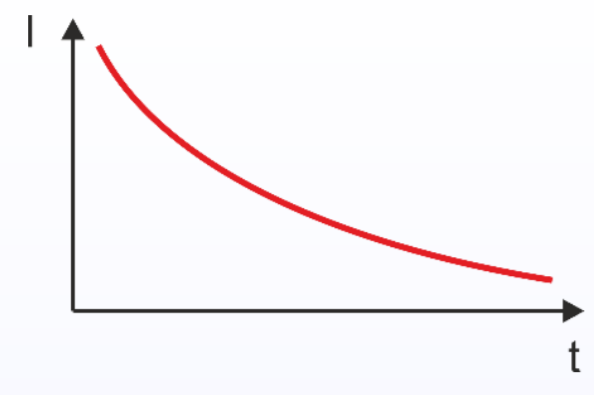
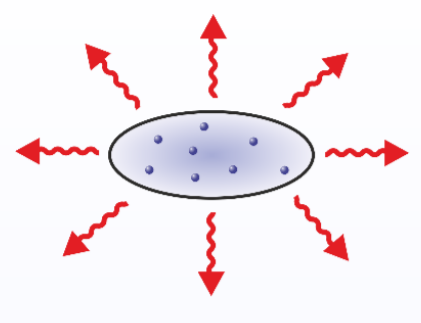
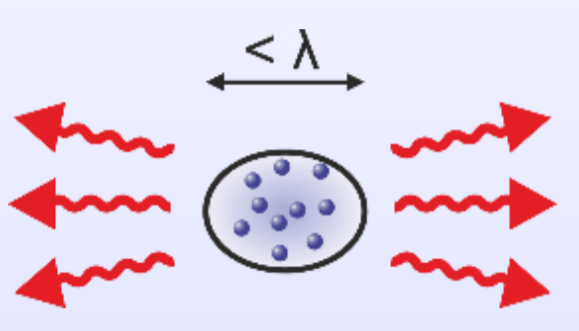


Collective effects



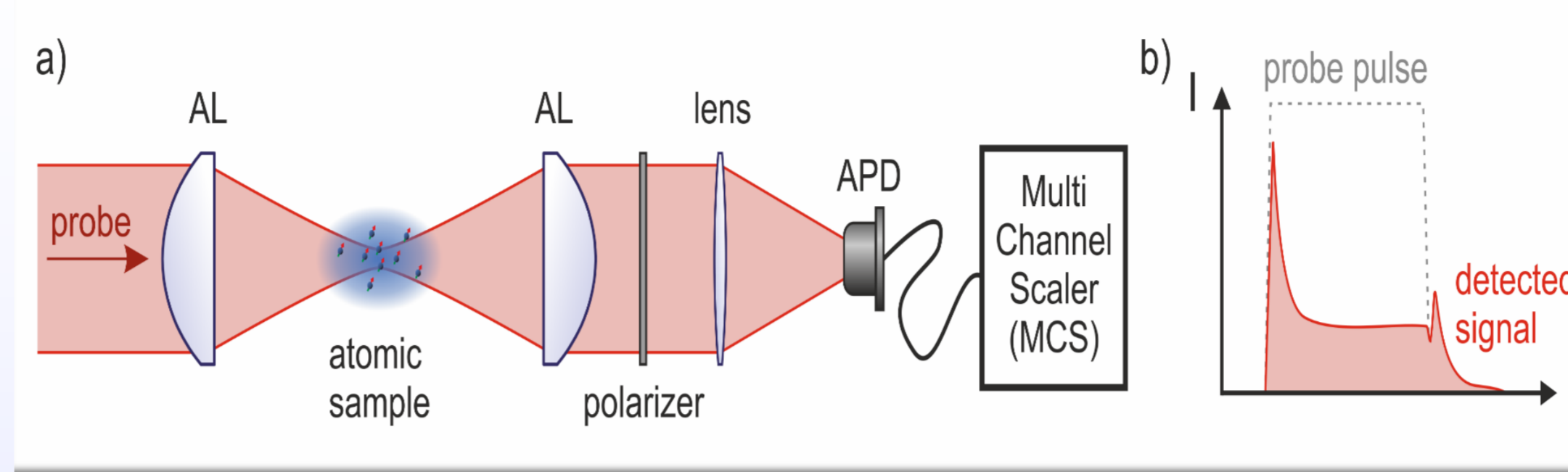
- Dilute samples
- Independent scattering events
- Exponential decay
- Randomized photon emission



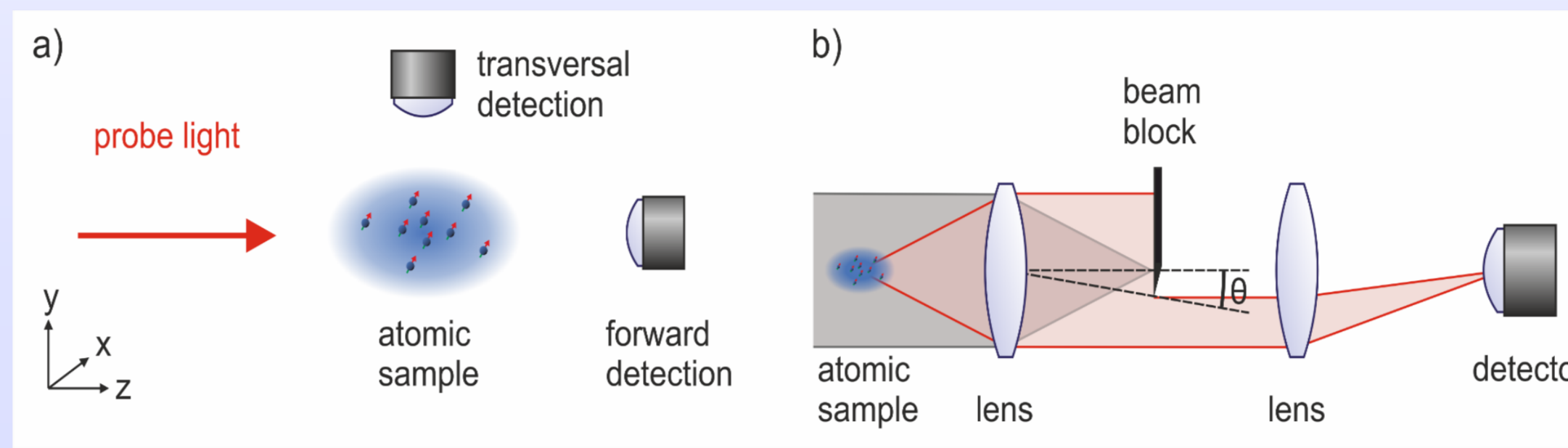
- Dense samples (N atoms in box with size $<$ wavelength)
- Enhanced decay rate and intensity
 - $I \propto N^2$
 - $\Gamma \propto N$
- Directionality in photon emission
- **Light-induced correlations between atomic dipoles**

Alterations in cooperative behaviour: Magnetic interactions

Temporal signature



Spatial signature



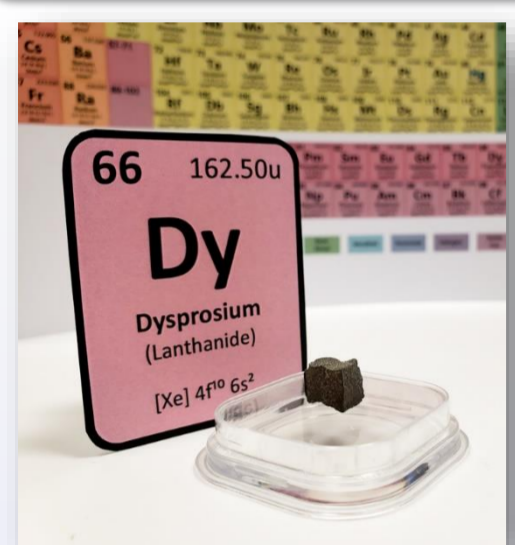
- Measure optical response of the atoms probed with short laser pulses.
- Observe decay dynamics after probe shut-off.
- Determine angular emission profile.
- Recurrent scattering can lead to scrambling of polarization.
- Enhanced scattering in forward direction

• Light-induced correlations and recurrent scattering influence light propagation.

• Magnetic interactions also impact light propagation. Dy is the ideal candidate.

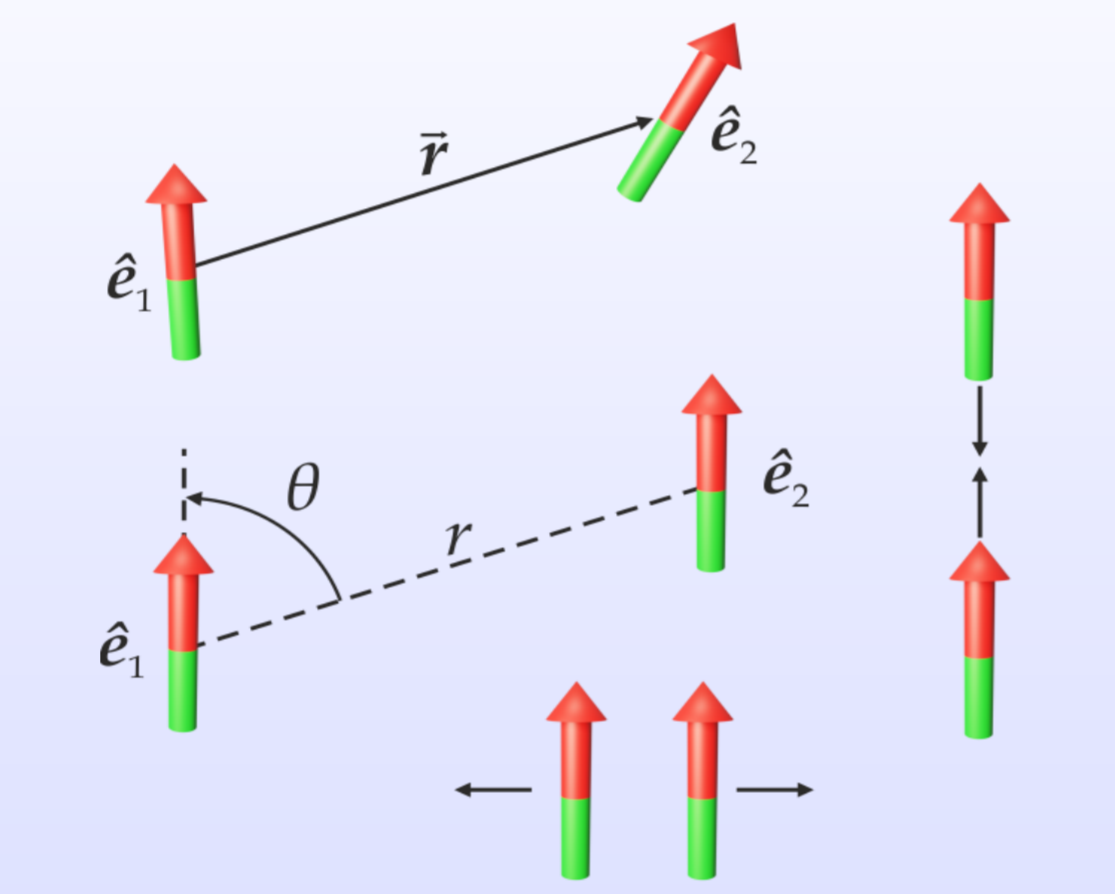
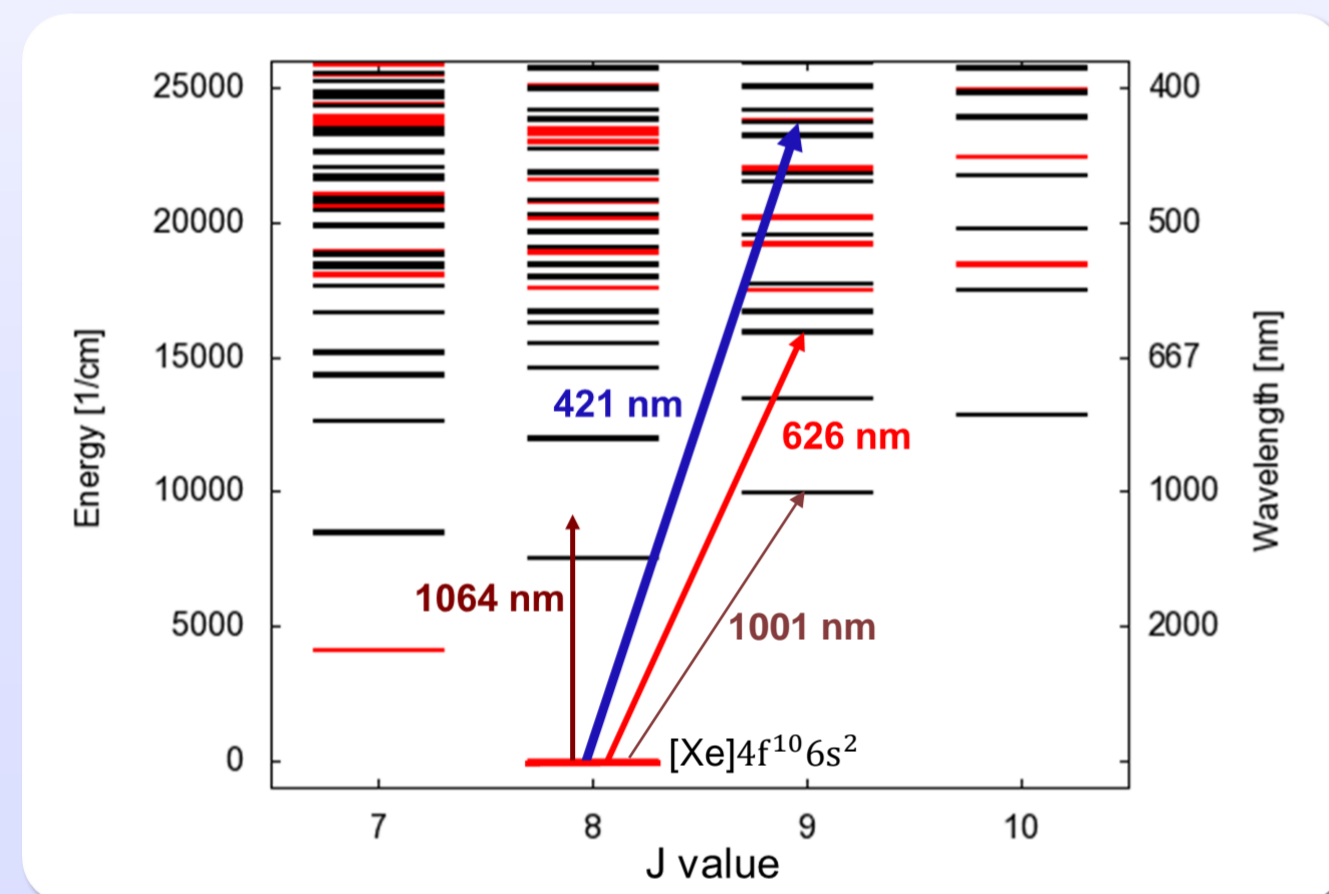
• We want to study the competition between these two processes.

Dysprosium



Why dysprosium:

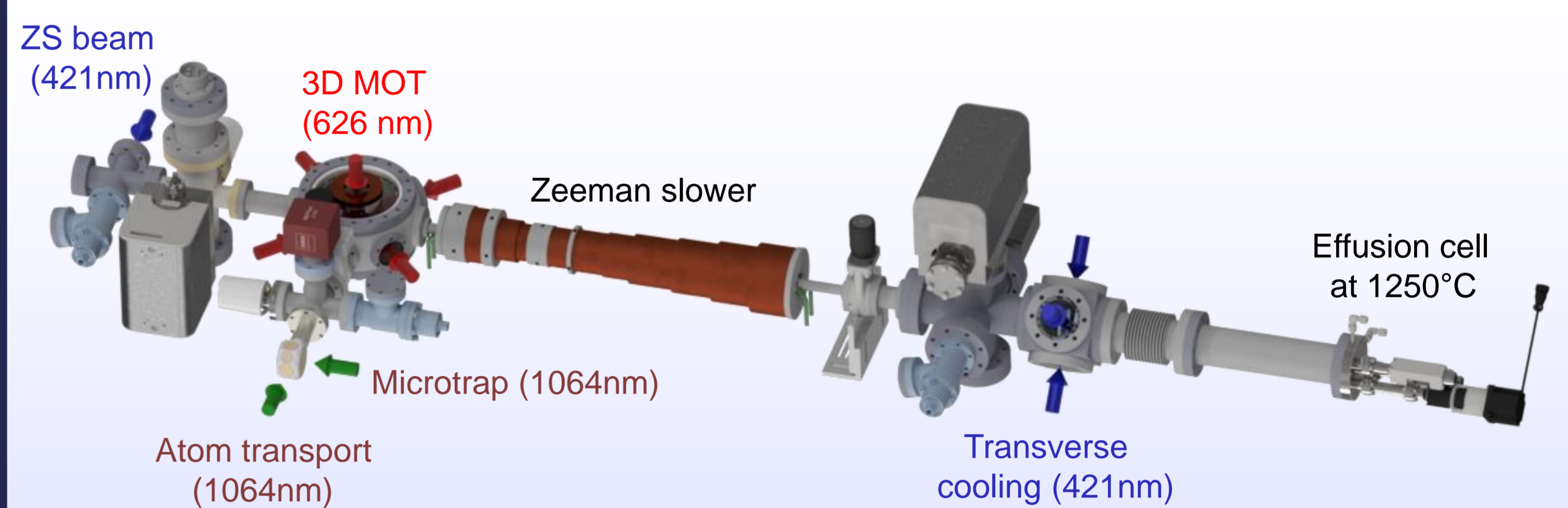
- Large ground state magnetic moment ($\mu = 10 \mu_B$)
- Long range, anisotropic magnetic dipole-dipole interaction
- Different linewidths enable widely different parameter regimes



Cooling transitions:

Line	$\Gamma/2\pi$	I_{sat}	$T_{Doppler}$
421 nm	32.2 MHz	56.4 mW/cm ²	774 μ K
626 nm	136 kHz	72 μ W/cm ²	3.2 μ K

Experimental setup



Initial cooling and imaging at 421 nm:

- Commercial ECDL: 60 mW at 842 nm
- Two home built Tapered Amplifier (TA) and Second Harmonic Generation (SHG) stages generate 220 mW at 421 nm each

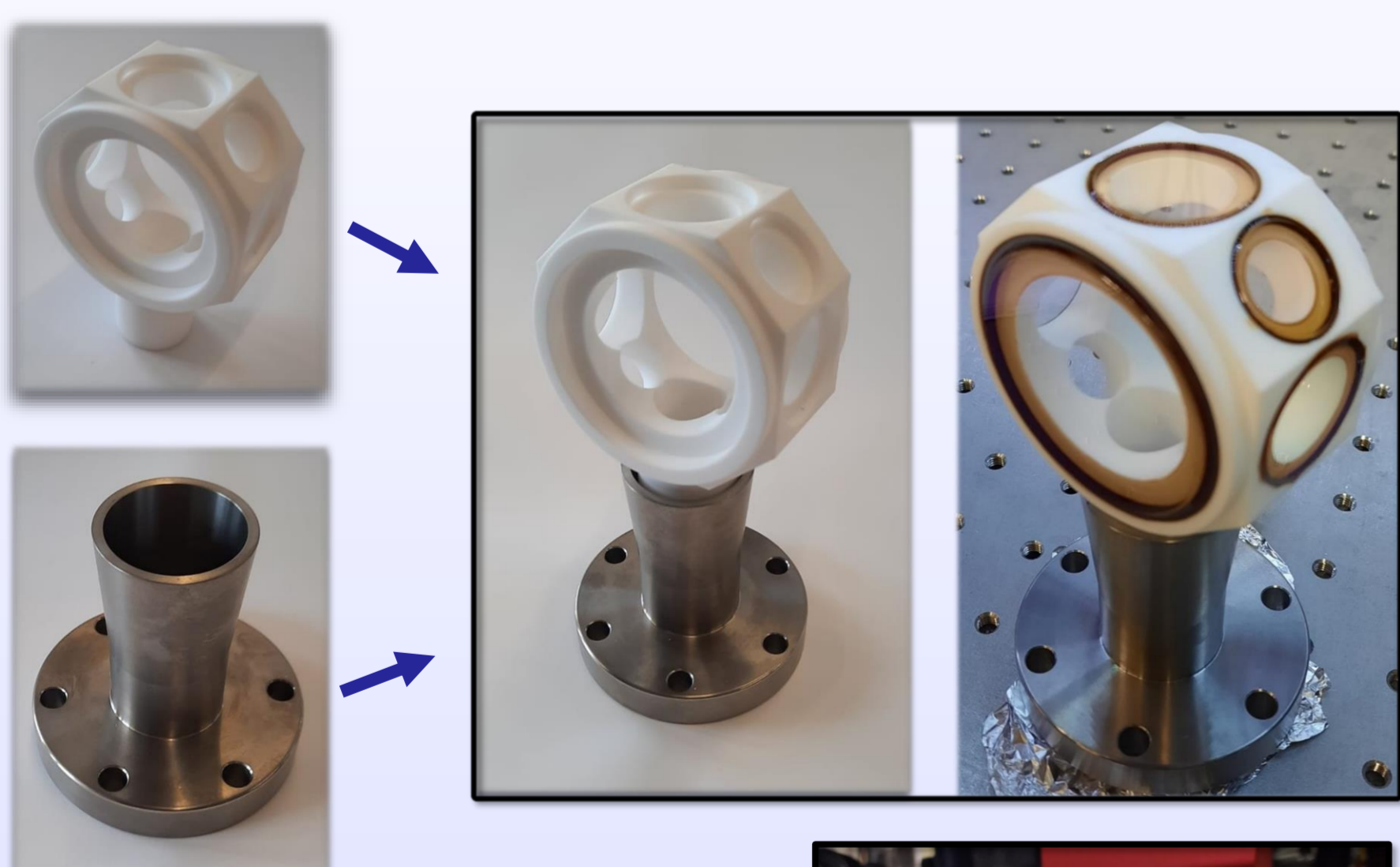
3D MOT at 626 nm:

- Commercial 5 W fiber lasers at 1550 nm and 1050 nm
- Sum Frequency Generation (SFG) in Periodically Poled Lithium Niobate (PPLN) generates 2.2 W at 626 nm

Science cell extension

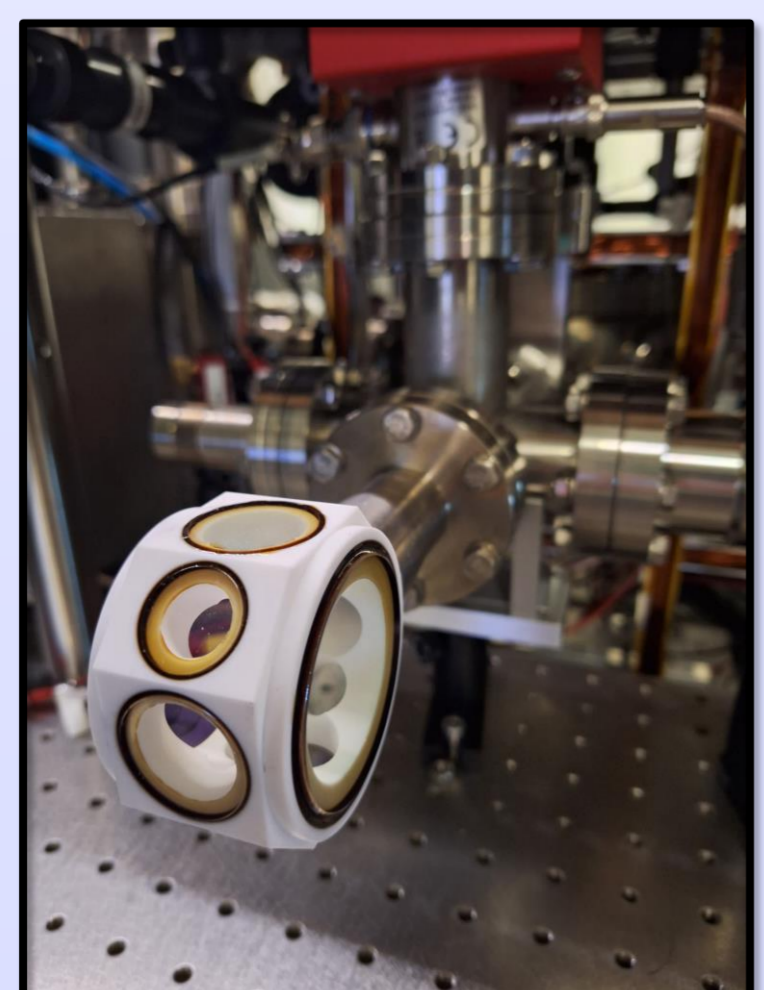
Science Cell

- Precise control of the atomic samples properties required \rightarrow high optical access
- Self-built epoxy bonding based UHV cell
- Conical adapter system of different opening angles to bond Macor \leftrightarrow Titanium
- Fused silica windows coated for 421nm, 626nm and 1064nm

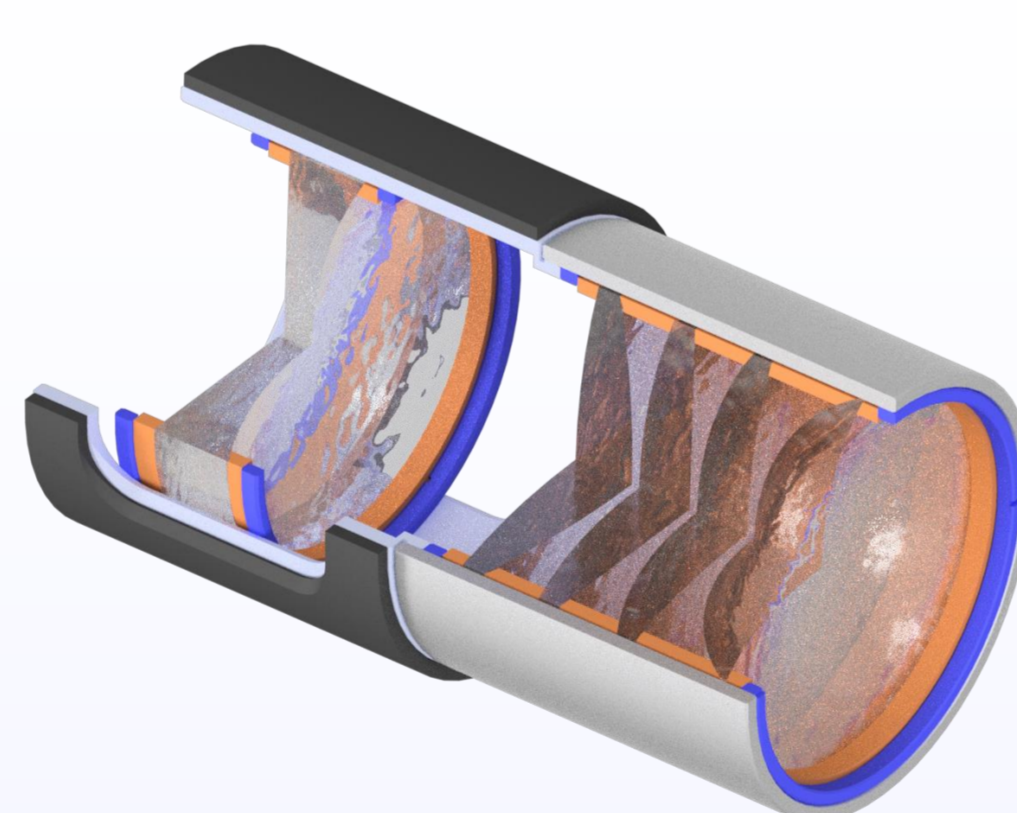


Implementation

- Pressure of $< 1 \cdot 10^{-10}$ mbar reached so far
- Atomic transport and dipole trap lifetime measurements ongoing...

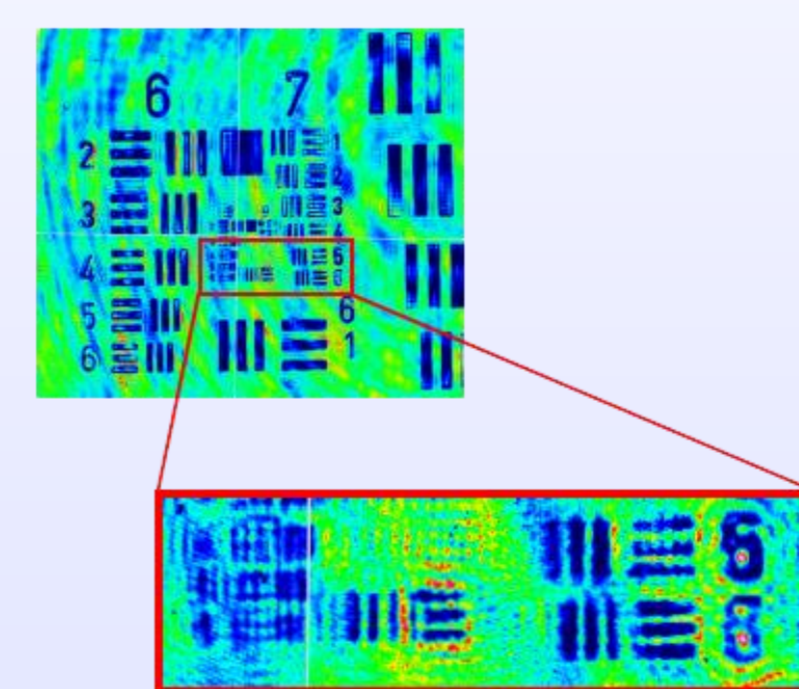


Microtrapping & Imaging



Microscopic optical dipole trap for creating dense Dy samples

- For average atomic distances $< \lambda$ an average density of $n_{avg} > 1 \cdot 10^{12}/cm^3$ is required
- Multi-color (1064 nm for trapping, 626 nm and 421 nm for probing)
- High numerical aperture (NA = 0.53)
- Working range ~ 32 mm
- Horizontal and vertical beam waist $\omega_H = 9.2 \pm 0.2 \mu m$ / $\omega_V = 7.0 \pm 0.2 \mu m$
- Resolution 256 lp/mm or 1.95 μm



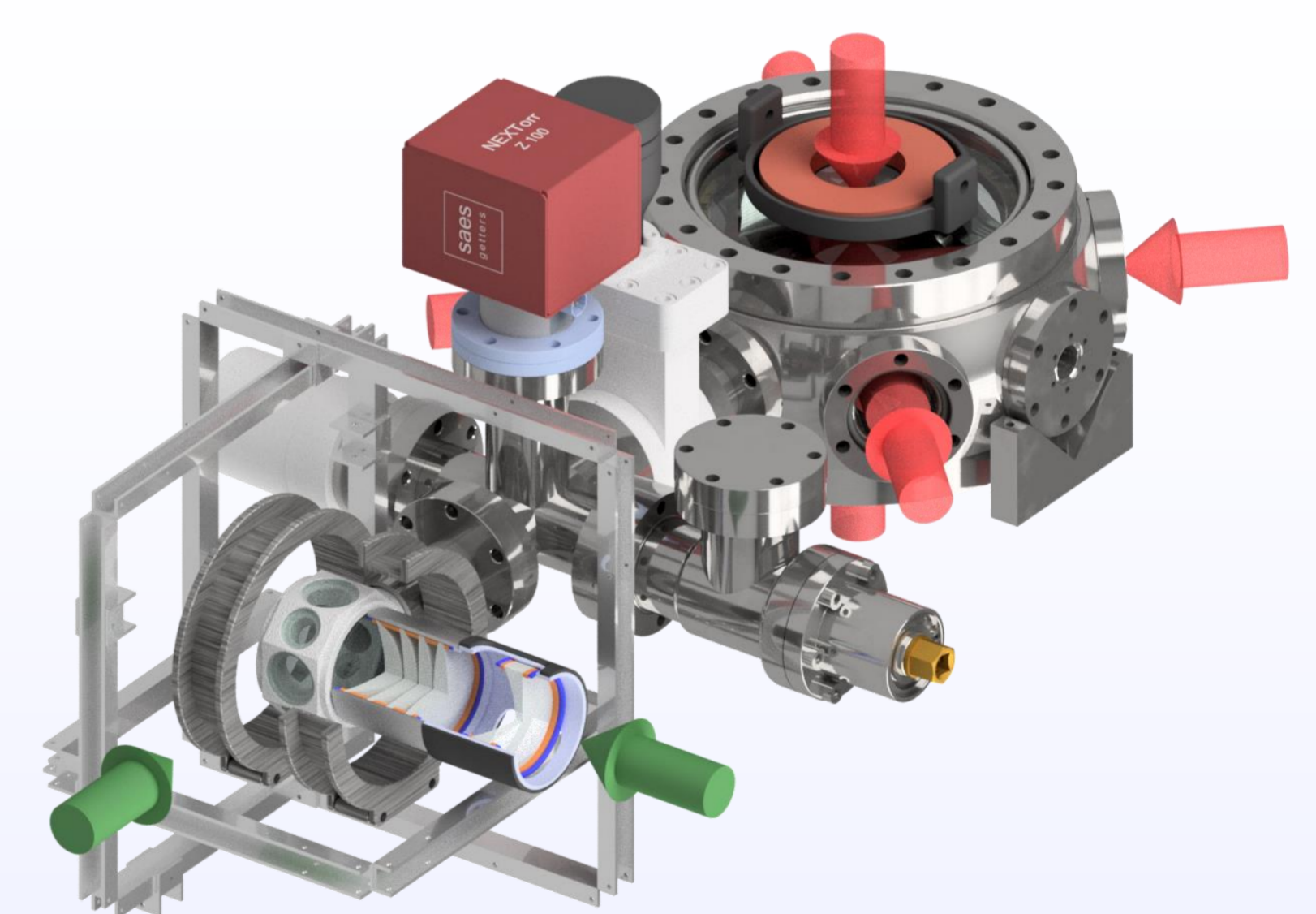
Andor iXon Ultra 888



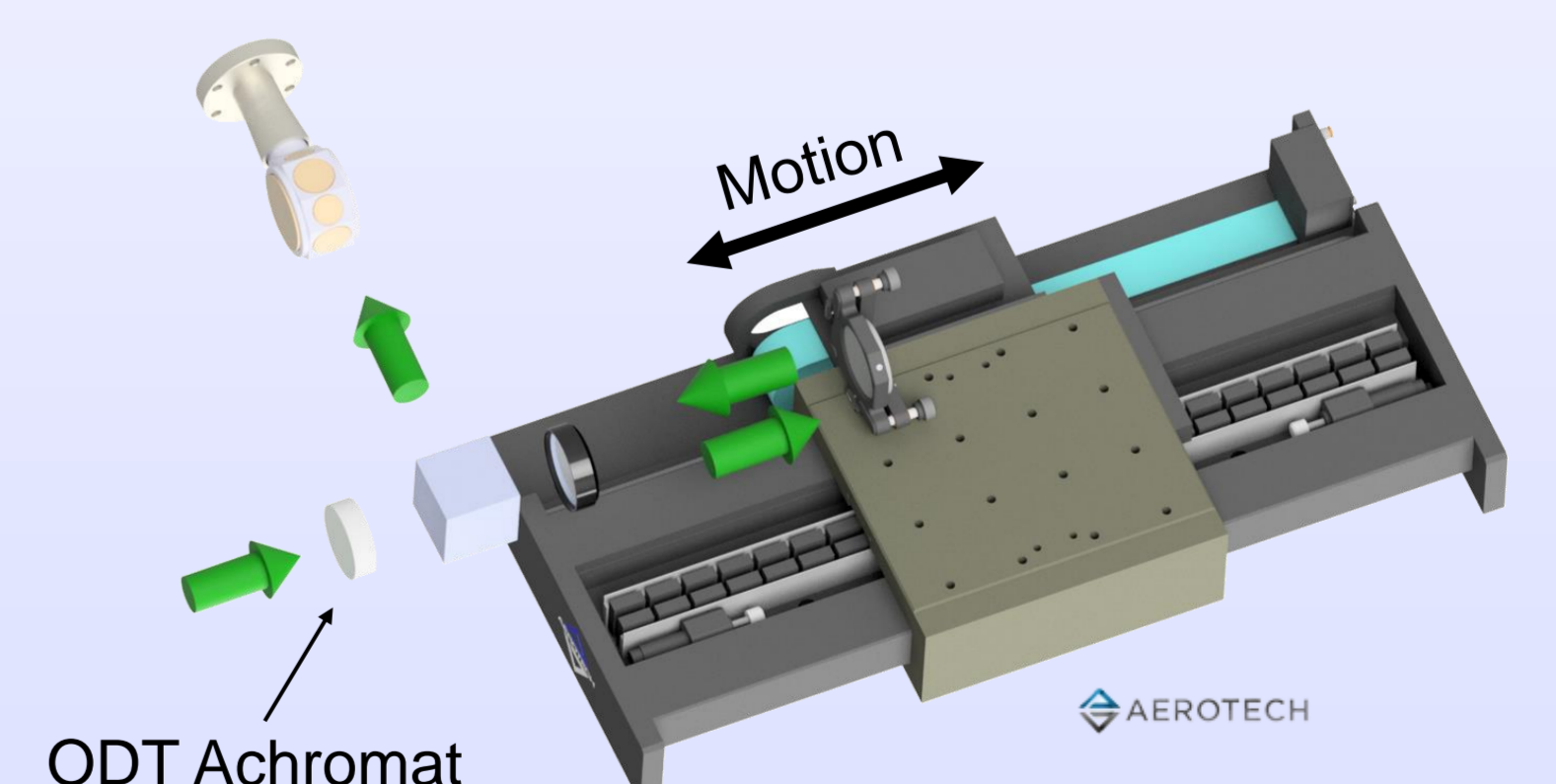
Fluorescence Imaging

- Few hundred atoms expected in the trap
- Fluorescence collection suited for low photon counts \rightarrow EMCCD
- Self-designed fluorescence collection + telephoto objective

Final assembly



- Optical transport from MOT chamber to science cell utilizing an air-bearing translation stage



- Differential out-pumping of science cell using NexTorr ion pump
- Subsequent trapping in microscopic ODT through power redistribution
- Helmholtz coils for tuning contact interactions

Acknowledgement: We thank the funding agencies for supporting our work