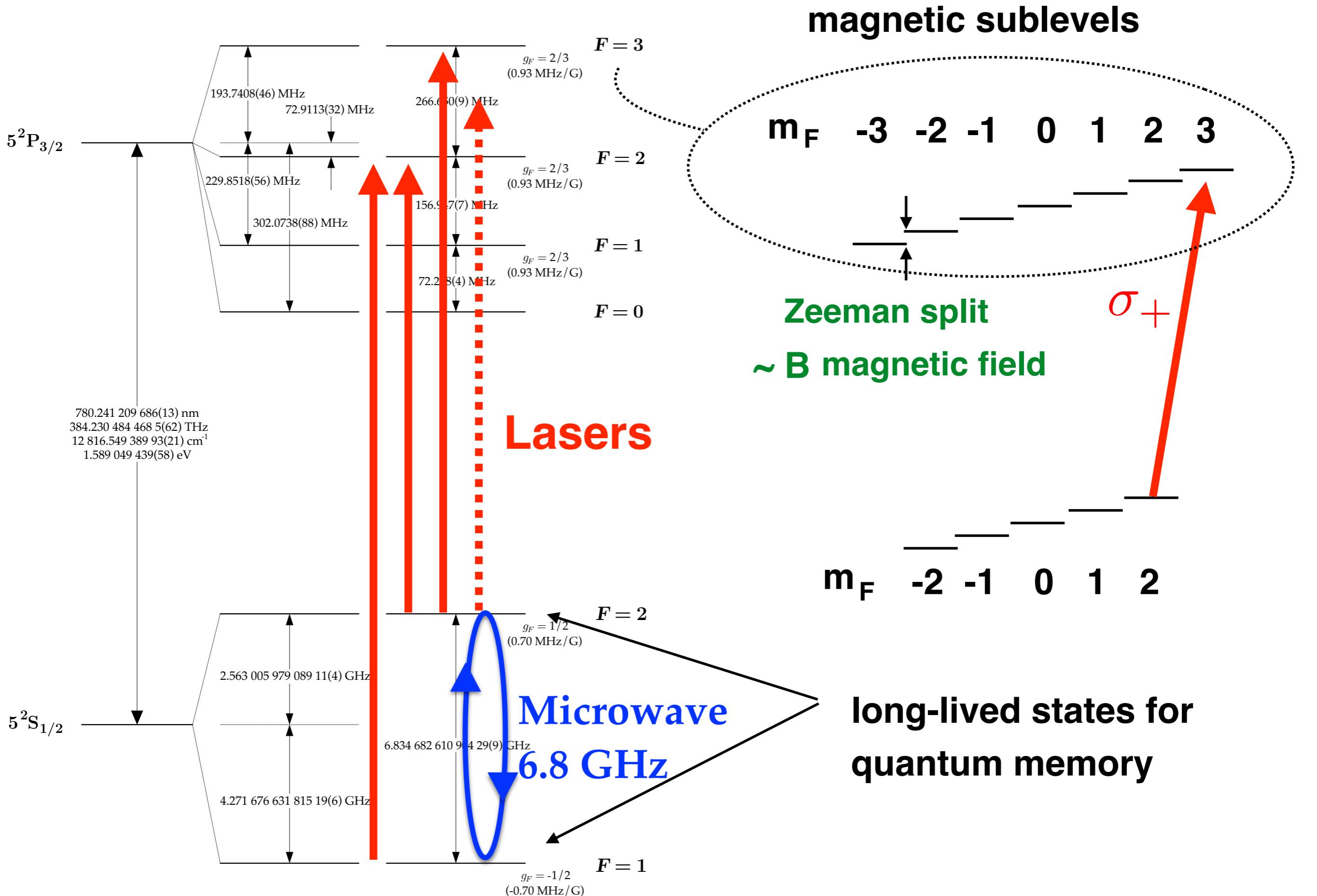
September 2018



March 2019

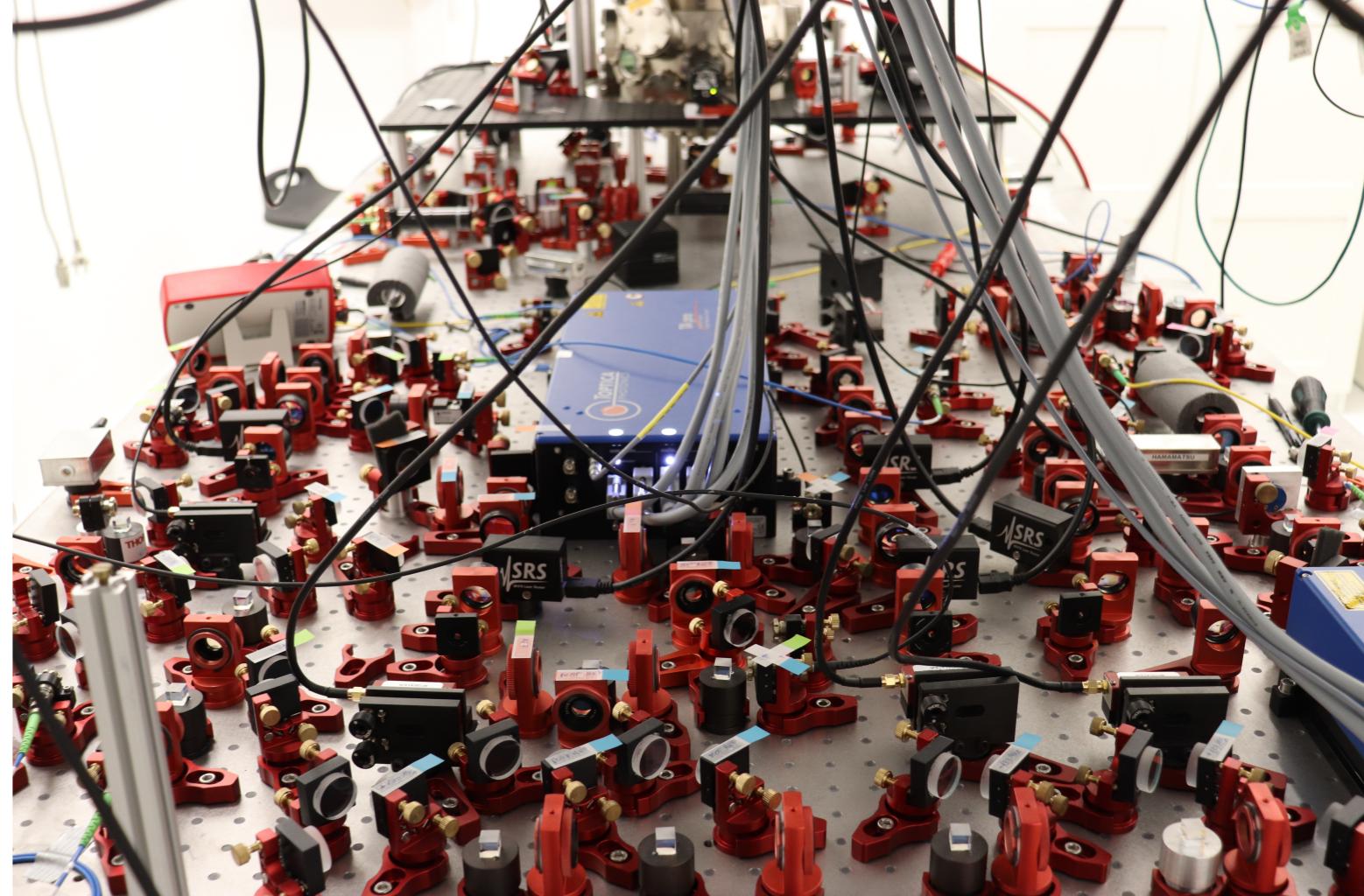
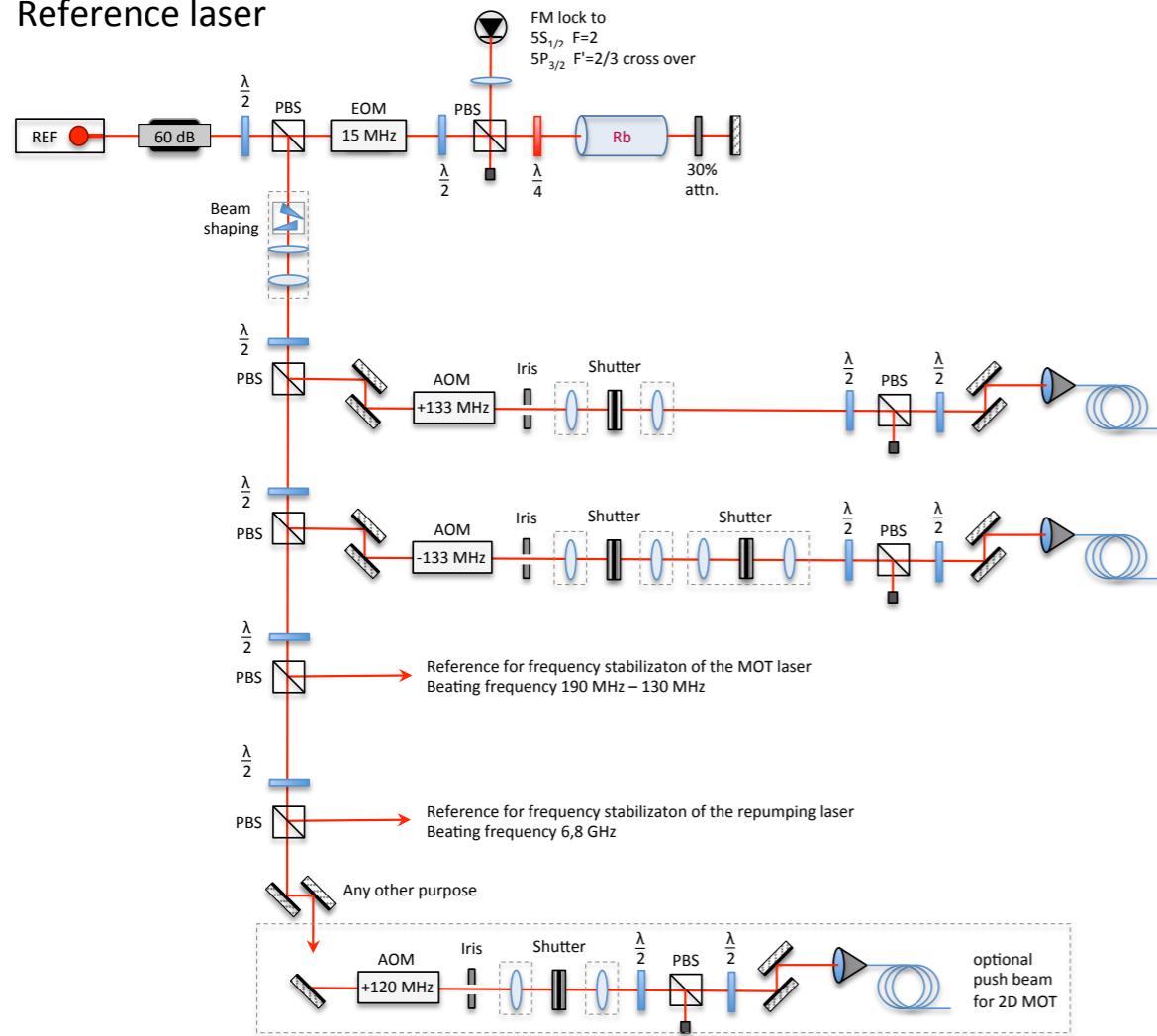


# The atom is a 'lab'

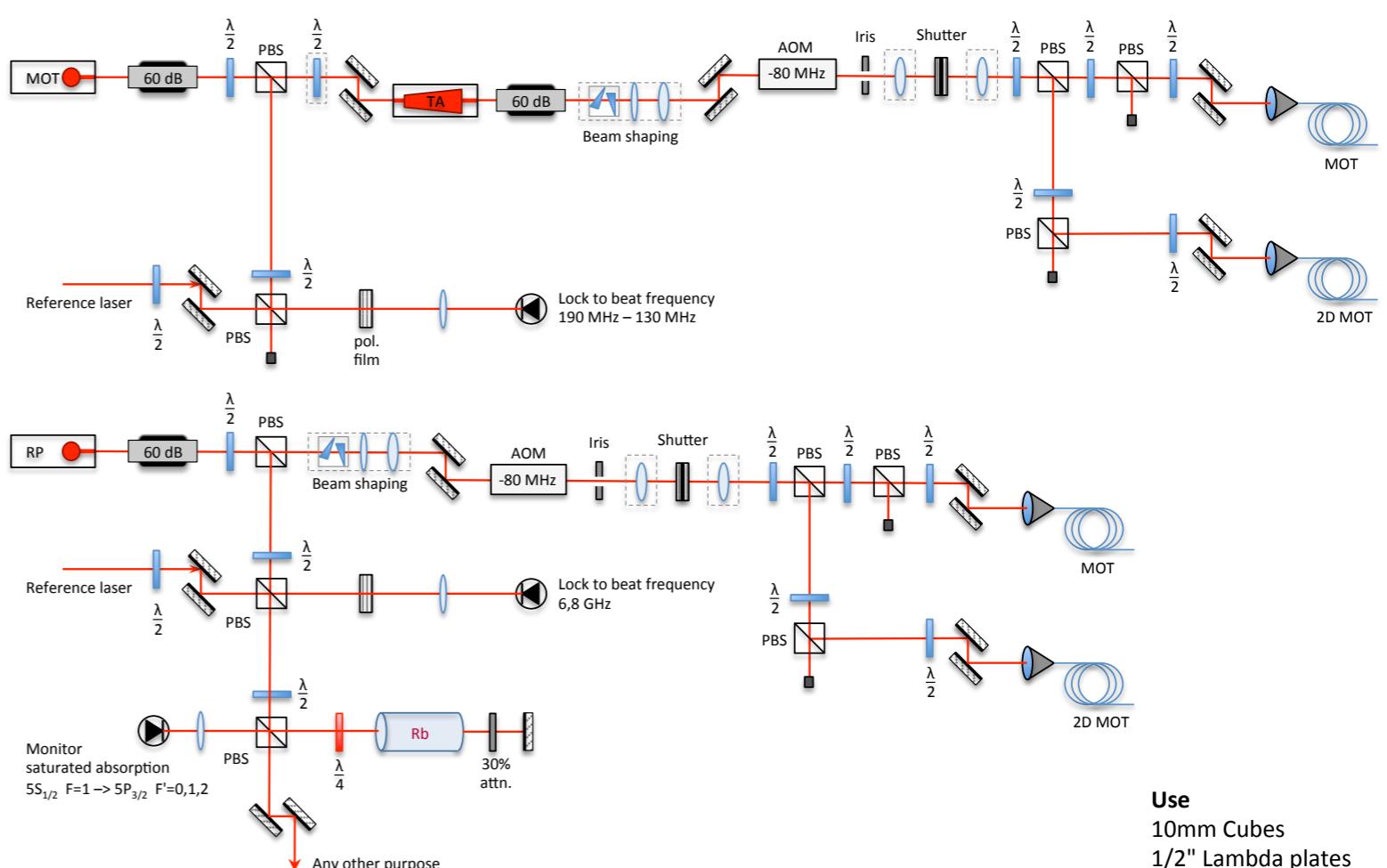


# Laser sources

Reference laser



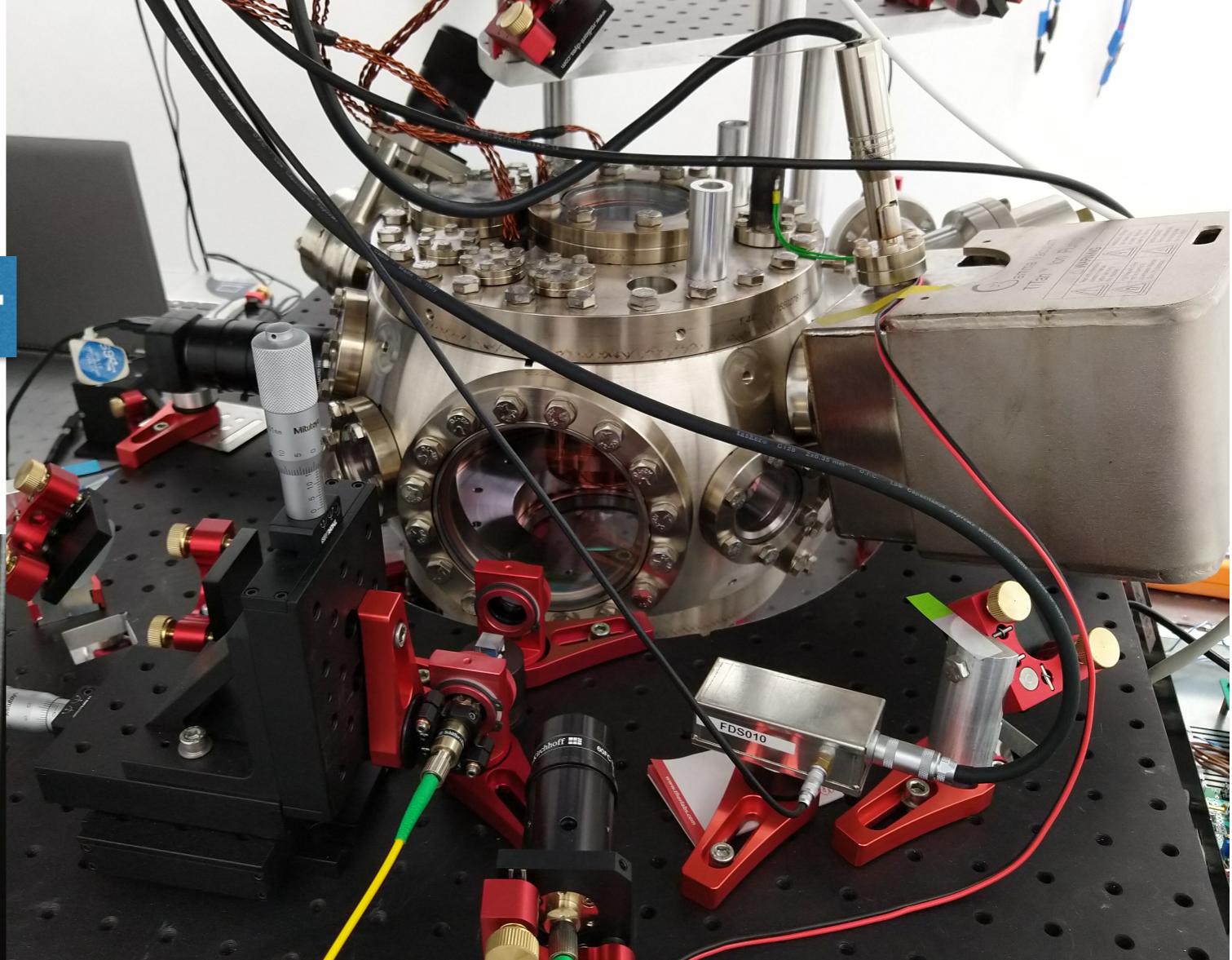
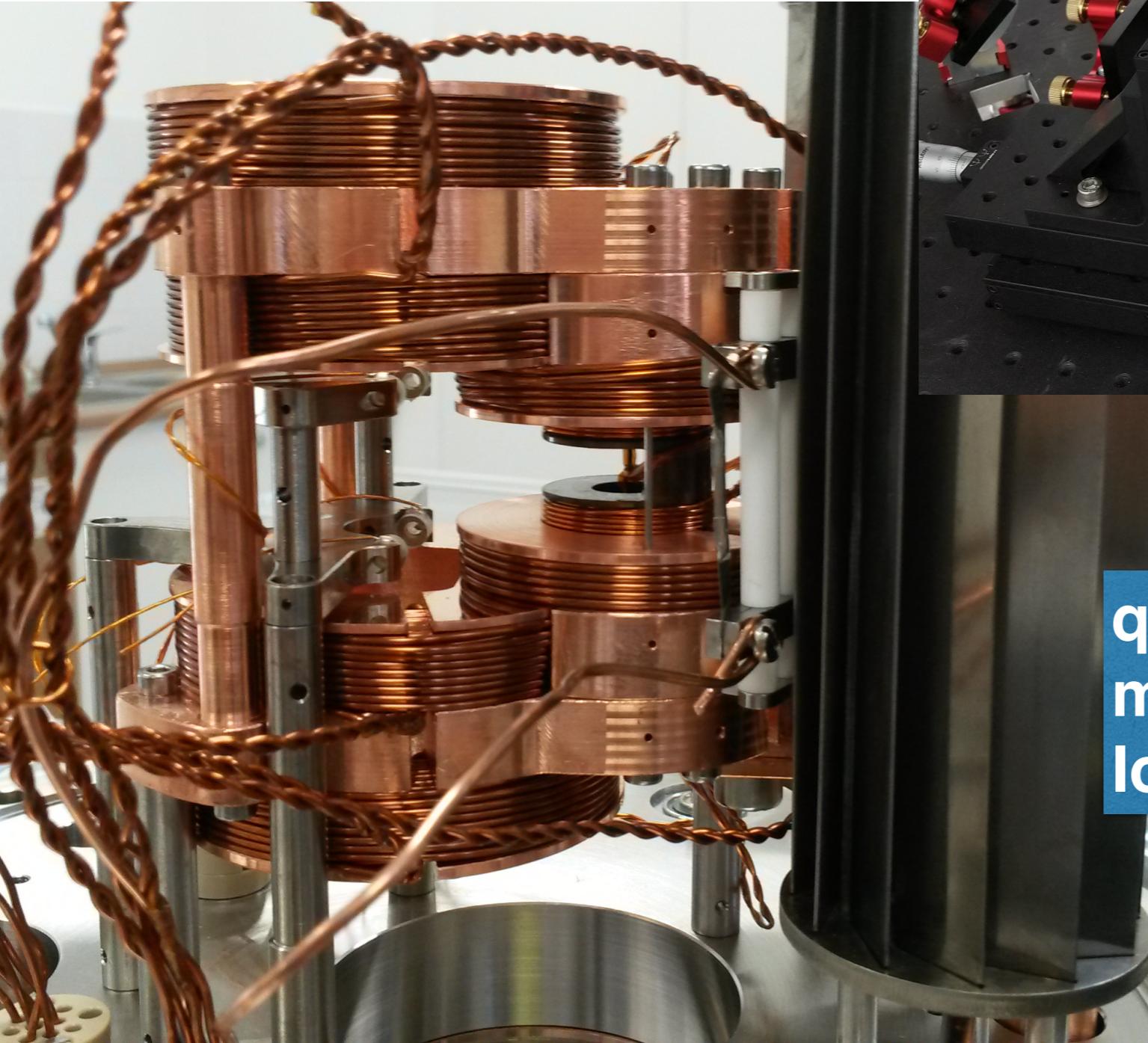
**frequency-stabilized  
narrow-band lasers**



**Use**  
10mm Cubes  
1/2" Lambda plates

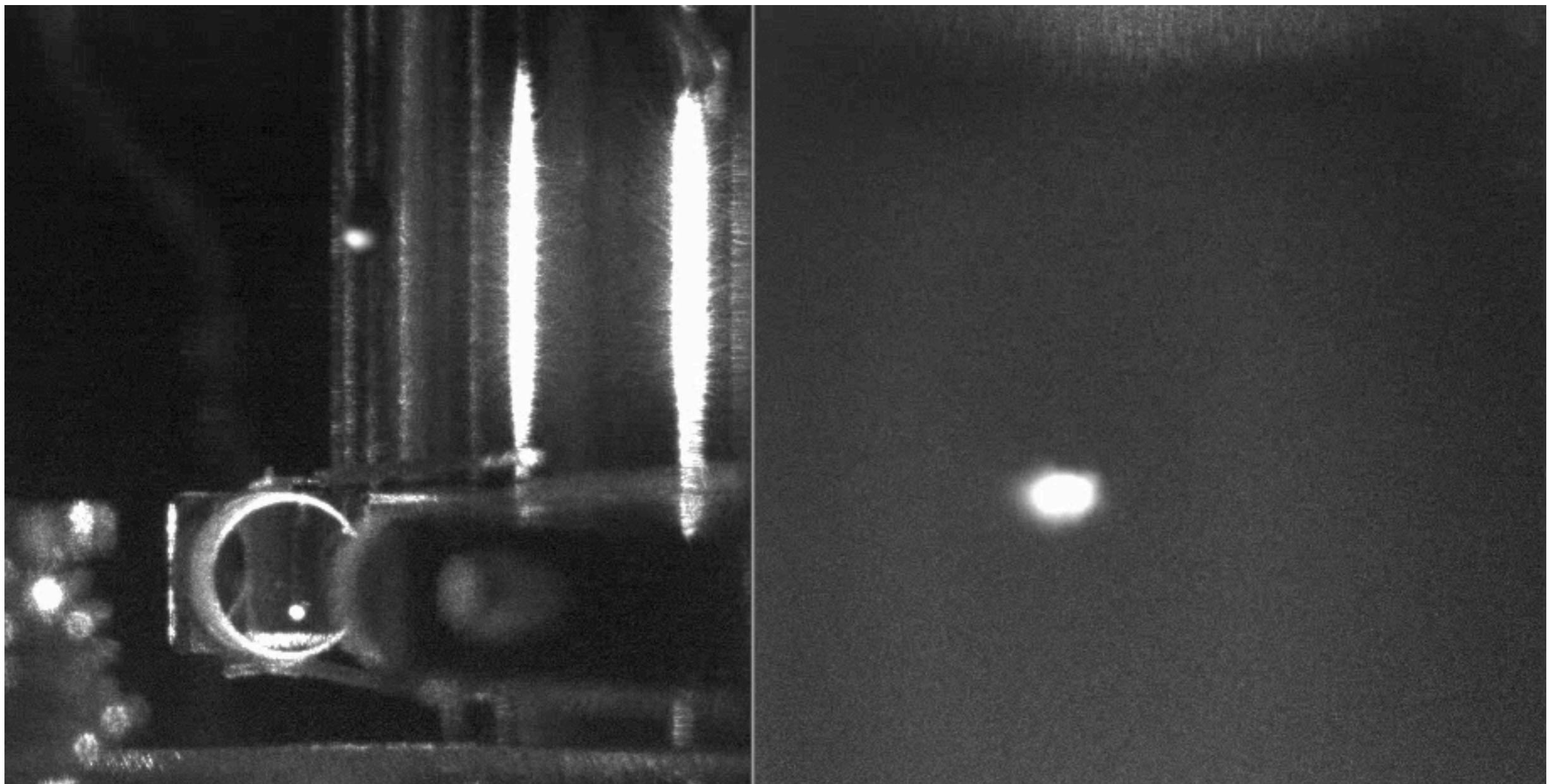
# UHV system

$\sim 10^{-11}$  mbar

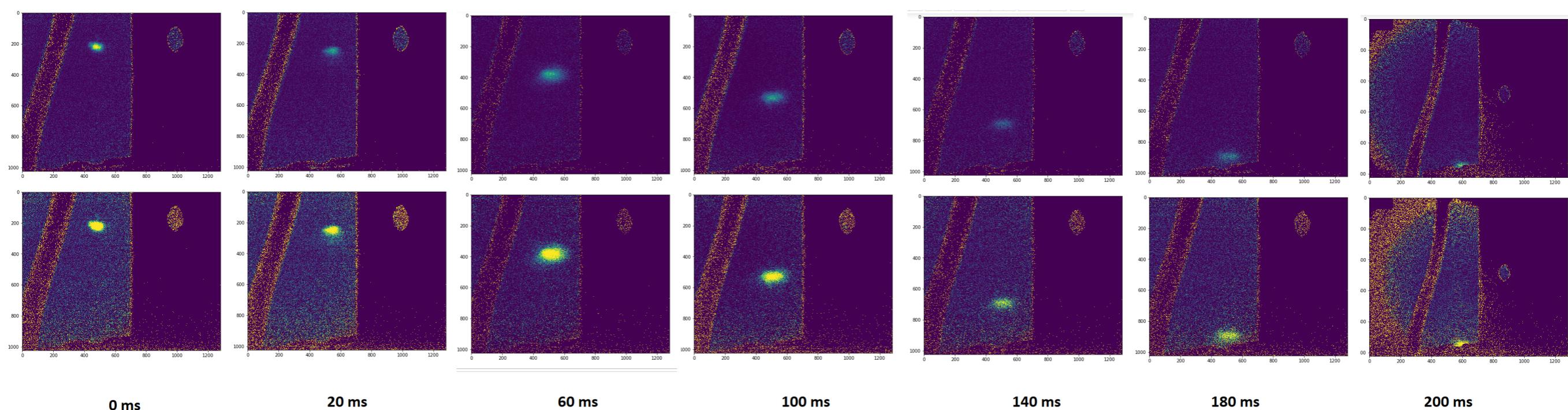


quadrupol trap +  
magnetic transport +  
Ioffe-Pritchard trap

# Cold atoms in the MOT

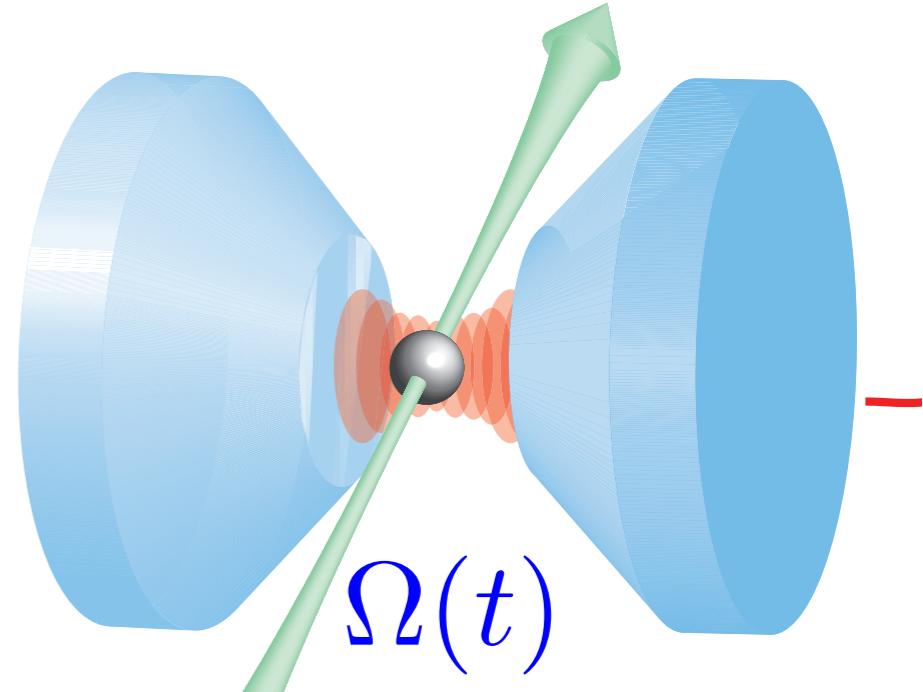
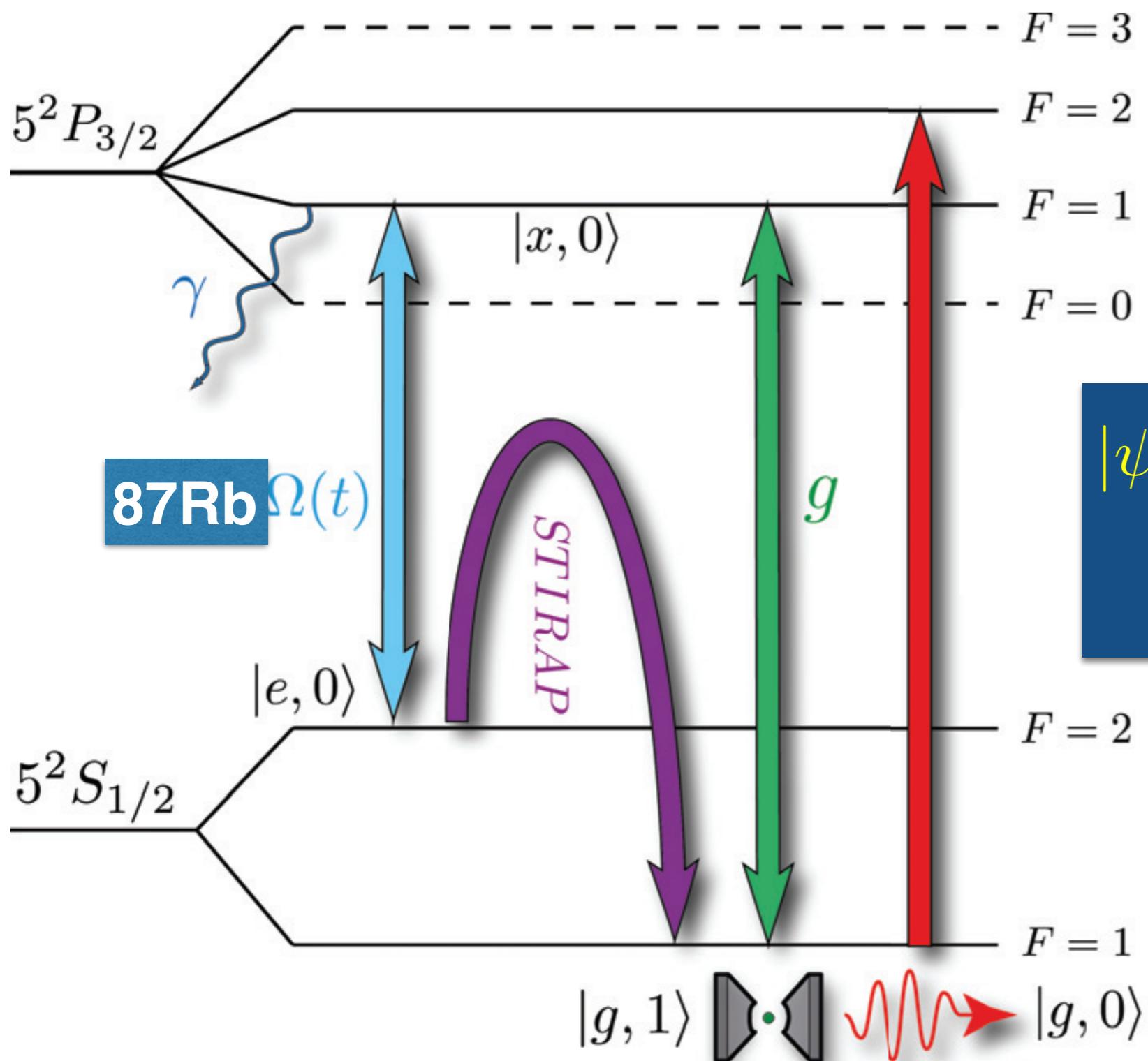


# Transporting the MOT into the cavity



# Quantum nonlinear optics

## Vacuum StiRAP



$$|\psi\rangle = \cos\theta|e, 0\rangle - \sin\theta|g, 1\rangle$$
$$\tan\theta(t) = \Omega(t)/2g$$

coherent pro

# Progress report

## Mérföldkövek

- Kvantummemória építéséhez az atom-foton interfész elemeinek beszerzése és az optikai rendszer kialakítása** 
- Az atom-foton rendszer vákuumkörnyezetének kialakítása** 
- Demonstrációs kísérletek optikai rezonátorban csatolt atom-foton rendszeren**
- Kvantummemória kísérlet optikai rezonátorban csatolt atom-foton rendszeren**

# The Quantum Optics group

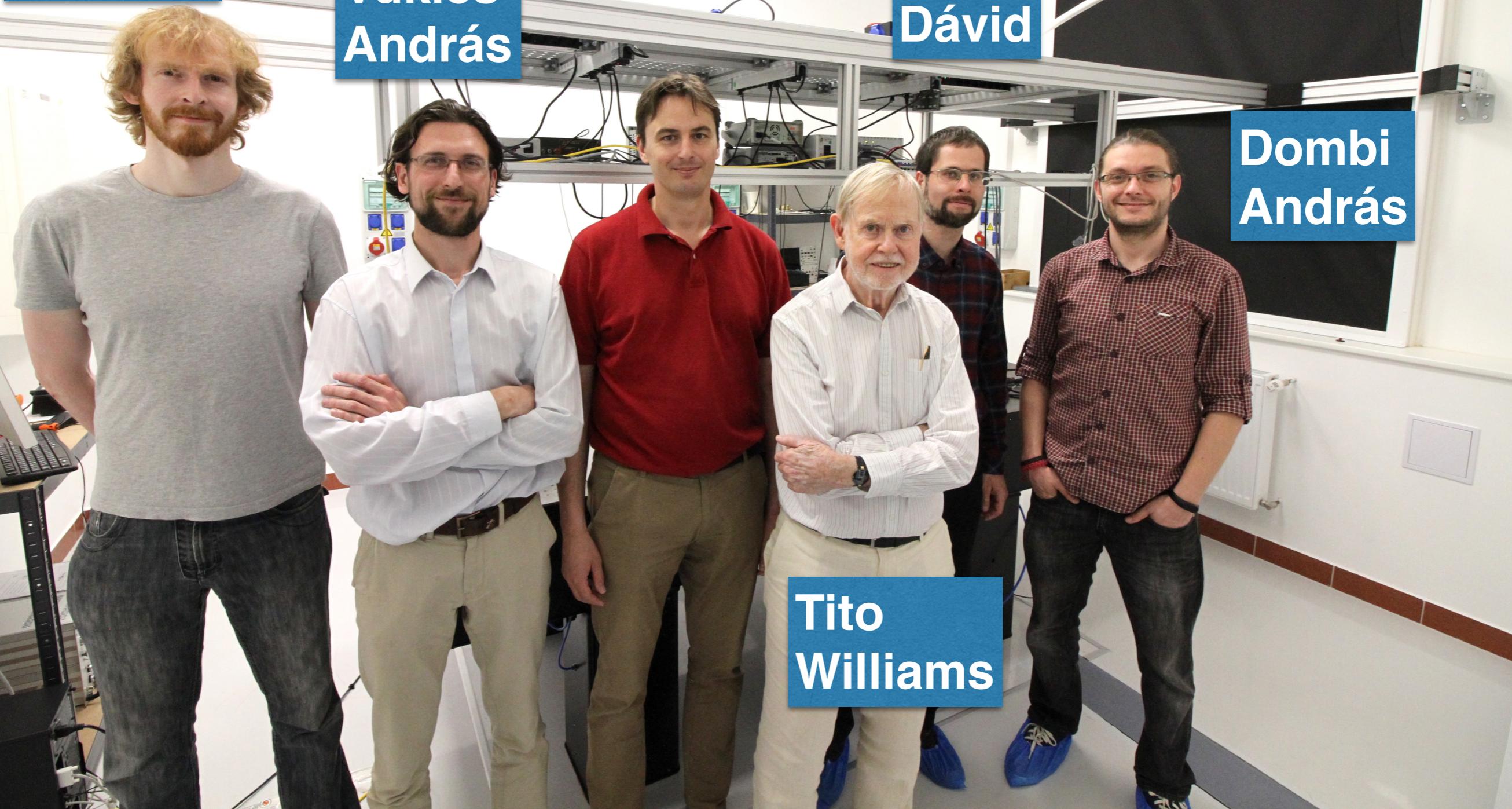
Thomas  
Clark

Vukics  
András

Nagy  
Dávid

Dombi  
András

Tito  
Williams



# Jaynes—Cummings model

+ loss + coherent drive + ...

$$H/\hbar = \omega_C a^\dagger a + \omega_A \sigma^\dagger \sigma + g(x) (a^\dagger \sigma + \sigma^\dagger a)$$

