Development of a universal polarization method for exotic isotopes

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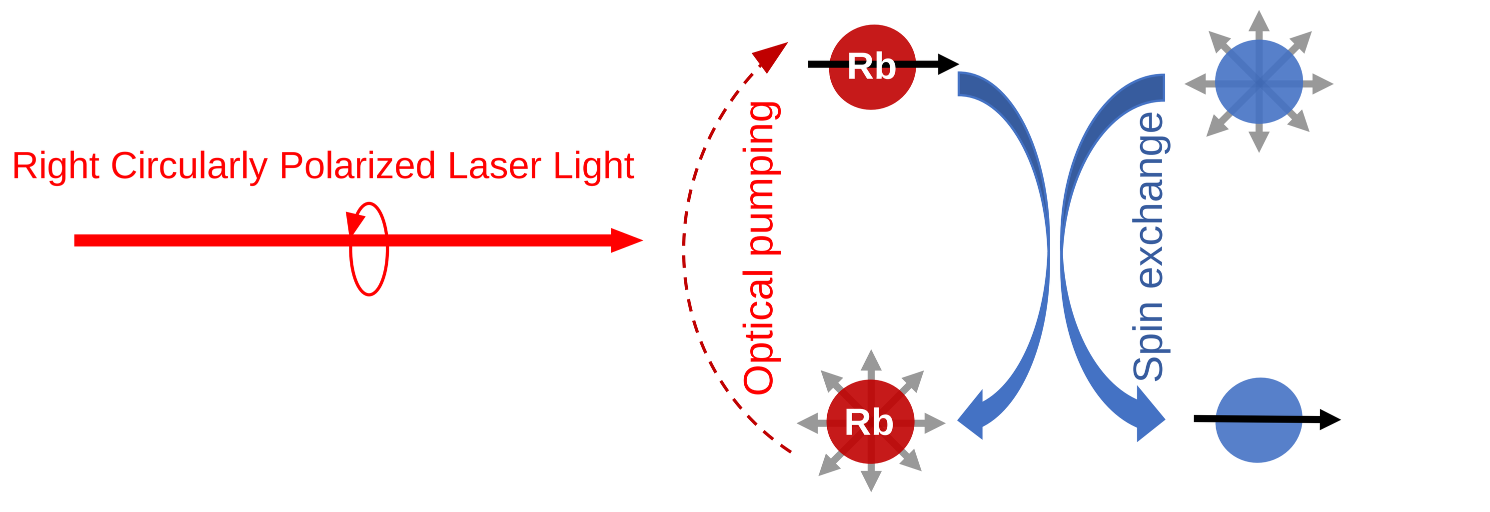
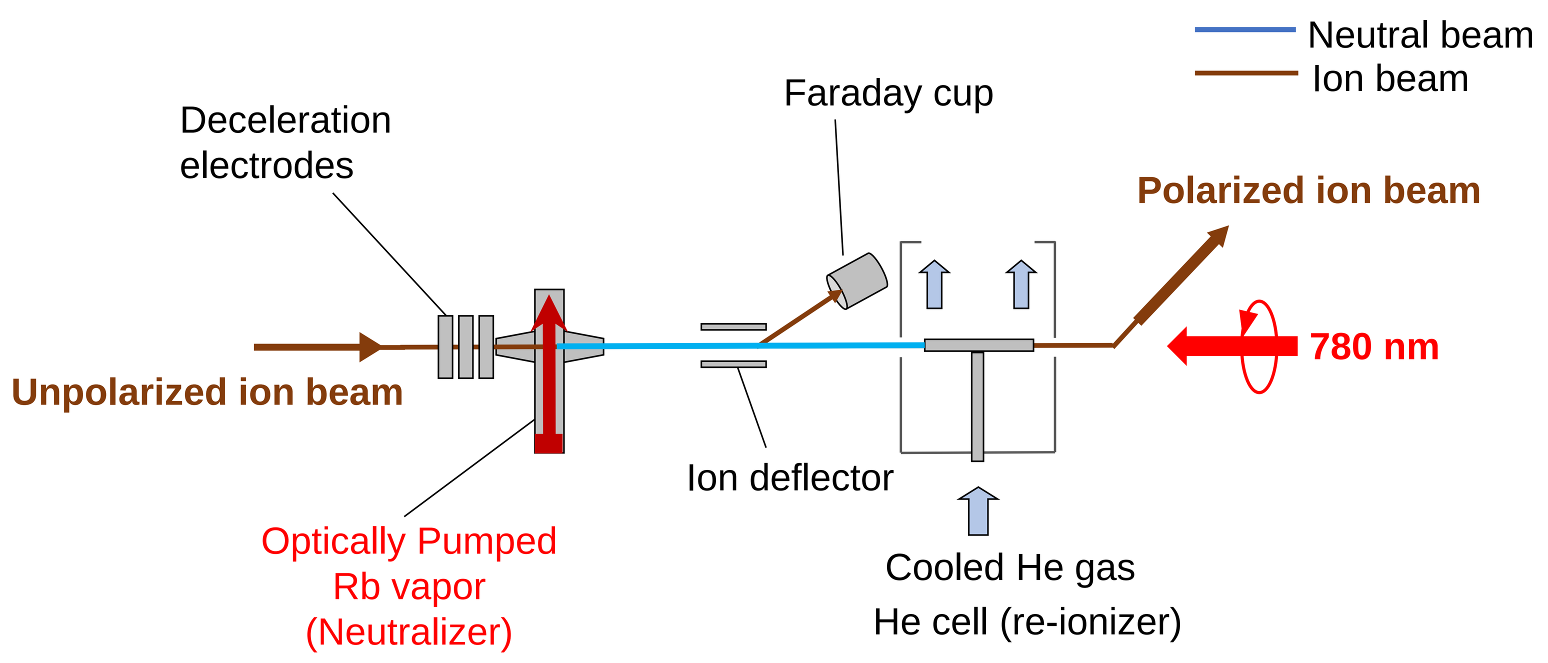
Abstract

A universal method to polarize exotic isotopes can be realized through spin-exchange optical pumping (SEOP), which orients the nuclear spin of these isotopes indirectly by using a highly spin-polarized alkali metal vapor as a spin-exchange medium to transfer polarization to the isotope beam of interest. Nuclear spin polarization is usually achieved via direct optical pumping, where new light frequencies are required for each isotope, making such approach equipment intensive. SEOP enables polarization of exotic isotopes without prior knowledge of their atomic structure and provides a universal polarization technique. As the spin polarization of the alkali vapor determines the efficiency of such a method, this study uses Faraday rotation to measure the spin polarization of Rb vapor, facilitating the optimization of optical pumping.

Spin exchange optical pumping

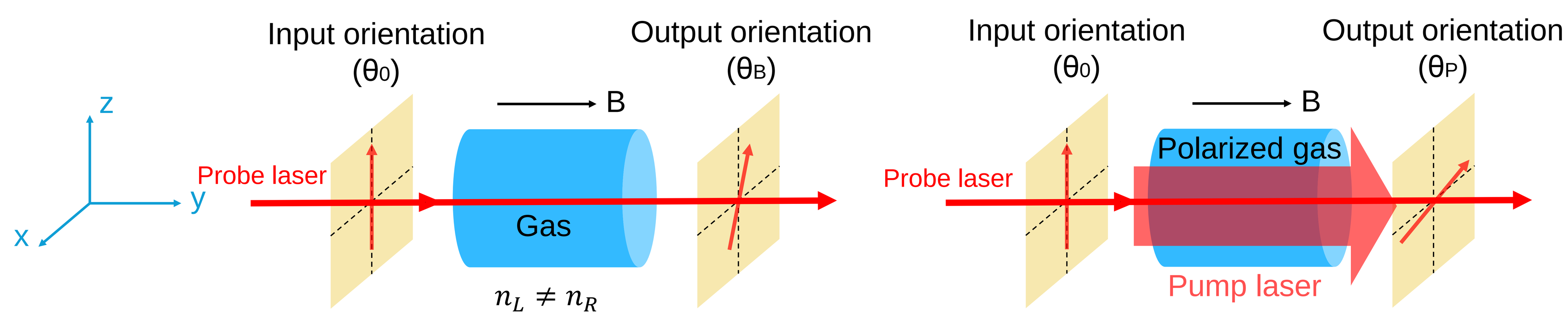


The basic principle for SEOP (Spin Exchange Optical Pumping) – circularly polarized light orients the spin of Rb, which is then transferred into the beam of interest.

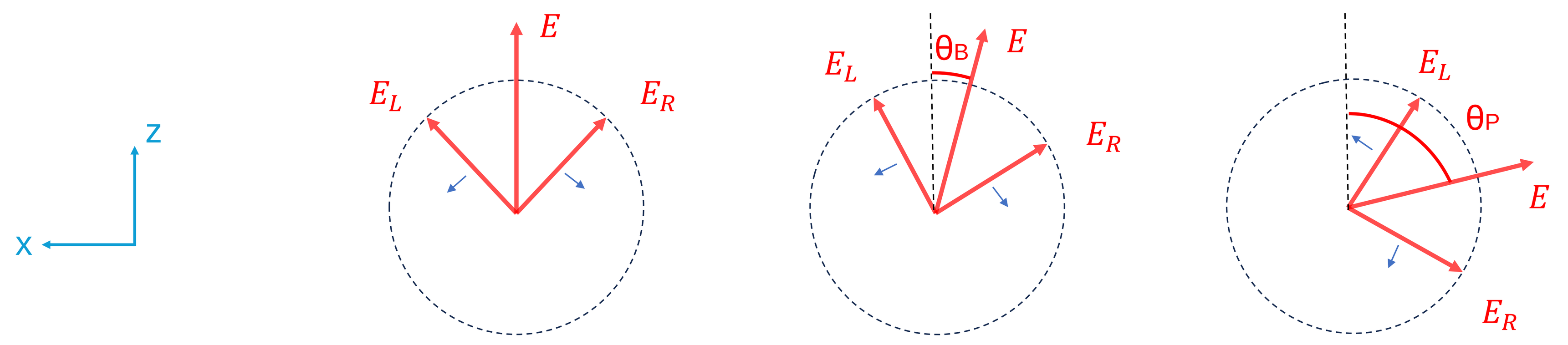


Polarizer beamline configuration.

Faraday rotation



When indices of refraction for left (n_L) and right (n_R) circularly polarized light differ (e.g., due to magnetic field and polarized gas), left and right circularly polarized light will travel at different speeds.

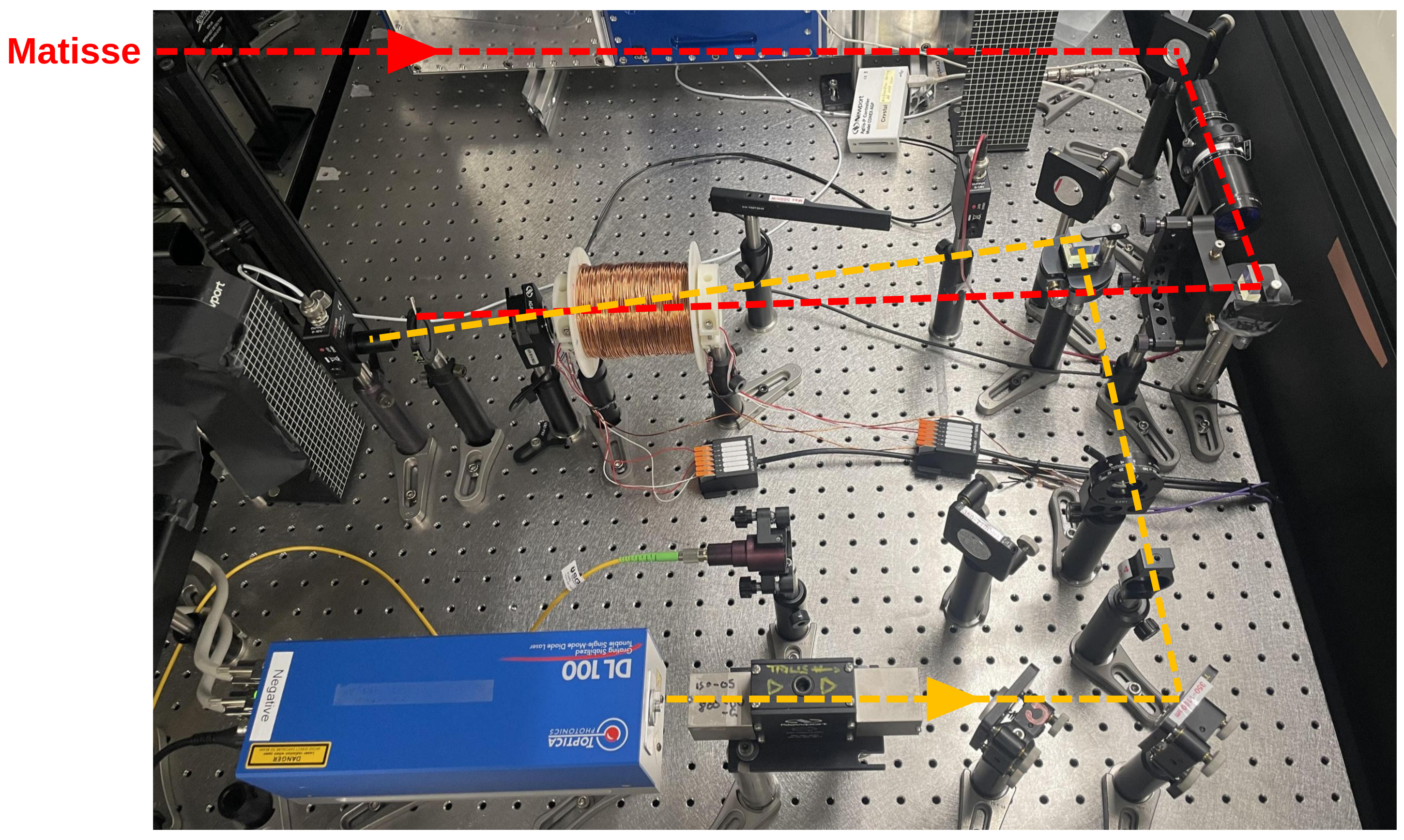


Since the linearly polarized light is the superposition of circularly polarized lights (E_R, E_L), a change in the relative phase of E_R and E_L due to different traveling speeds inside the gas leads to angle rotation.

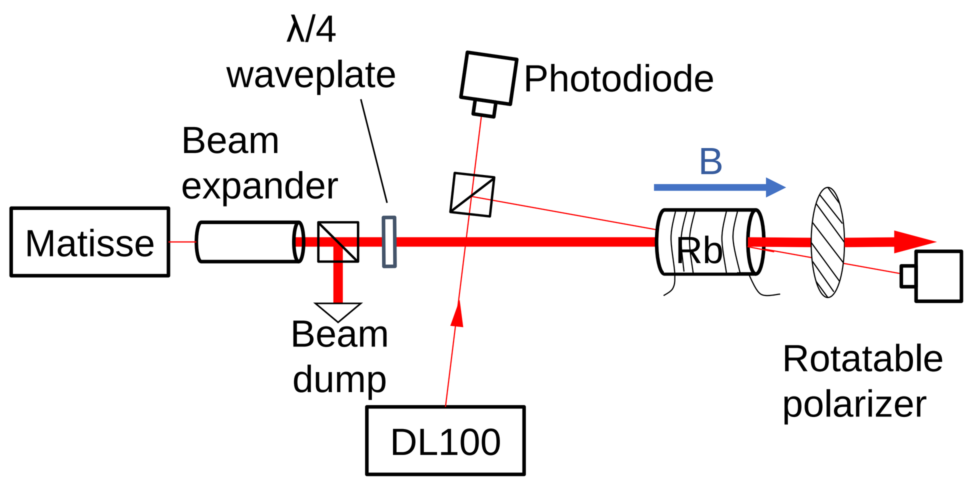
Properties of the gas is related to the rotation angles of the linearly polarized light:

$Nl = \dfrac{\theta_B - \theta_0}{V}$	$P = \dfrac{\theta_P - \theta_B}{\alpha(\theta_B - \theta_0)}$	V – Verdet constant α – alpha constant
N – atomic density (temperature dependent) l – length of interaction between gas and laser	P – spin polarization of the gas	Both constants depend on magnetic field and the wavelength of the laser.

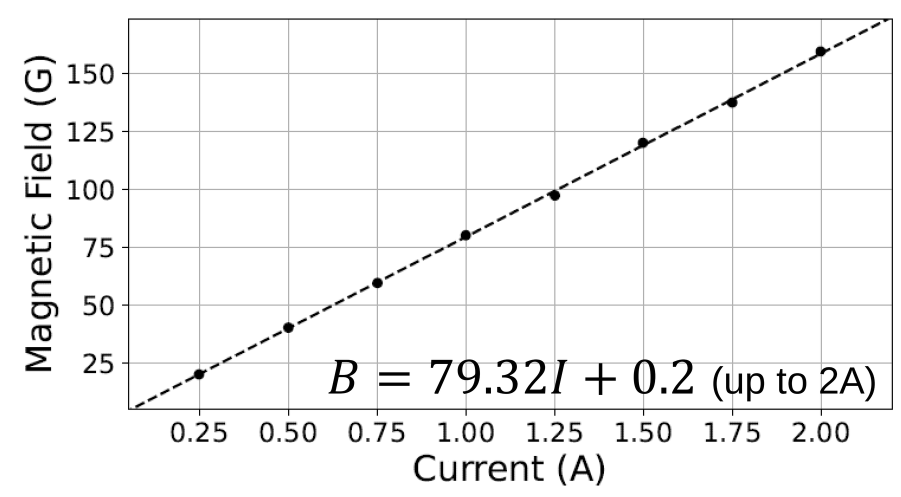
Experimental setup



- ❑ Matisse CW Ti:Sa laser provides the circularly polarized laser light to polarize the Rb vapor atoms via optical pumping.
- ❑ Toptica Diode laser DL100 provides a linearly polarized laser light. The rotated angle of the laser light polarization after passing the Rb vapor is measured to determine vapor polarization.

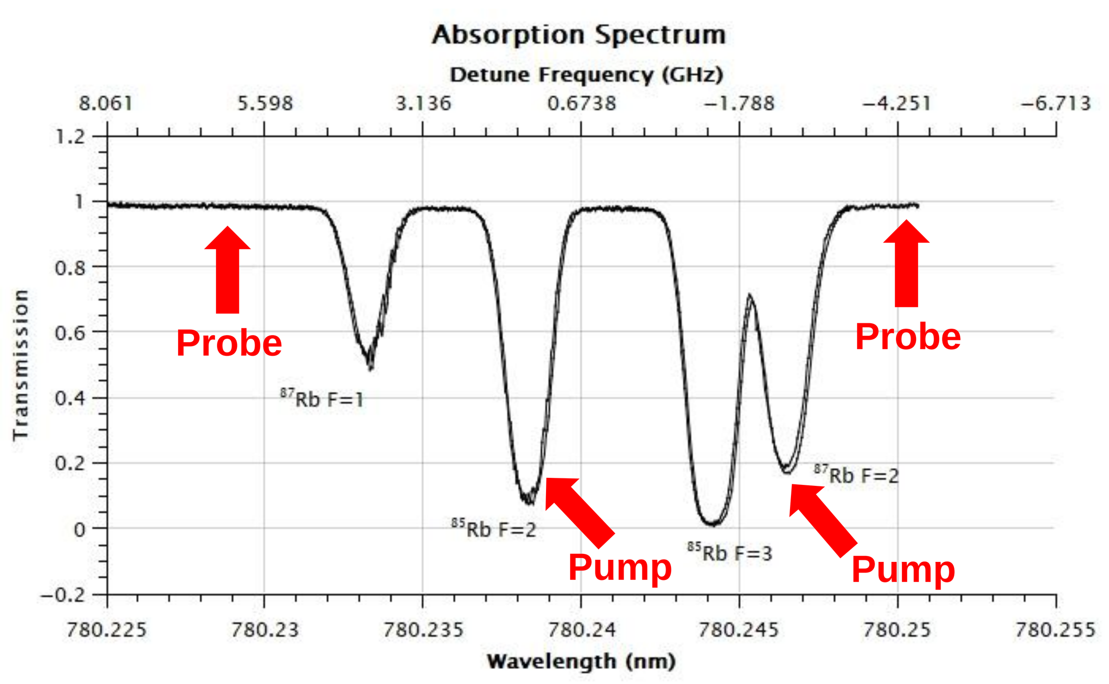


Simplified schematic diagram of the setup.

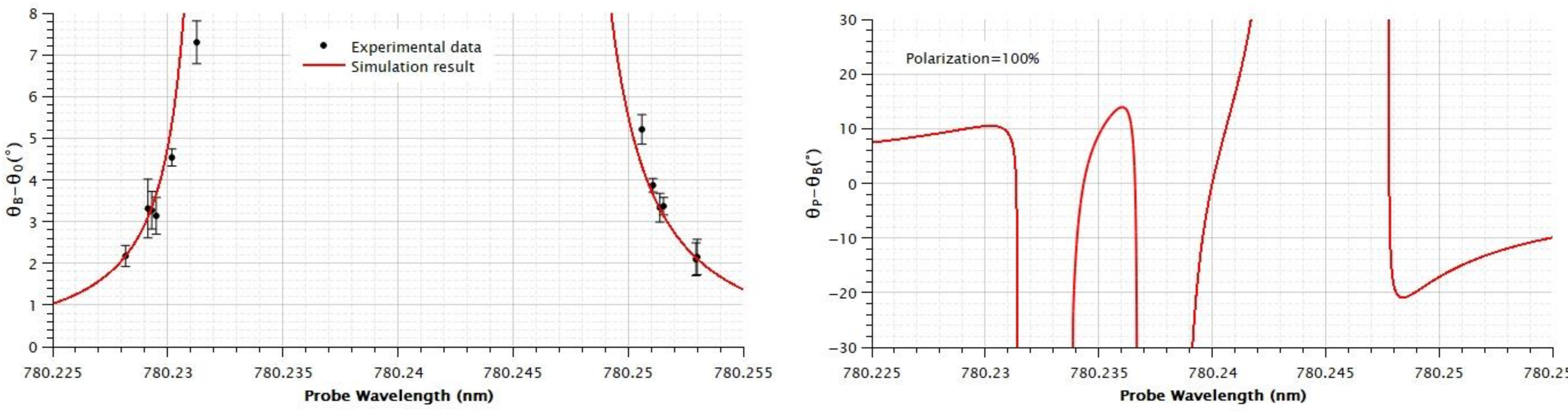


External magnetic field experienced by the Rb vapor atoms due to the solenoid.

Experimental and Simulation Results



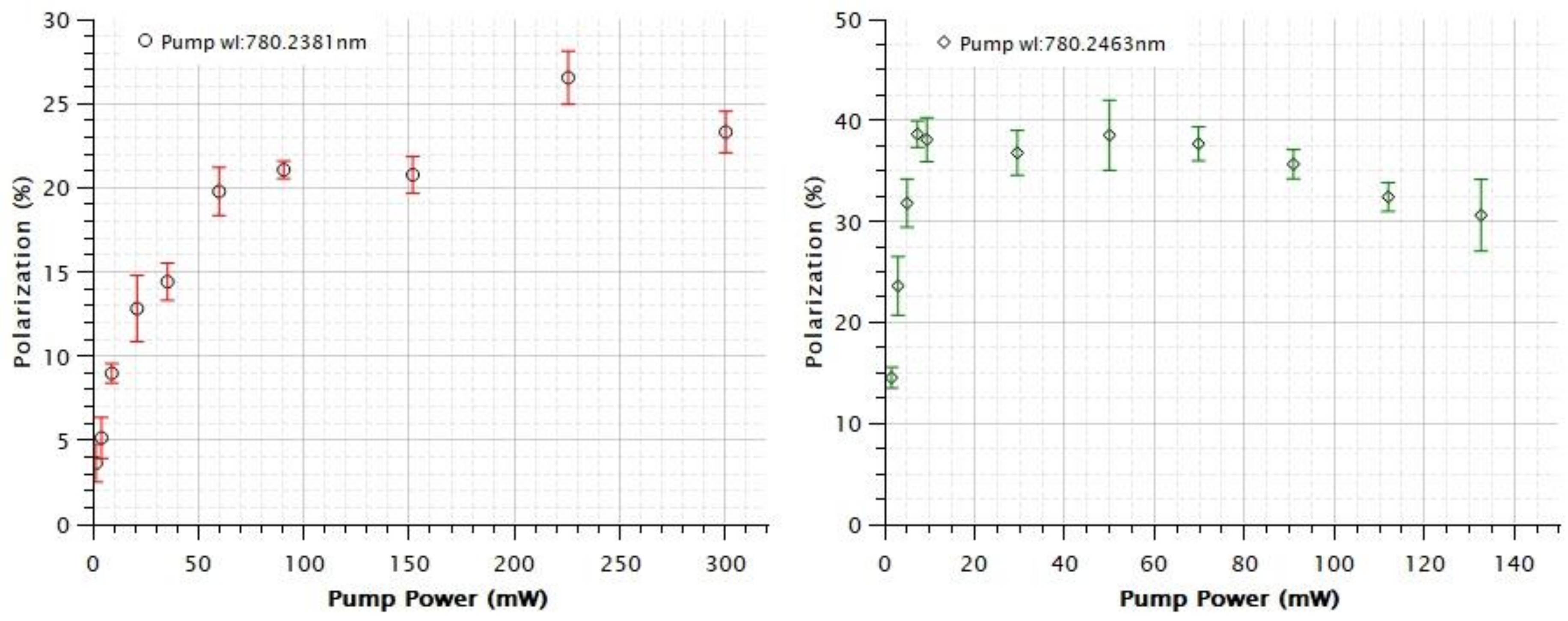
D2 lines of ^{85}Rb and ^{87}Rb without external magnetic field. Detune frequency is relative to 780.241 nm.



Simulated $(\theta_B - \theta_0)$ (left) and $(\theta_P - \theta_B)$ (right) near the D2 transition lines of ^{85}Rb and ^{87}Rb, compared with experimental data. Magnetic field is 120 G, length of interaction is 71.8 mm, and temperature is 53 °C.

Outlook

- ❑ Optically pump different D2 hyperfine lines and measure the highest achievable polarization and corresponding saturation powers.
- ❑ Measure the depolarization rate by pulsing the pump laser.
- ❑ Optically pump different D1 hyperfine lines and compare with the result of optically pumped D2 lines
- ❑ Install the same setup for the Rb jet vapor cell in the polarizer facility, measure and optimize the laser parameters to achieve high spin polarization of Rb vapor atoms.
- ❑ Validate polarization measurements using other fast techniques to confirm previous results.



Power dependence of Rb polarization, optically pumped at 780.233nm (left) and 780.245nm (right), respectively.

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