



Transverse Field Zeeman Slower for ^7Li from Permanent Magnetic Dipoles

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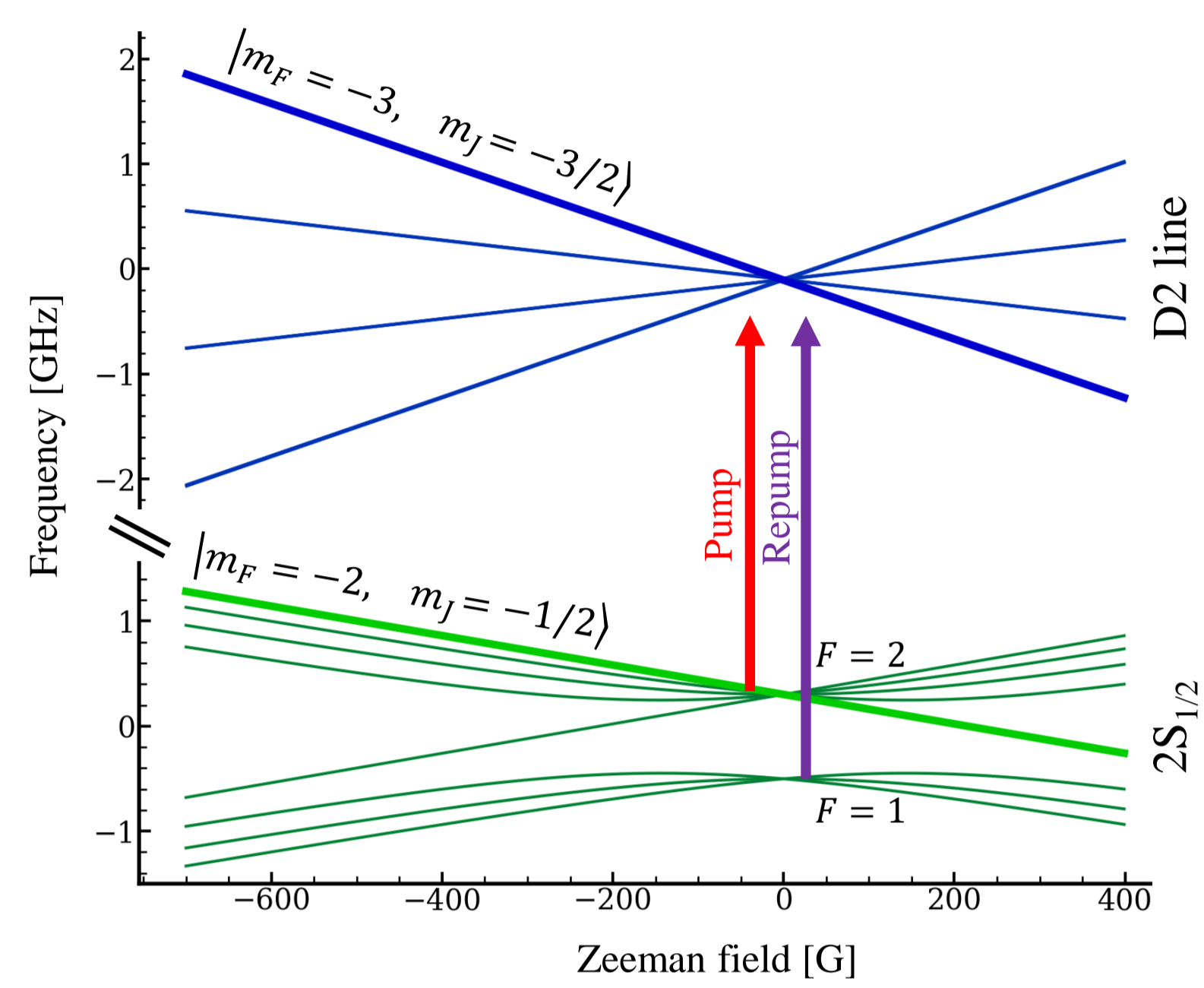
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Abstract

In the field of ultracold atoms Zeeman slower are commonly used for slowing down atomic beams. The conventional method typically involves electromagnets with high current which require water cooling and introduce further complications to the system. Here we present our design of a Zeeman slower made from an array of individual magnetic dipoles in a cylindrical Halbach configuration. This alternative method creates a stable and robust uniform transverse field while allowing high tunability of the spatial dependence of that field along the symmetry axis. Due to some details of lithium energy spectrum, a zero-crossing transverse field configuration poses unique challenges to its characterization. We present experimental result of its performance, together with theoretical description of interesting features found in this device.

^7Li Zeeman Spectra



Field Functional Form

Maximal deceleration due to photon recoil: $a_{max} = \frac{F_{max}}{m} = \frac{1}{m} \frac{\Delta p}{\Delta t} = \frac{\Gamma \hbar k}{2m}$

Scattering rate: $\gamma = \Gamma \cdot \frac{s_0}{1 + s_0 + (2\delta/\Gamma)^2}$ $s_0 = I/I_{sat}$

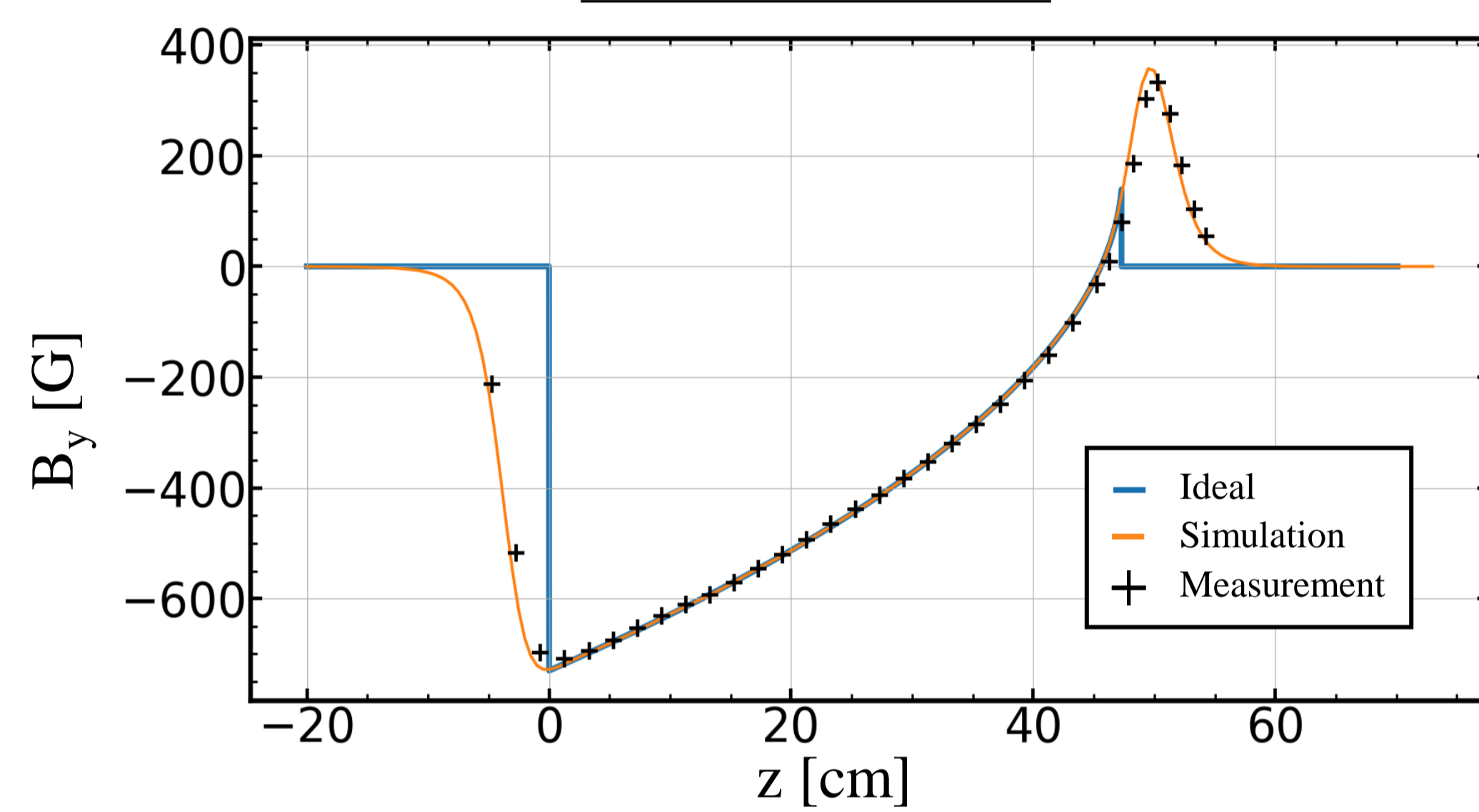
$v_z = \sqrt{v_0^2 - 2az}$ \rightarrow $B(z) = \frac{\hbar\delta_0}{\mu} - \frac{\hbar k}{\mu} \sqrt{v_0^2 - 2\eta \frac{\Gamma \hbar k}{2m} z}$

Margin for field deviations: $a = \eta a_{max}$ $\eta = 0.5$

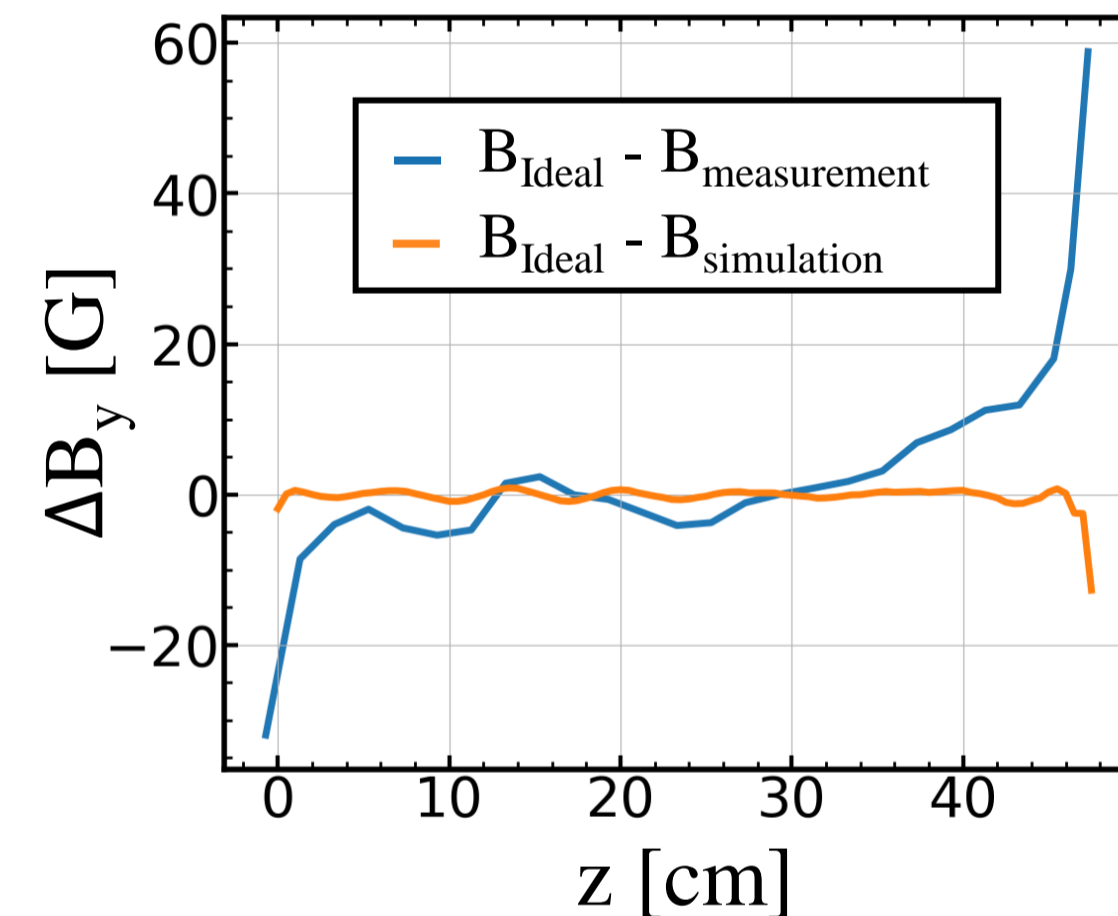
Zeeman shift to compensate for doppler shift: $\delta = \delta_0 - \vec{k} \cdot \vec{v} - \frac{\mu B}{\hbar} = 0$

$v_0 = 850$ m/s $\delta_0/2\pi = -240$ MHz
 $v_f = 30$ m/s

Field Measurement

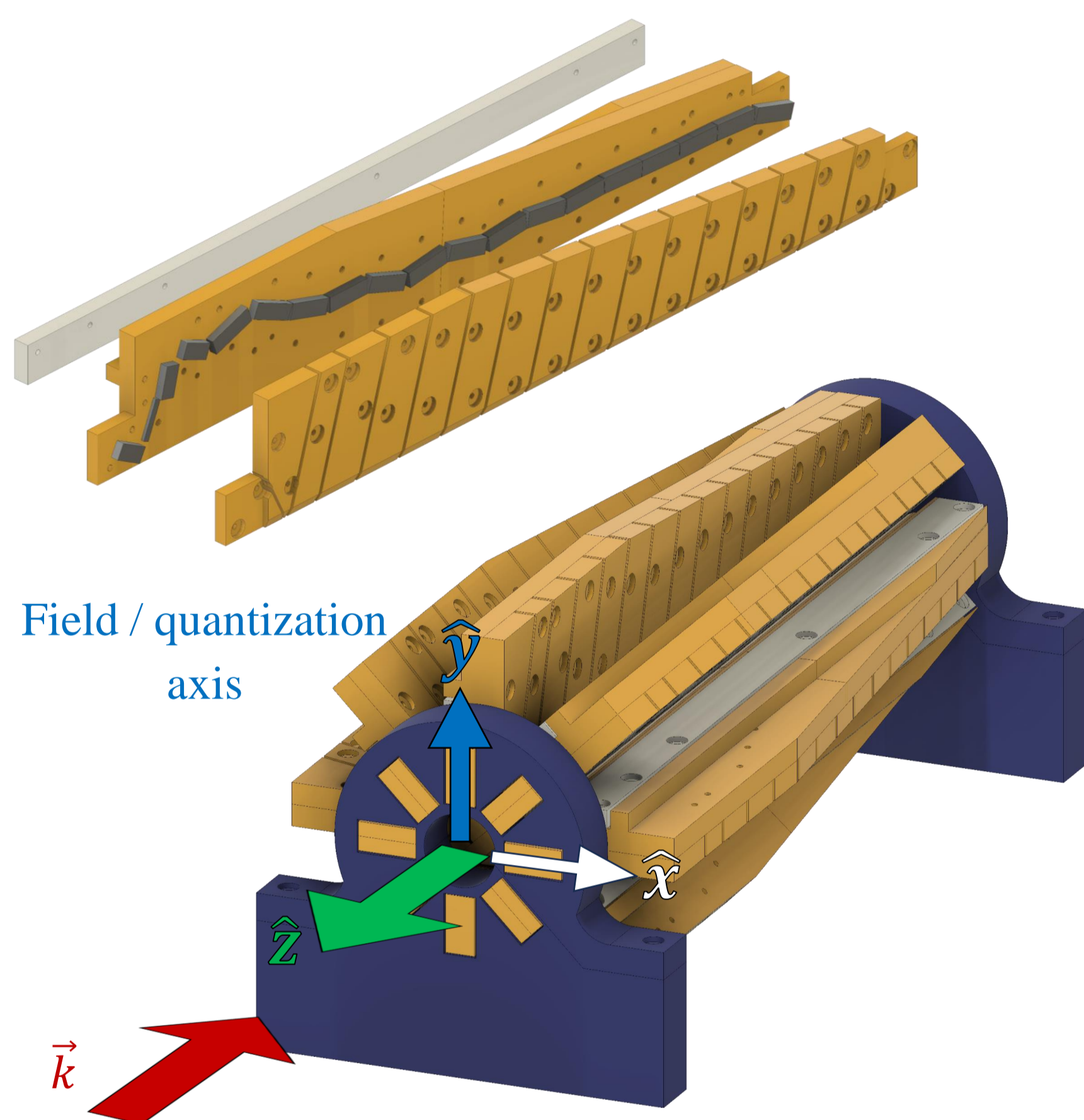
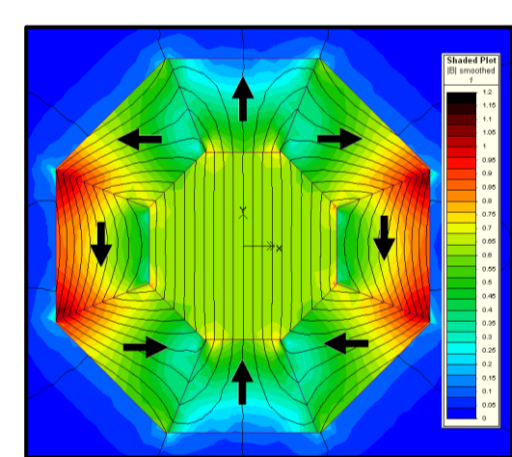


Field Difference



Cylindrical Halbach array

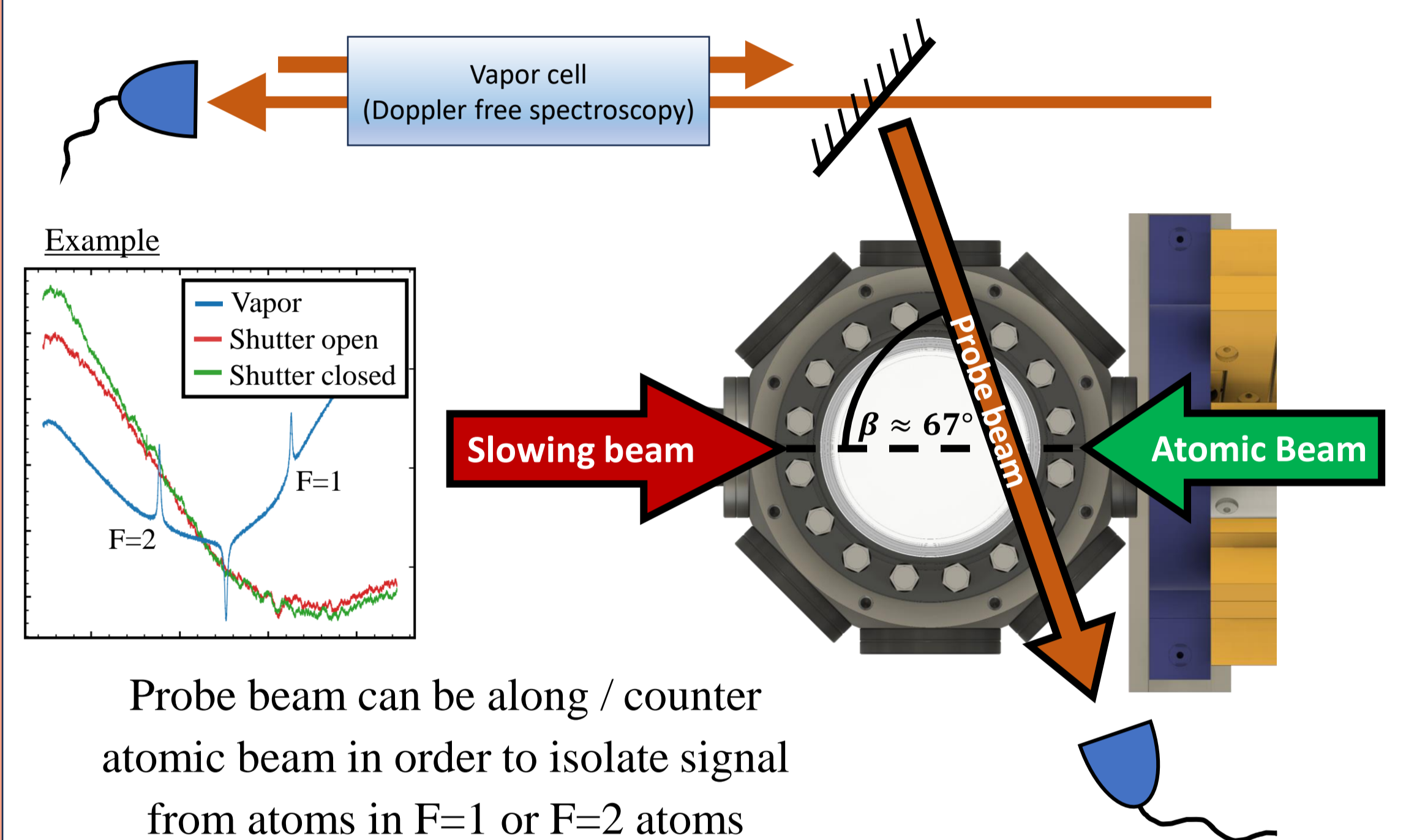
- Uniform transverse field between the magnets.
- Vanishing field in the outer area.
- Simple flexible assembly.



Field / quantization axis

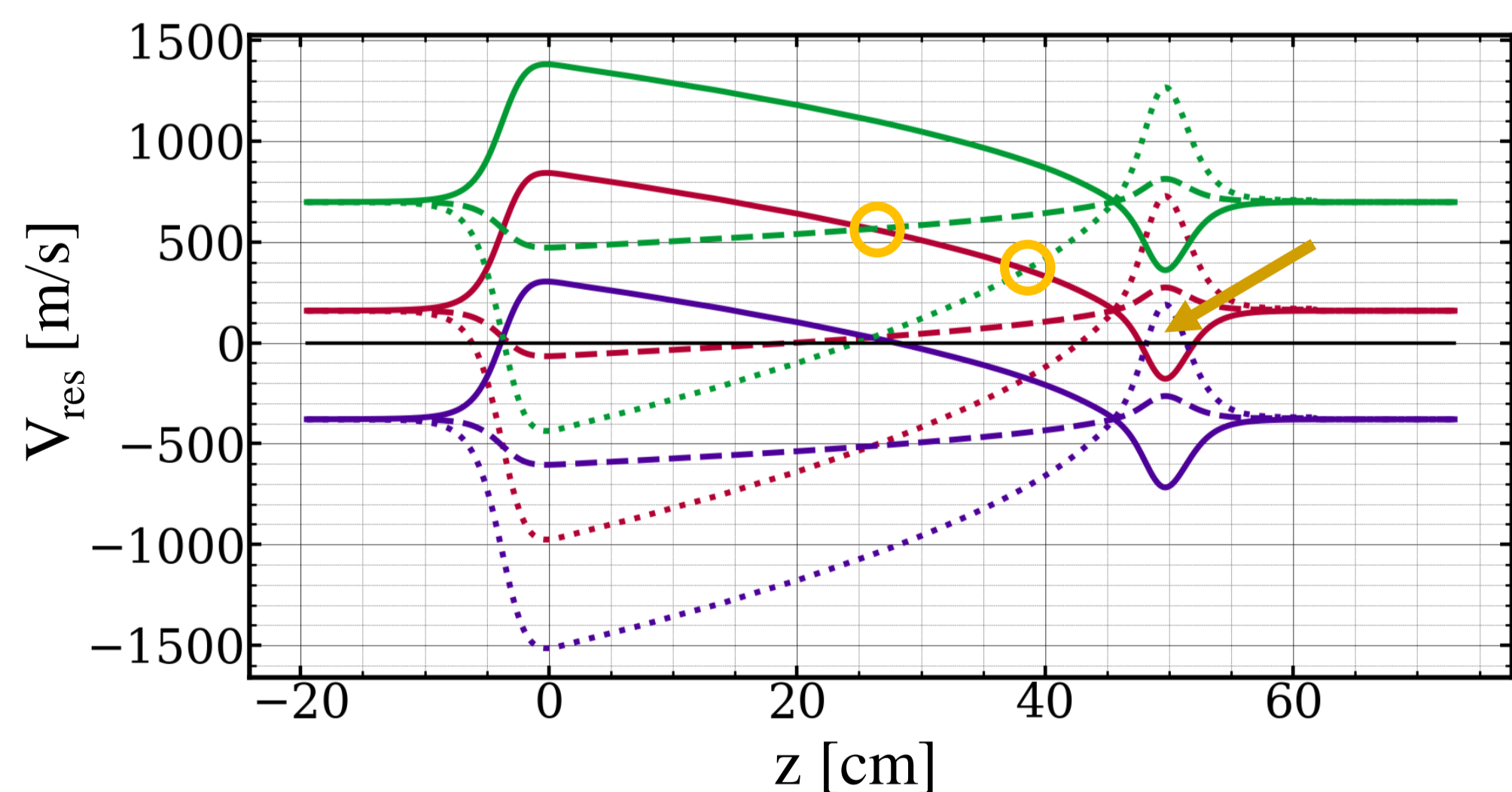
Light polarization: $\hat{x} = \sigma^+ + \sigma^-$ \rightarrow 50% of the light is in the wrong polarization

Velocity Sensitive Flux Measurement



Probe beam can be along / counter atomic beam in order to isolate signal from atoms in F=1 or F=2 atoms

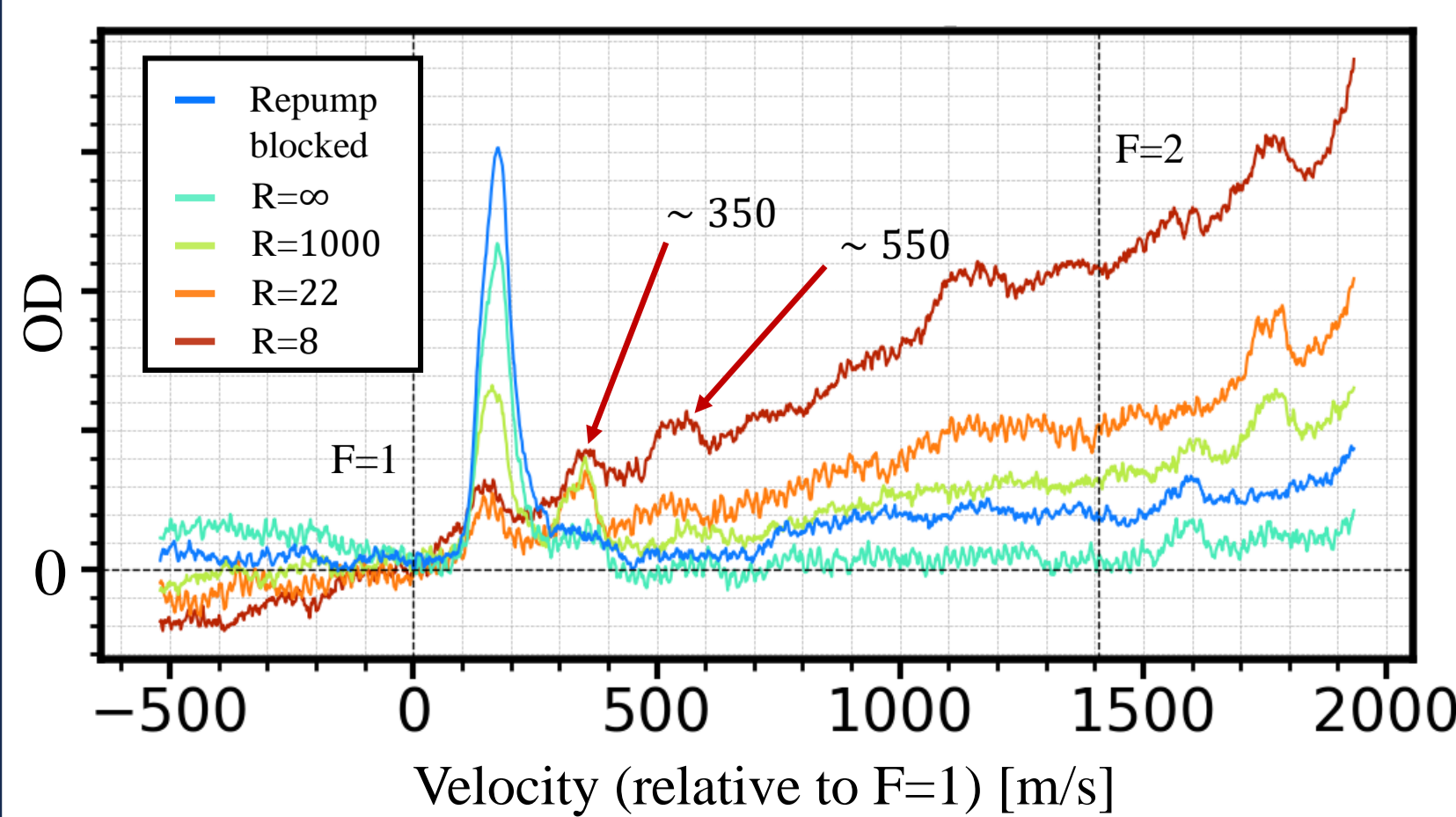
Optical Transitions from $|m_F = -2, m_j = -1/2\rangle$



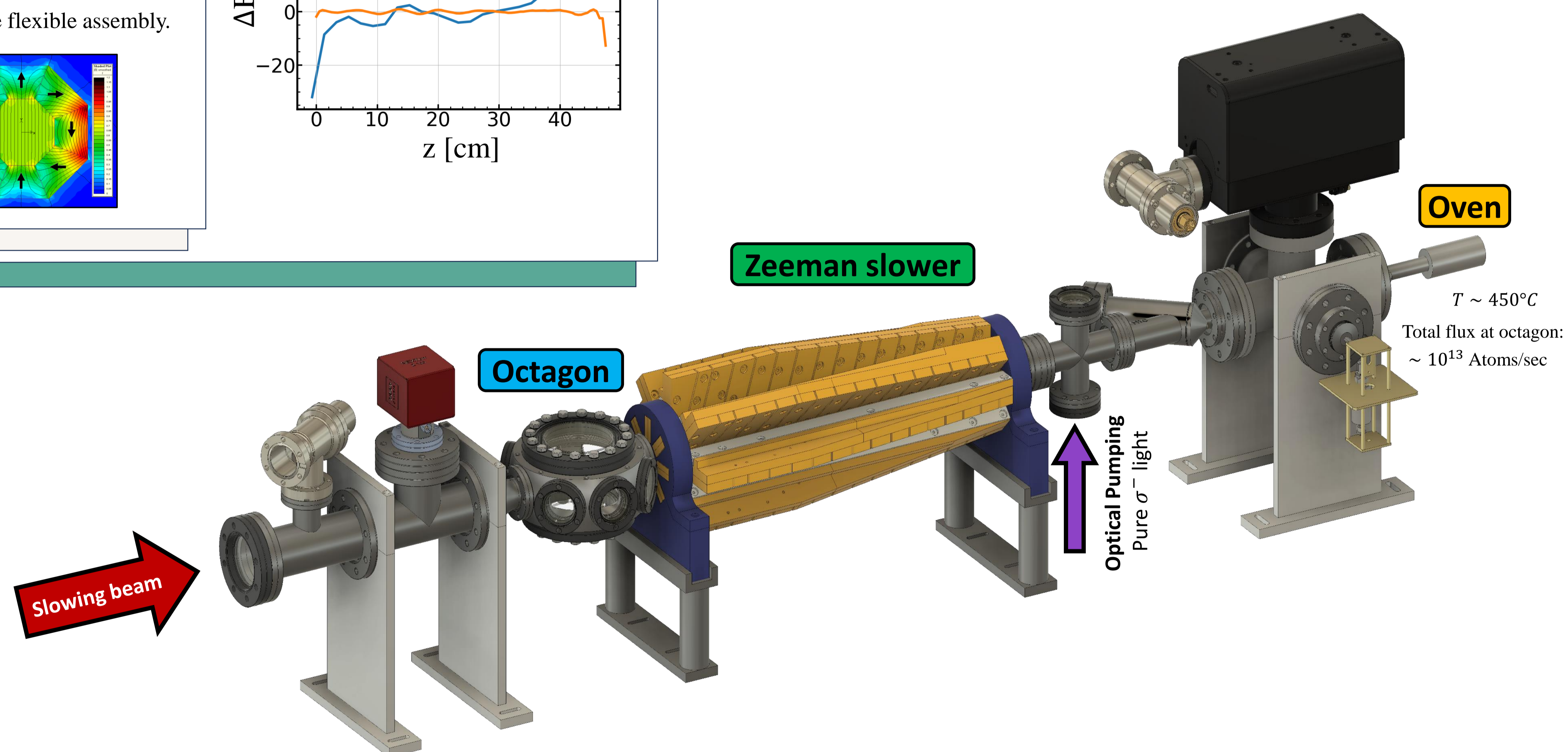
- σ^- (solid black), π (dashed black), σ^+ (dotted black)
- pump (solid red), repump (solid purple), sideband (solid green)

• Sidebands can be introduced by amplifying both frequencies on the same amplifier.

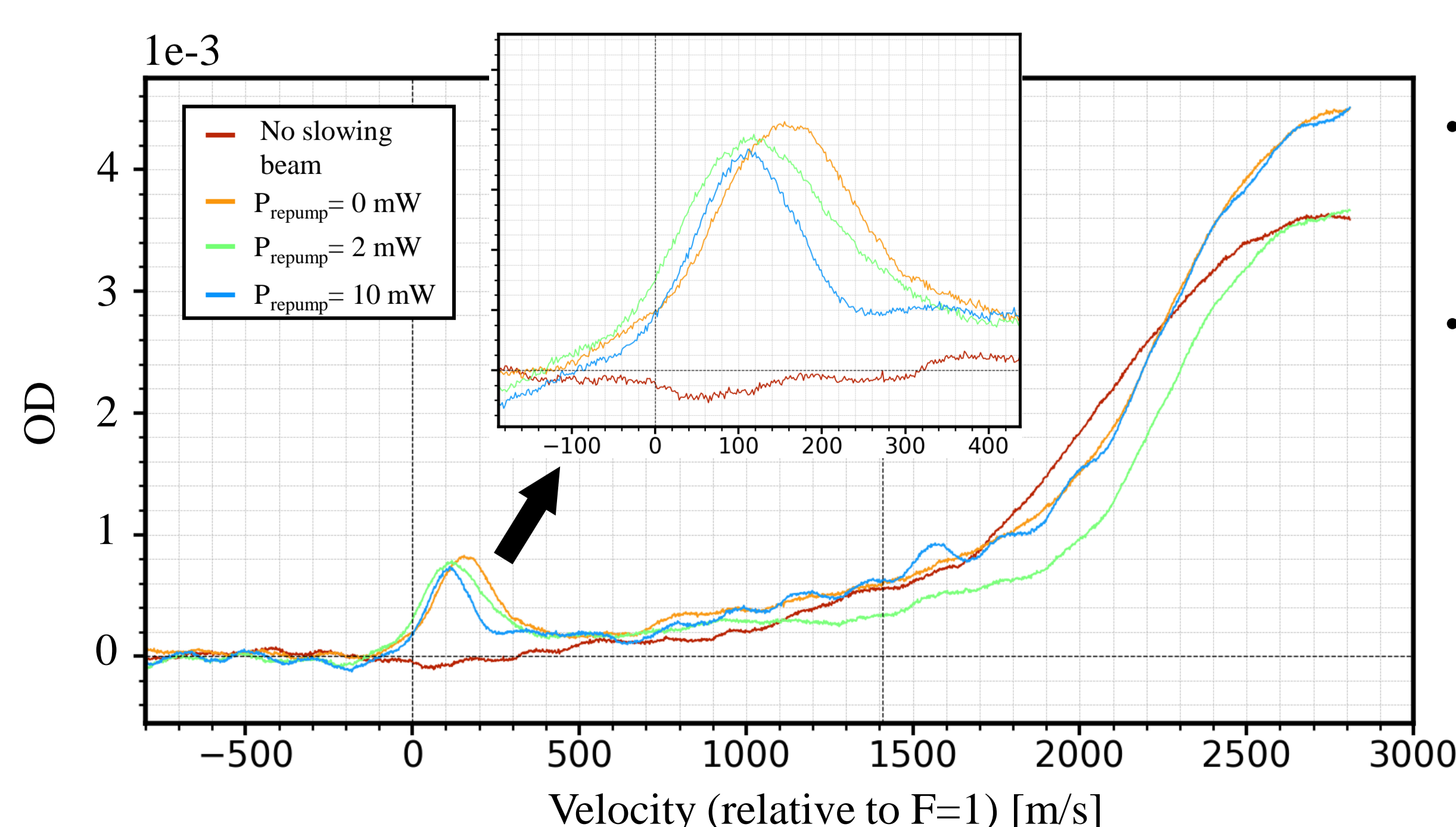
• σ^+ or π transitions de-pump atoms into dark states.



$R \equiv \frac{P_{pump}}{P_{repump}}$



Performance measurements



- Without repump beam, atoms are slowed down to ~ 160 m/s which is the target velocity at the zero field crossing.
- With repump beam, atoms are pushed to lower velocities. The exact velocity is somewhat unmeasurable due to current poor resolution.
- Slow atoms are depumped back into F=1 after the slowing process.

