

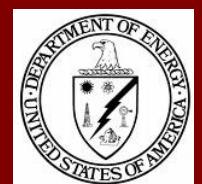
# On Production and Optimization of Hybrid SEOP Polarized $^3\text{He}$ Target Cells

Peter Dolph

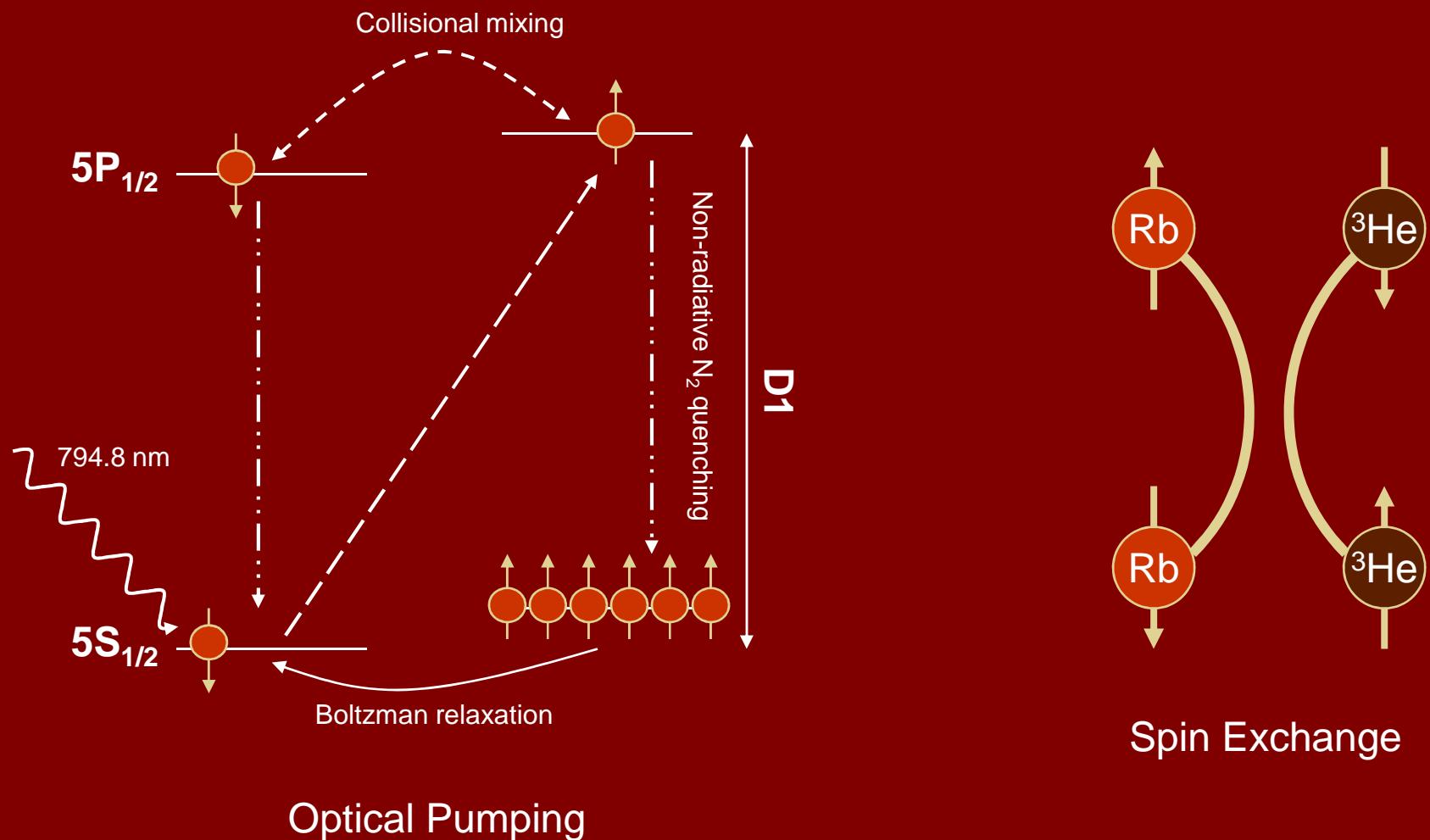
UNIVERSITY OF VIRGINIA



3.18.08



# Spin Exchange Optical Pumping (SEOP)



Optical Pumping

assumes I = 0

2/198

# Spin Exchange Optical Pumping (SEOP)

equilibrium  ${}^3\text{He}$  polarization

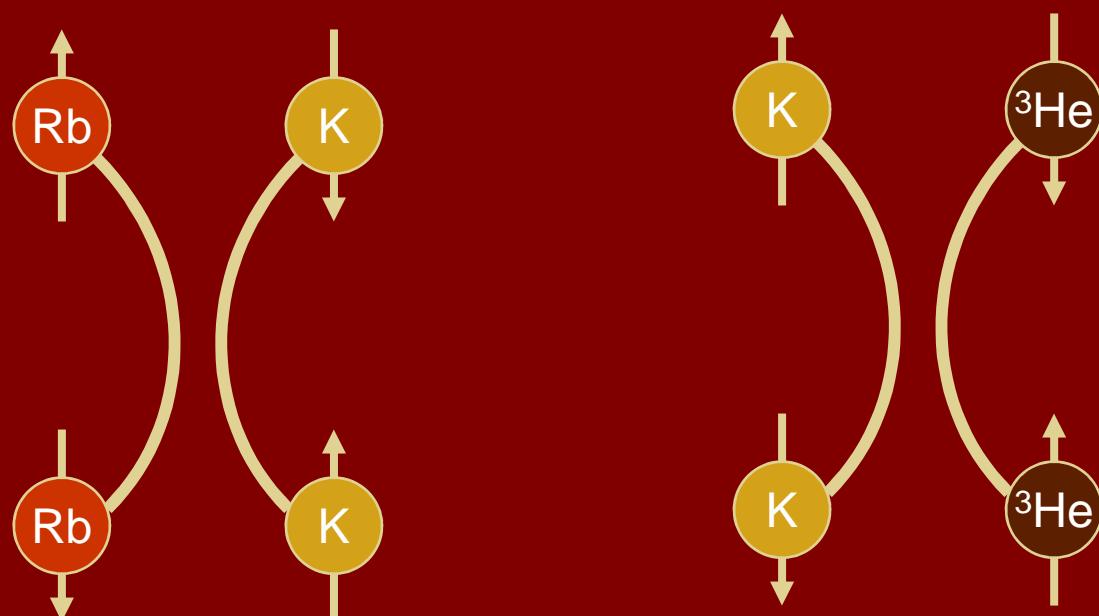
$$P_{He} = P_{Rb} \frac{1}{1 + \frac{\Gamma}{\gamma_{se}}}$$

$$\gamma_{se} = k_{se}^{Rb}[Rb]$$

$\Gamma$  =  ${}^3\text{He}$  relaxation rate

# Hybrid SEOP

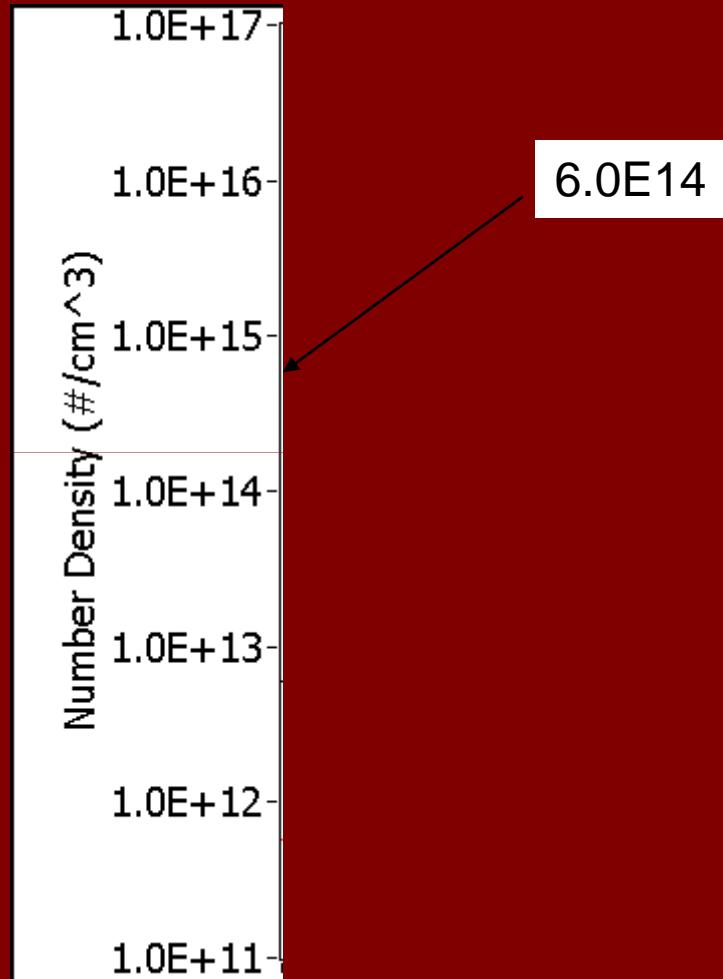
Atoms Interacting	Spin-Exchange Efficiency
Alkali-Alkali	~1
Rubidium- <sup>3</sup> Helium	.005
Potassium- <sup>3</sup> Helium	.07
Hybrid- <sup>3</sup> Helium	.045



$$\eta_A = \frac{\gamma_{se}^A [{}^3\text{He}]}{\Gamma_A[A]}$$

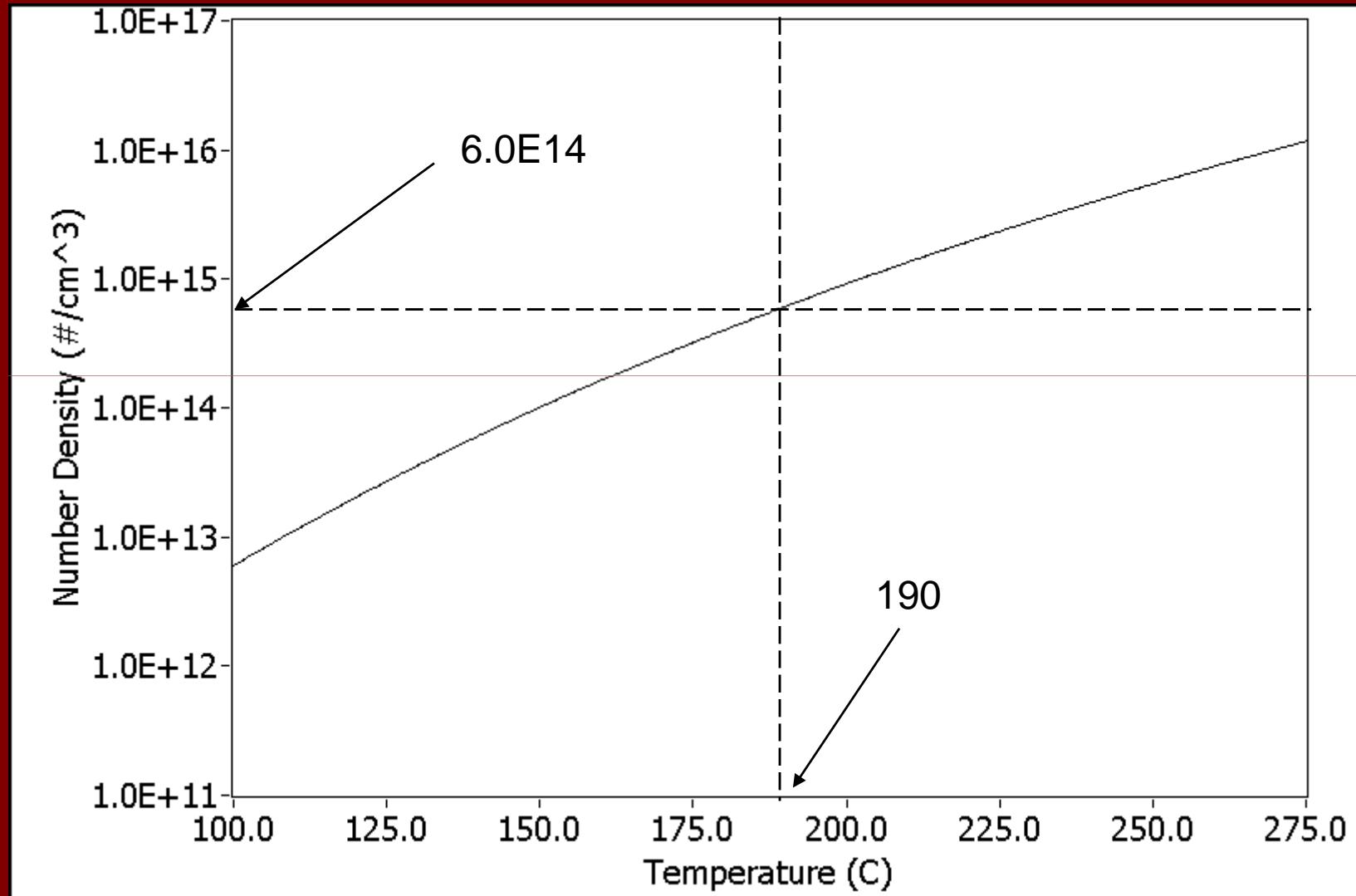
Source: Chen et al. PRA 2007

# Number Density Curves

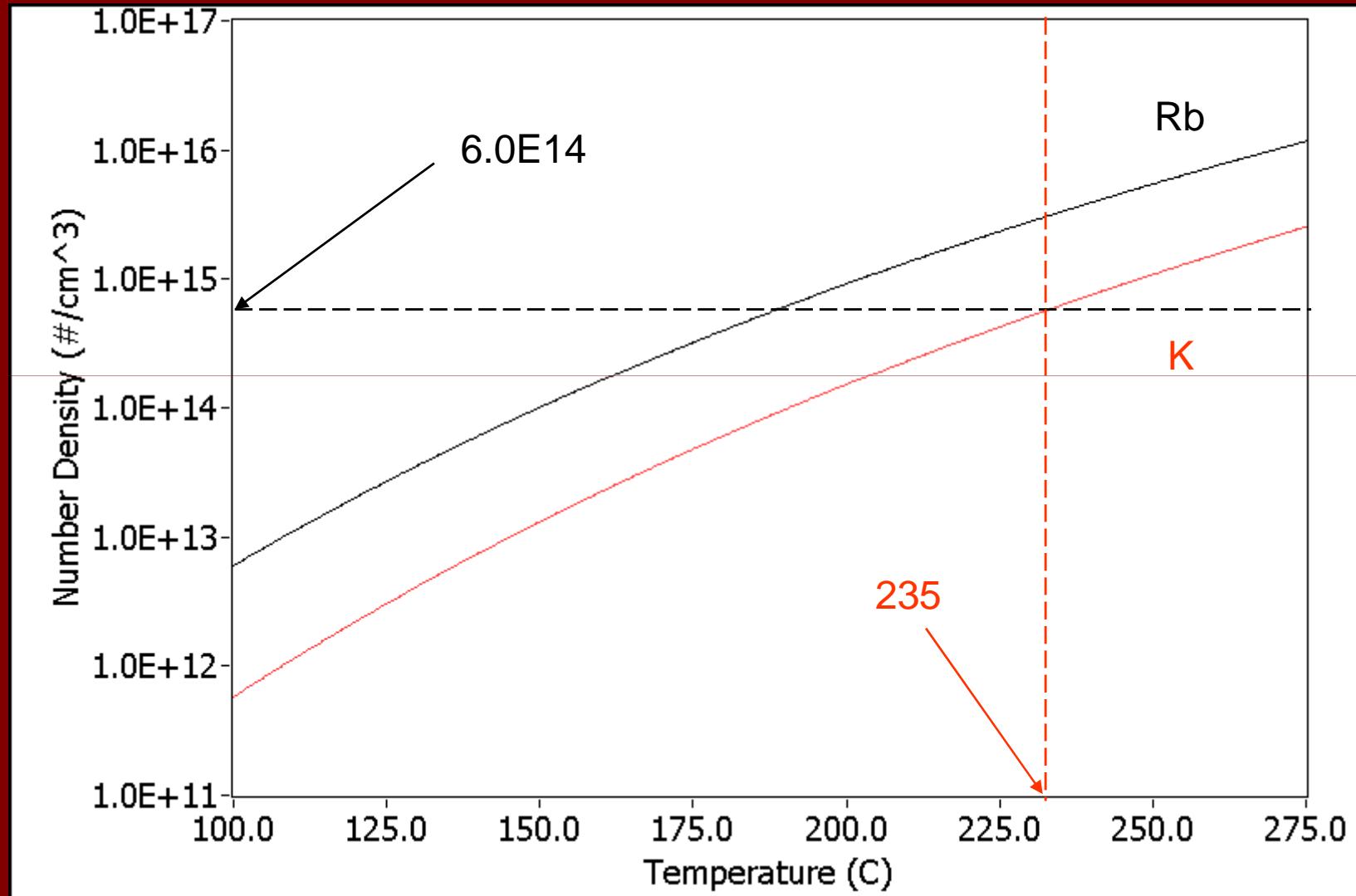


$$\gamma_{se} = k_{se}^{Rb}[Rb]$$

# Number Density Curves



# Number Density Curves



# Hybrid SEOP

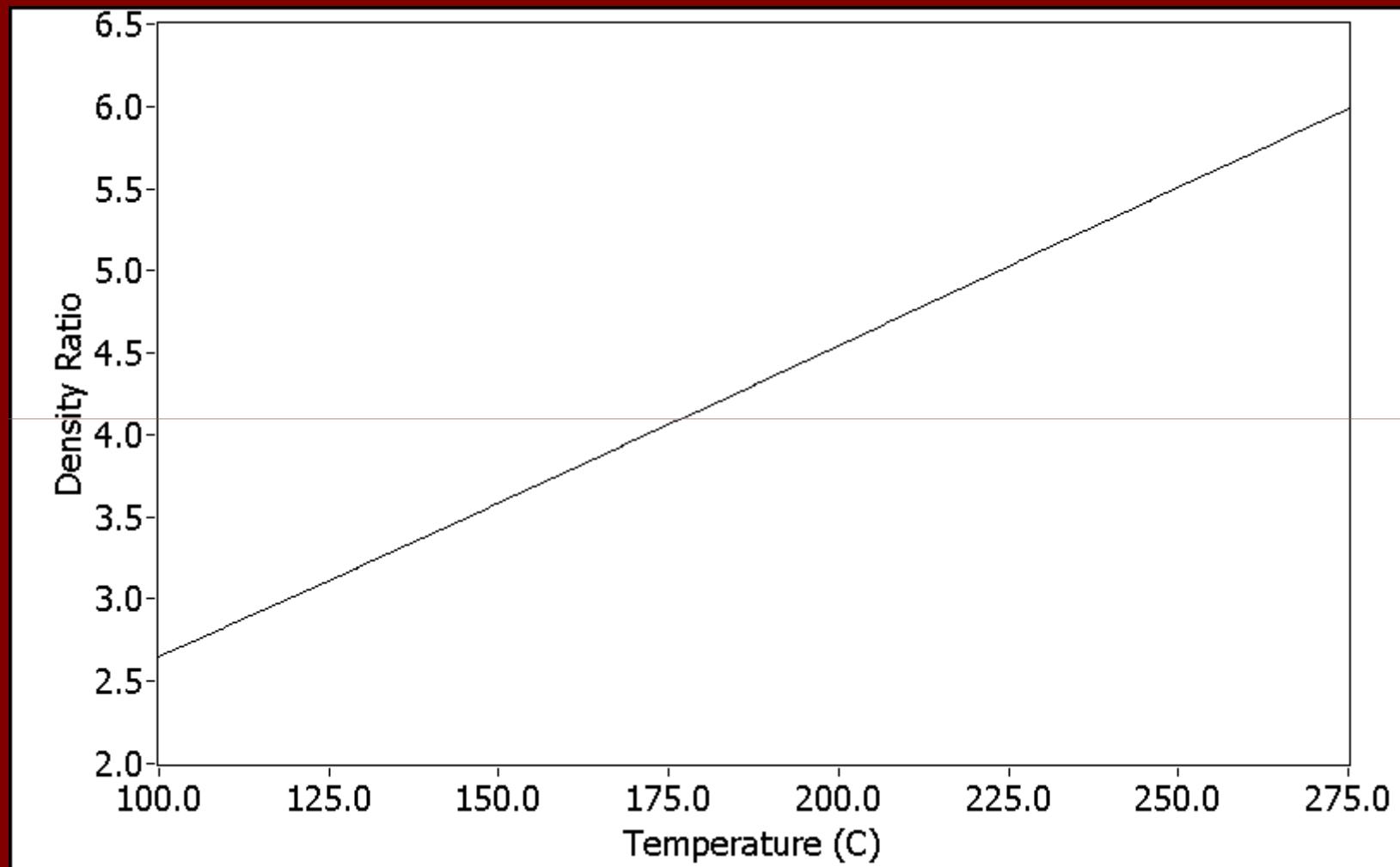
Relevant Quantity:

$$D = [K]/[Rb]$$

Spin Exchange

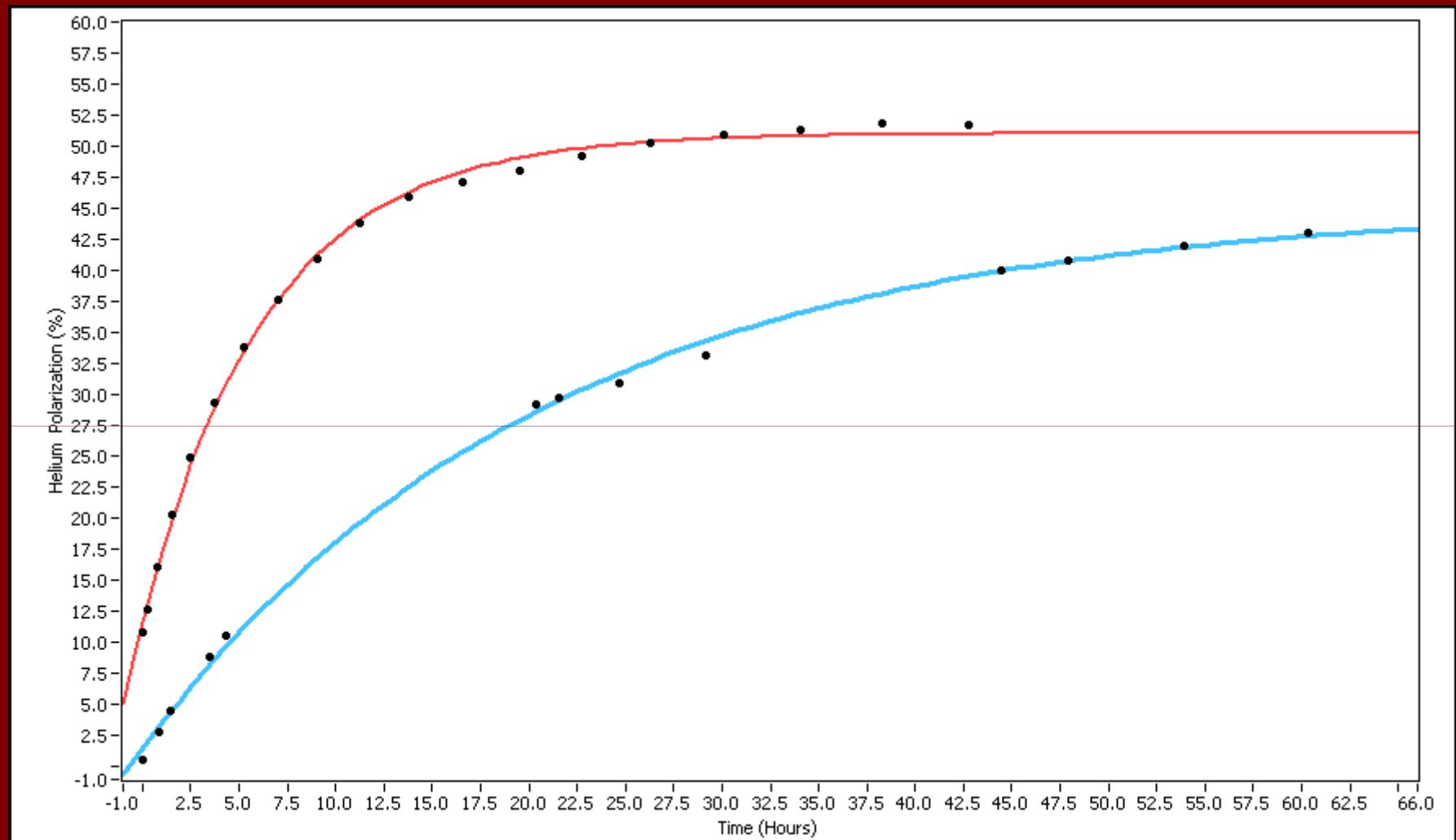
Optical Pumping

# Density Ratio vs. Temperature



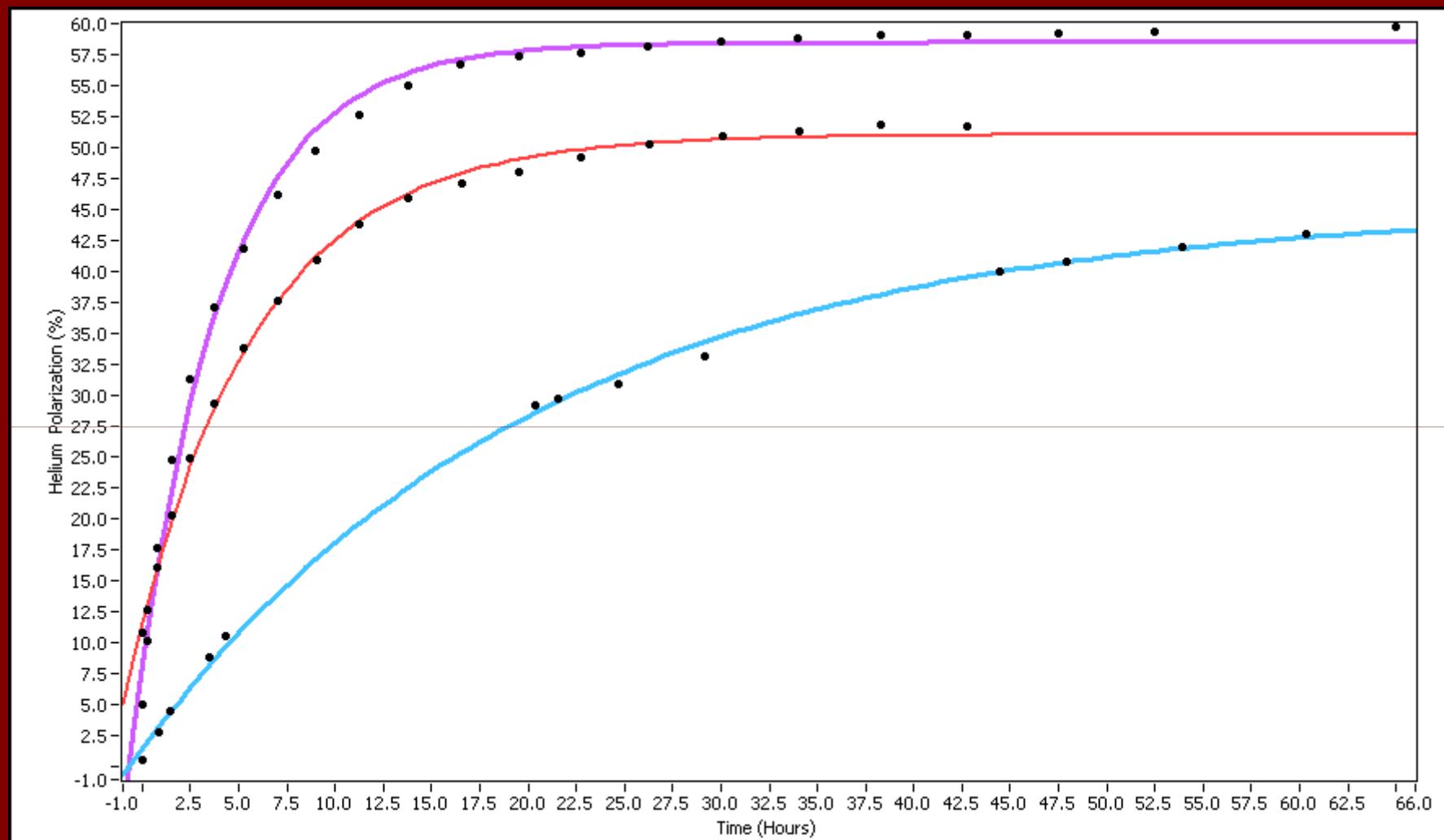
$$D_{235} = 5.0$$

# Hybrid SEOP



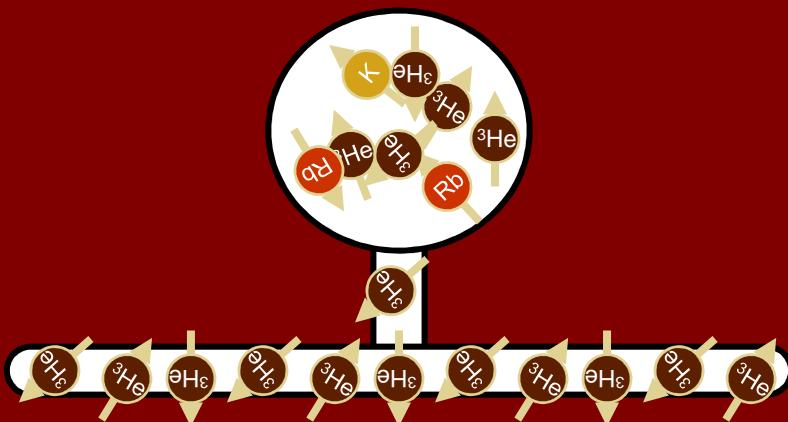
Samantha (5:1 FAPs, 235C) Priapus (0:1 FAPs, 180C)

# Hybrid SEOP



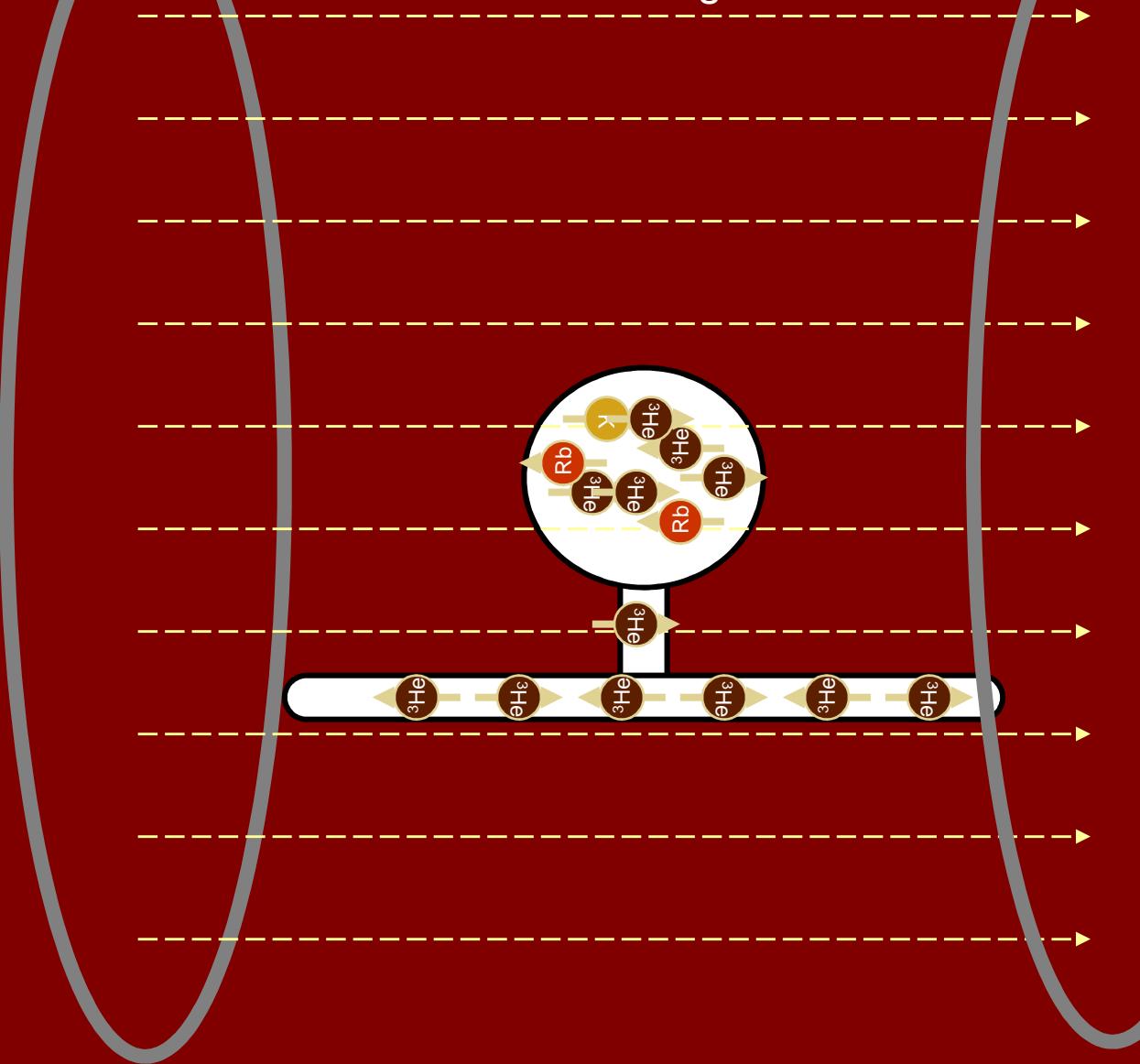
Simone (20:1, FAP + Comets, 255C) Samantha (5:1 FAPs, 235C) Priapus (0:1 FAPs, 180C)

# Experimental Setup



# Experimental Setup

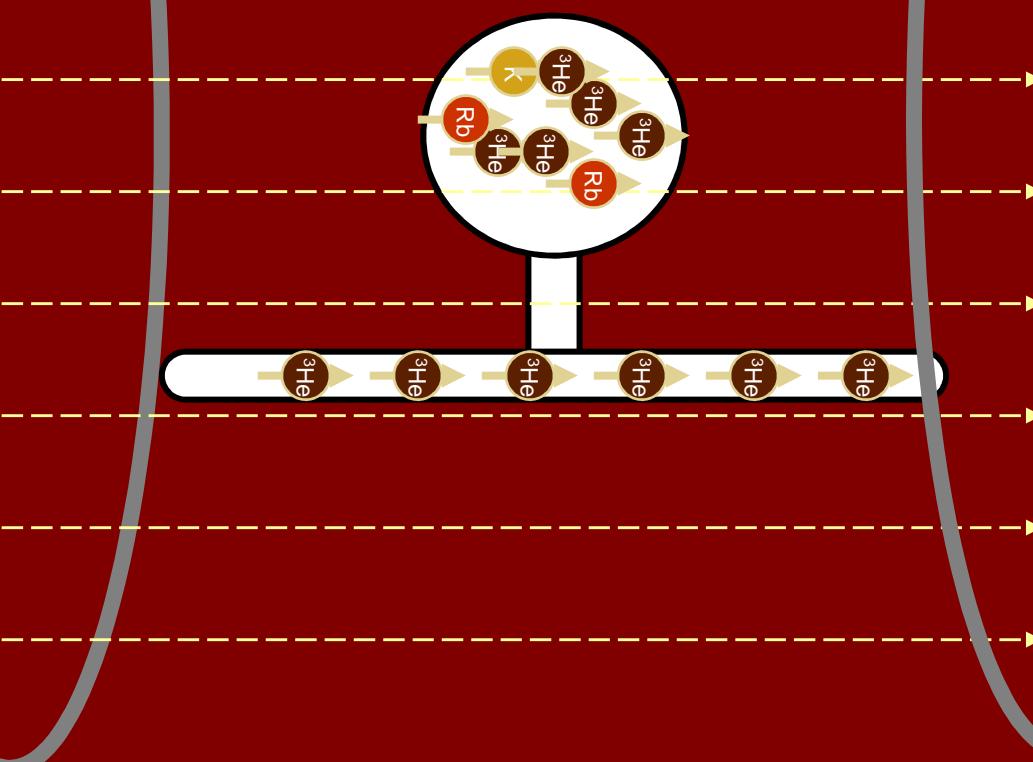
External Magnetic Field



# Experimental Setup

External Magnetic Field

D1 PUMP LASER



# Experimental Setup

External Magnetic Field

Forced Air Oven

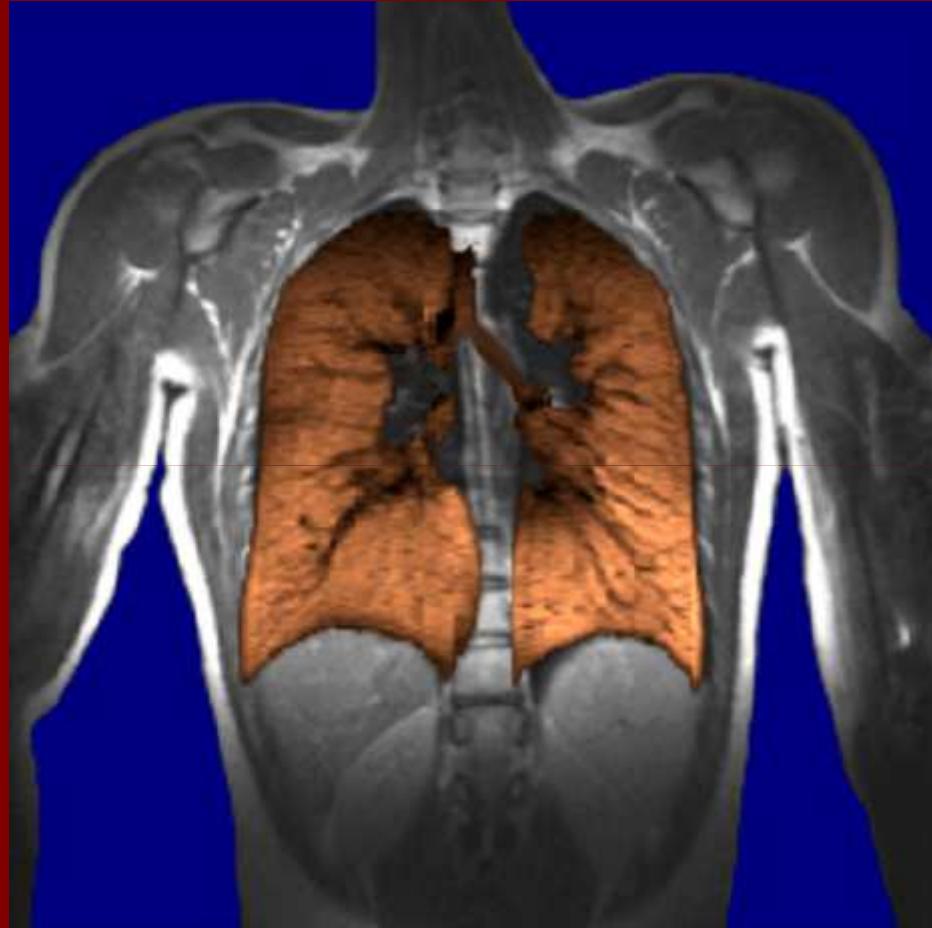
D1 PUMP LASER



# Experimental Setup



# Other Applications



Conventional MRI

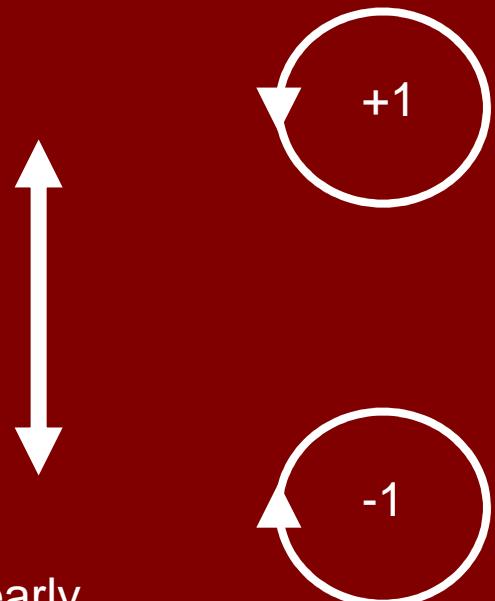
${}^3\text{He}$  MRI

# Production

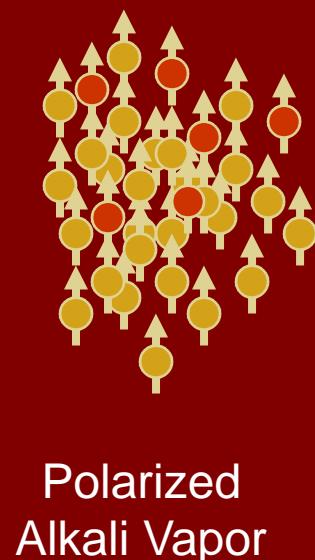


# Characterization by Faraday Rotation

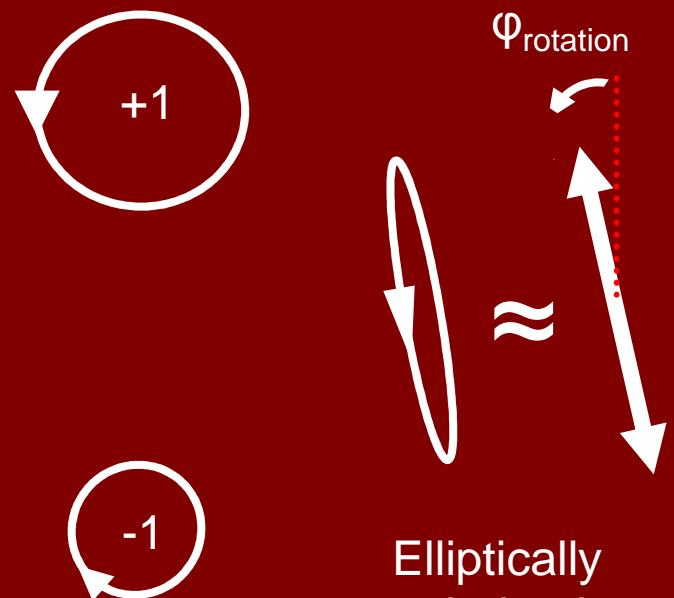
- Circular Birefringence



Projected onto  
Atomic Basis



- Circular Dichroism

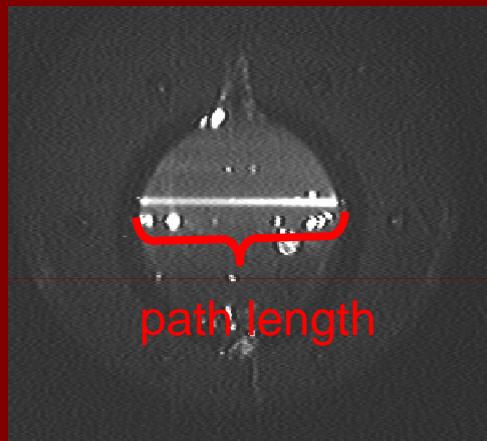


Right circular component is absorbed and lags behind

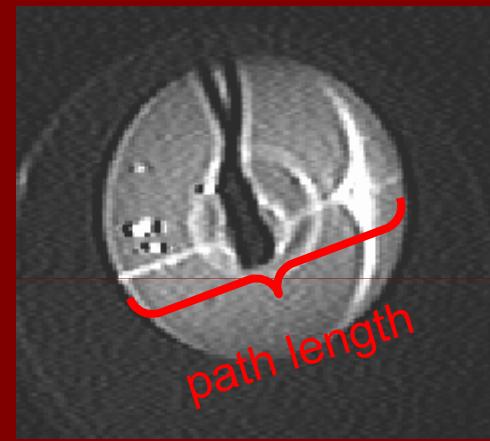
Elliptically polarized light exits at an angle

# Path Length Determination

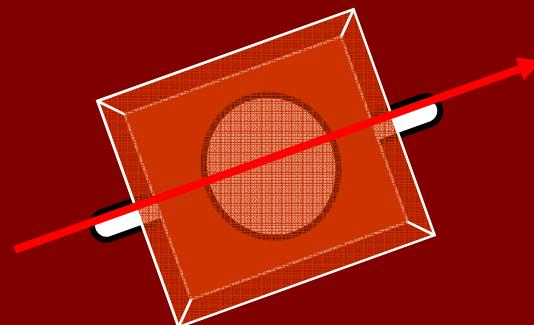
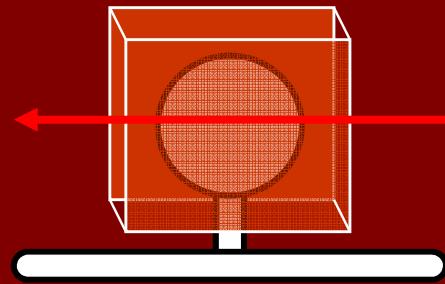
Side View



Top View

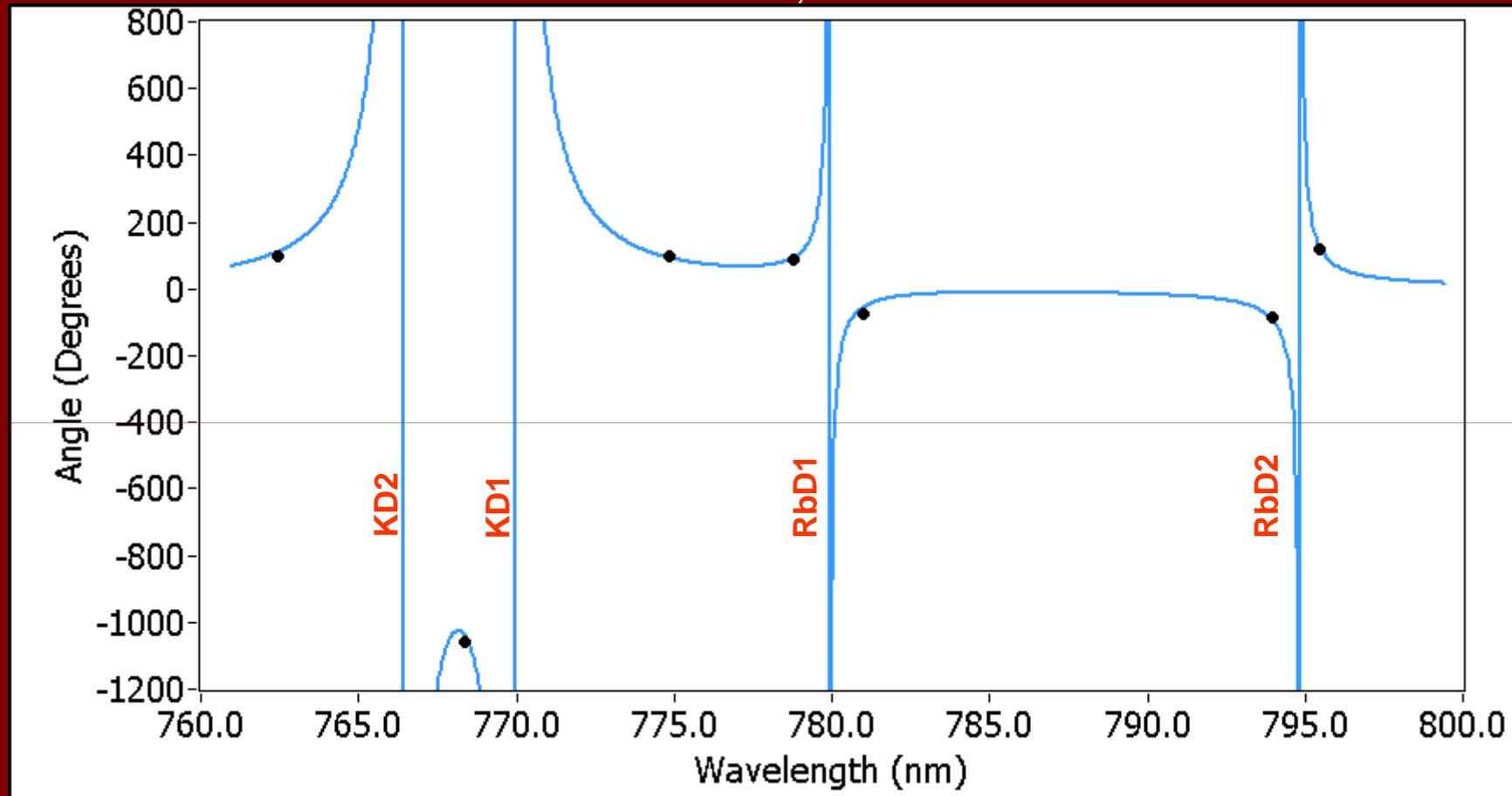


$$\ell = 5.66 \pm .33 \text{ cm}$$



# Results

Simone “255C”, 3 Lasers



$$D = 12.5 \pm .84$$

$$\ell = 5.66 \pm .33 \text{ cm}$$

$$P = 98 \pm 2\%$$

$$[K] = 10.42 \pm .66 \times 10^{14}/\text{cm}^3$$

$$T = 249.2 \pm 1.9 \text{ C}$$

$$\phi_P = l \left( \frac{e^2}{12mc\epsilon_0} \right) \left( [K]P_K \left[ \frac{1}{\Delta_{\frac{3}{2}}} - \frac{1}{\Delta_{\frac{1}{2}}} \right] + [Rb]P_{Rb} \left[ \frac{1}{\Delta_{\frac{3}{2}}} - \frac{1}{\Delta_{\frac{1}{2}}} \right] \right)$$

$$\Delta_D = \omega - \omega_D$$

Errors are rescaled to give  $\chi^2_{\text{reduced}} = 1$

# Intermission

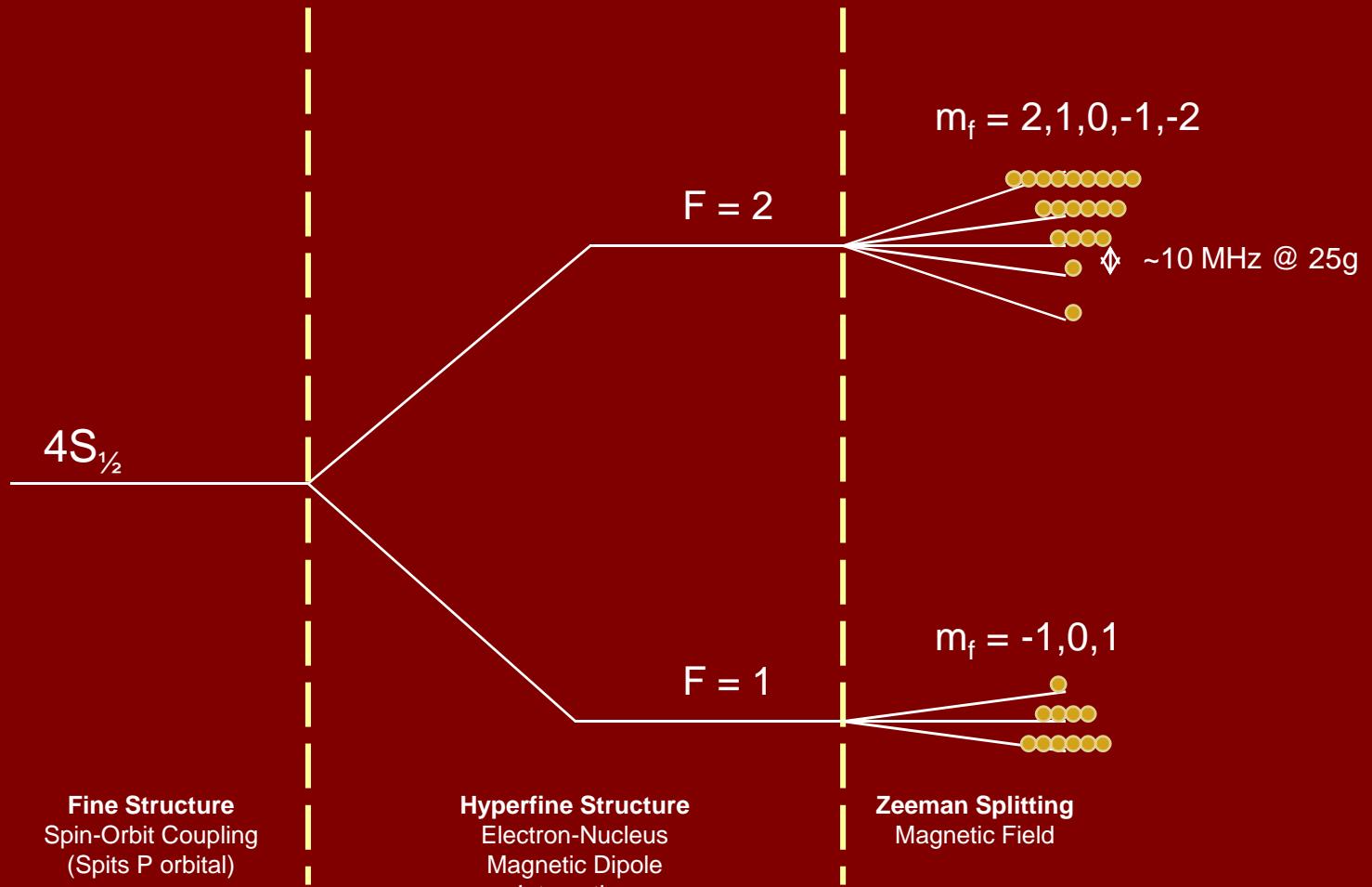


The Rock of Cashel  
Cashel, Ireland

# Alkali Polarization

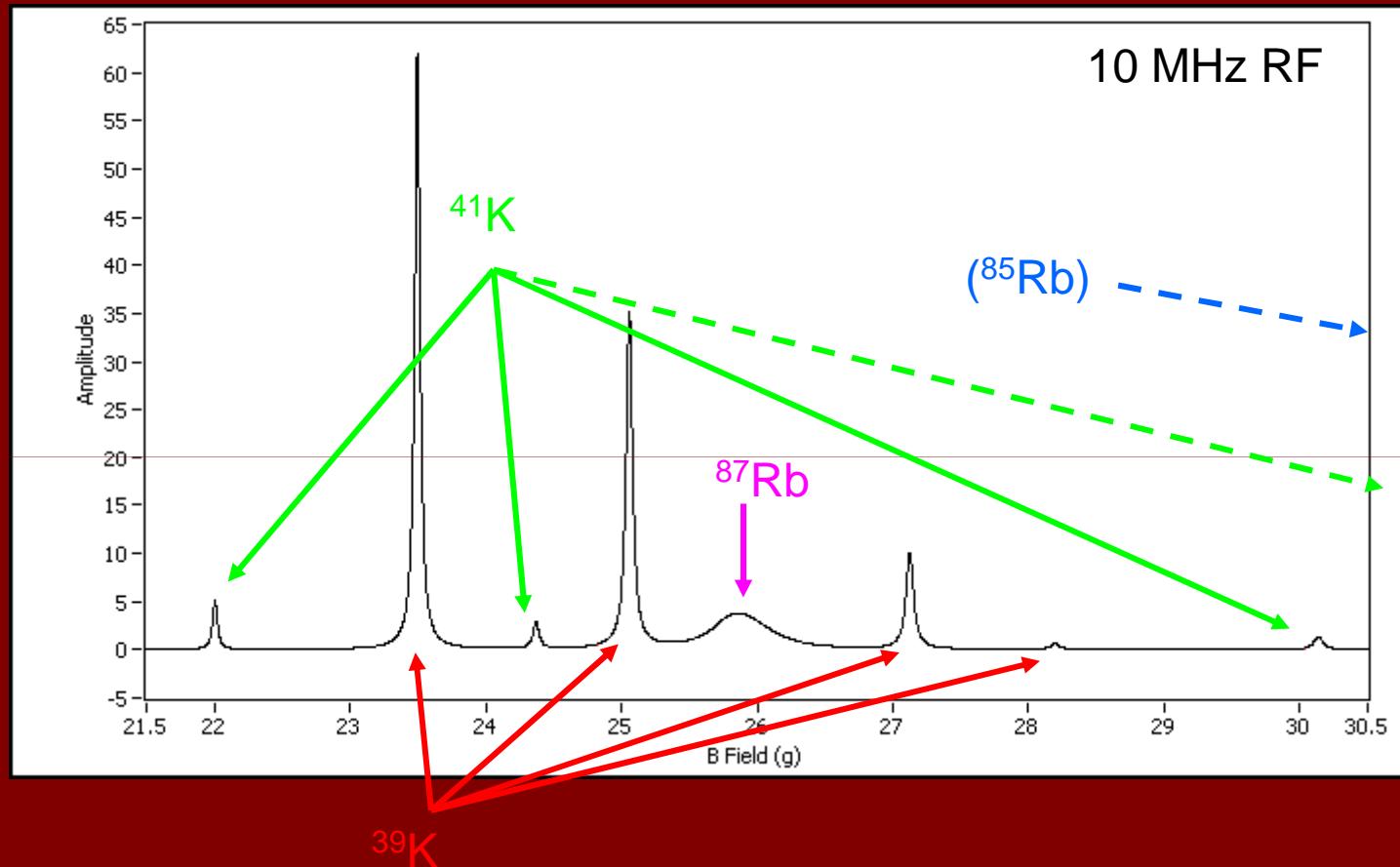
$^{39}\text{K}$  Ground State Energy Level Diagram ( $I = 3/2$ )

50% Polarization

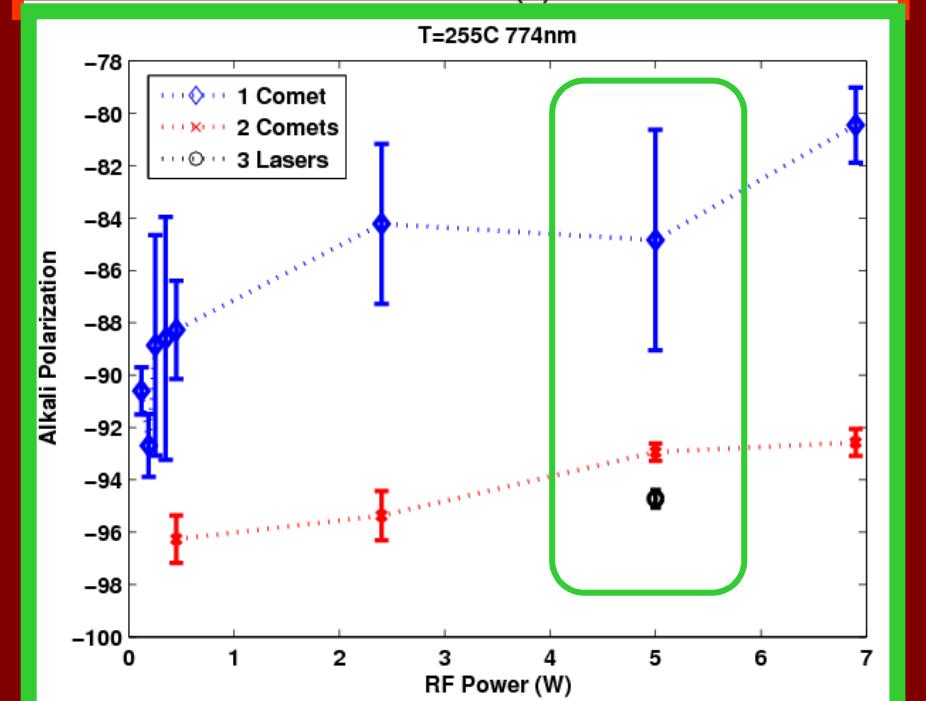
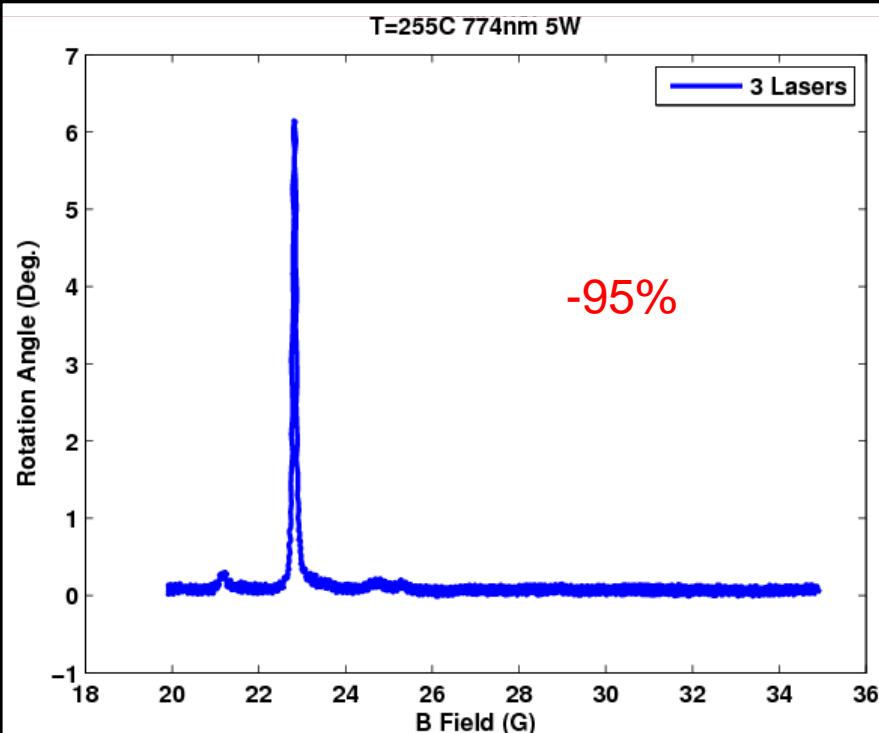
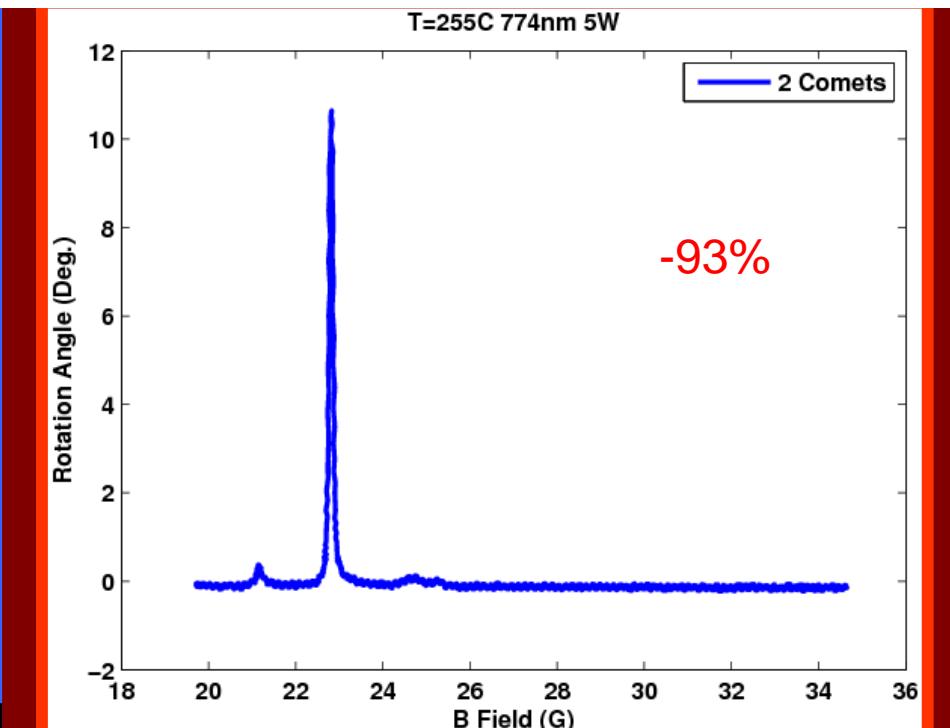
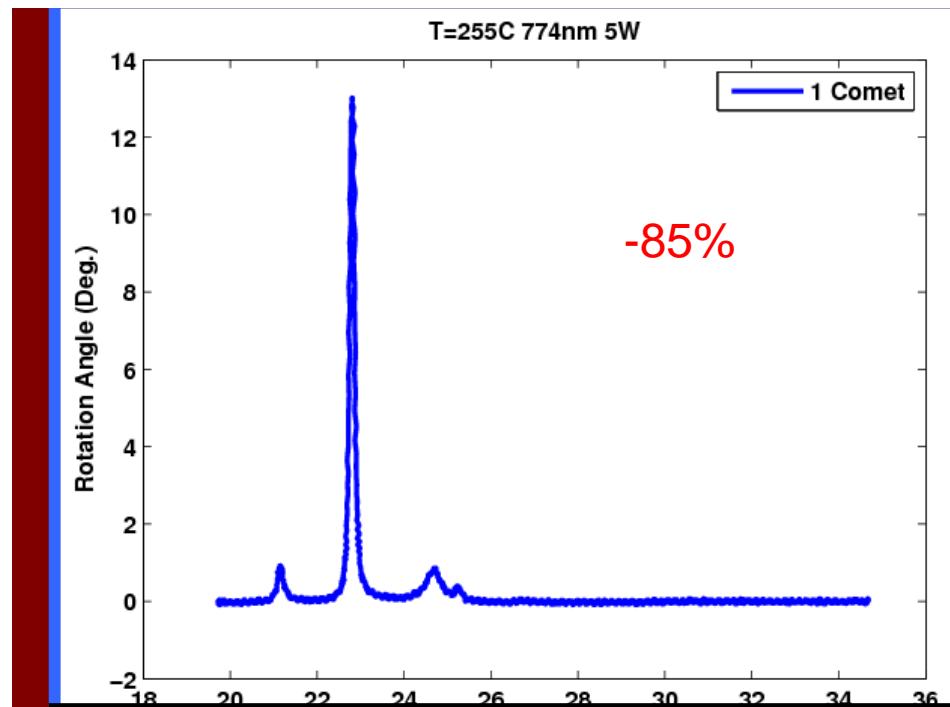


# Simulation Results

-50% Polarization



- Size (area) of transition peaks corresponds to the relative population difference between 2 adjacent states
- Alkali Polarization can be extrapolated by comparing the areas of 2 transitions from the same isotope



# Optimization

Control the following Inputs (sort of...)

- Alkali Number Density & Ratio
- Alkali Polarization

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Control the following Inputs (sort of...)

- Alkali Number Density & Ratio
- Alkali Polarization

*Adjust Nominal Ratio ( $D$ )*

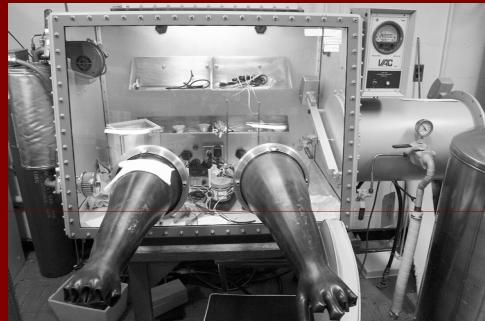


# Optimization

Control the following Inputs (sort of...)

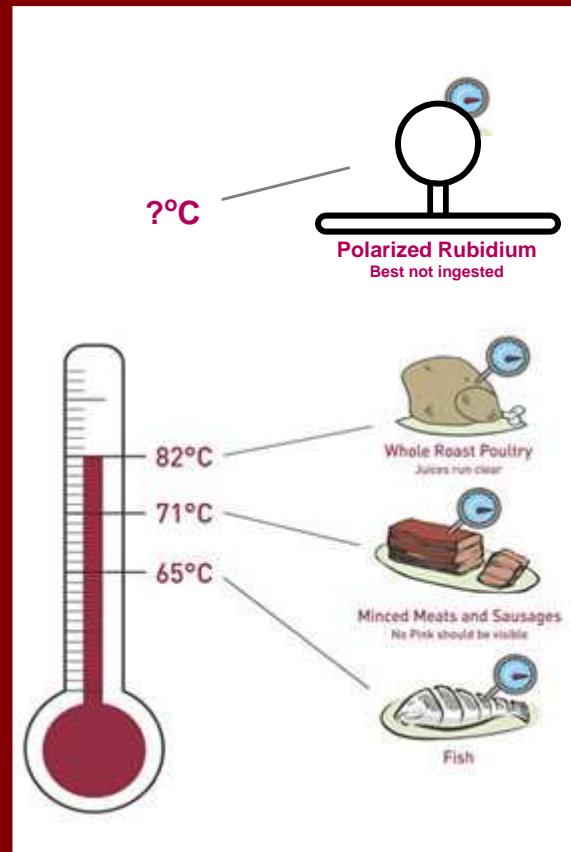
- Alkali Number Density & Ratio

*Adjust Nominal Ratio (D)*



*Turn up temperature*

- Alkali Polarization



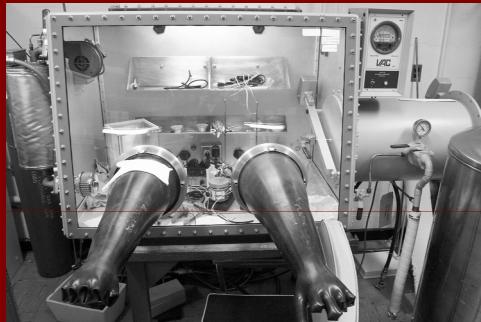
<http://www.foodauthority.nsw.gov.au/consumer/img/Termometer.jpg>

# Optimization

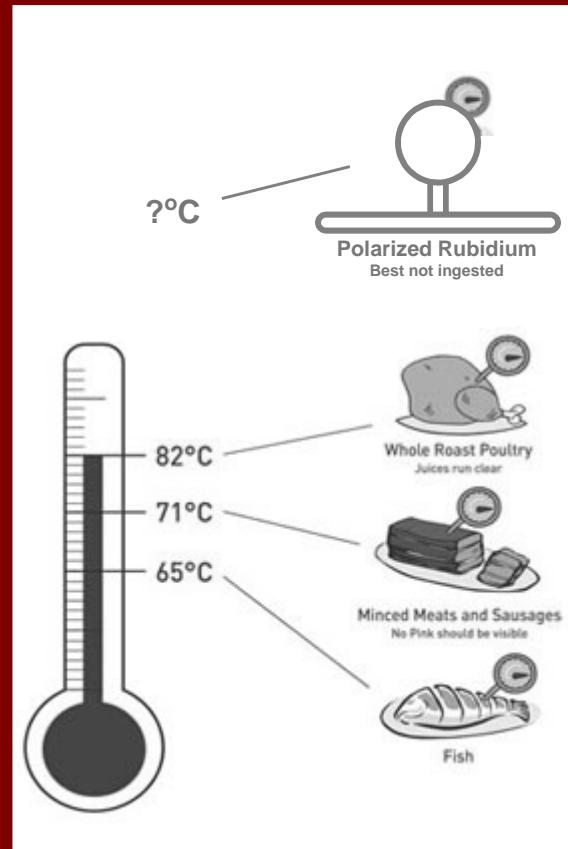
Control the following Inputs (sort of...)

- Alkali Number Density & Ratio

*Adjust Nominal Ratio (D)*

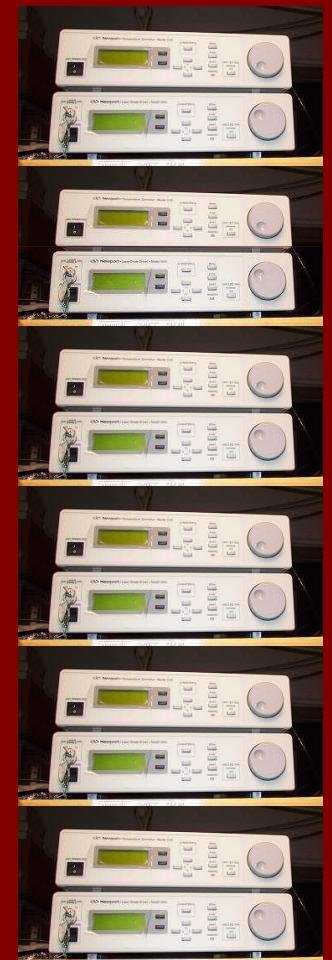


*Turn up temperature*



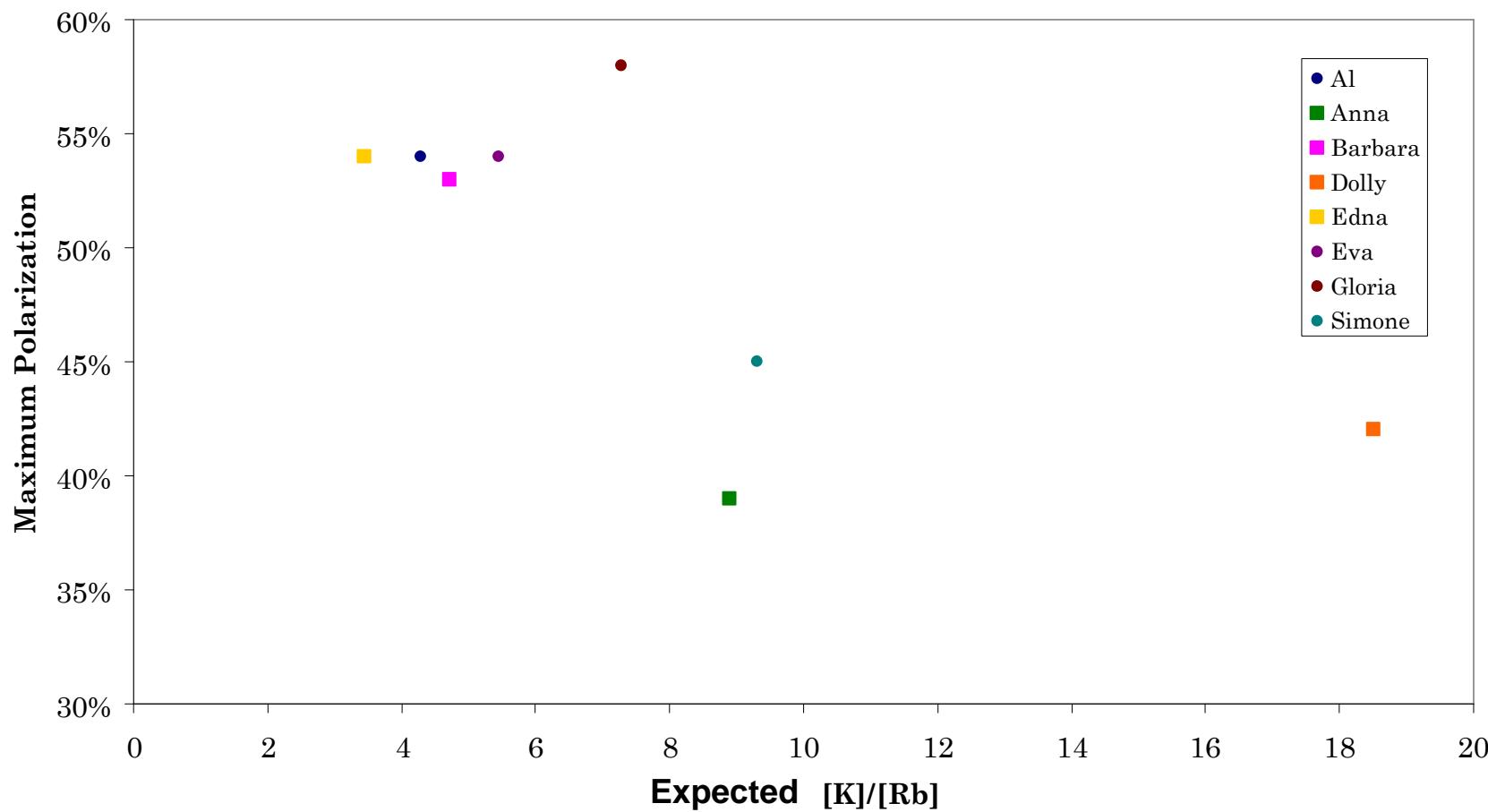
- Alkali Polarization

*Add Lasers/Adjust Spectrum*



# Future Work

## Cell Performance



# That's It

