A Rubidium Spin Filter - Prototype and Prospects for a Turnkey Source of Polarized Electrons

Perpetrators

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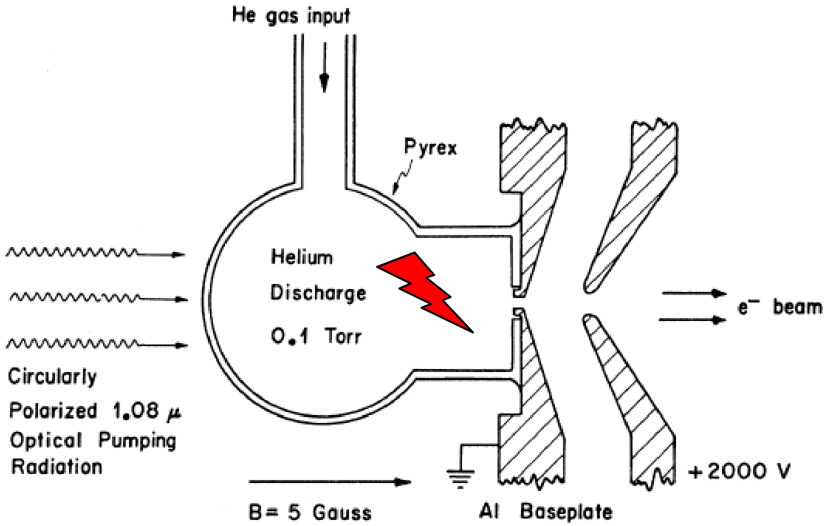
He direct extraction source



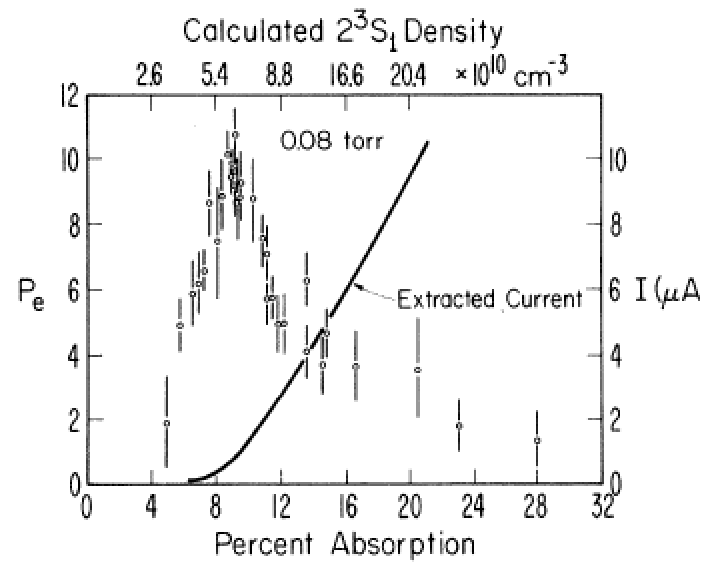
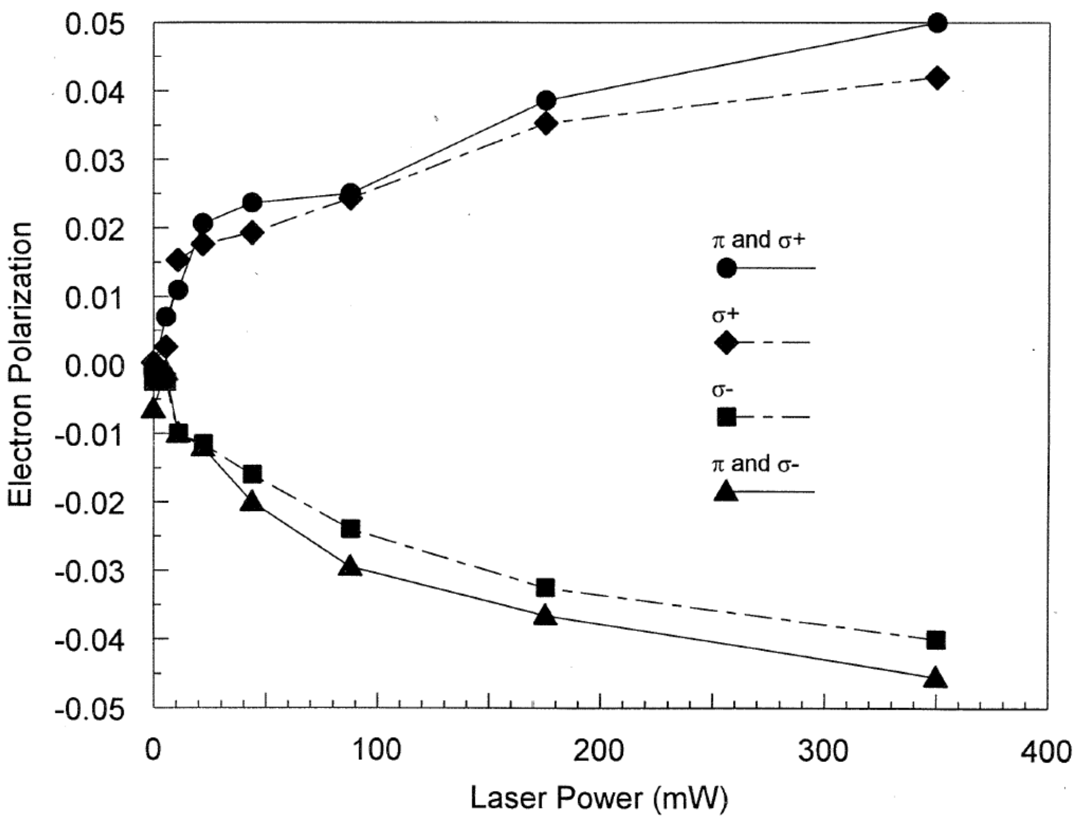


FIG. 6. Observed polarization and beam intensity of electrons extracted from an active discharge vs discharge intensity. The gas pressure is 0.08 torr. As in Figs. 1, 2, and 3 the relative absorption of the 1.08-μ pumping light characterizes the discharge intensity.

McCusker, Hatfield and Walters, PRA ***5****, 177 (1972)*

Rolla Source Results

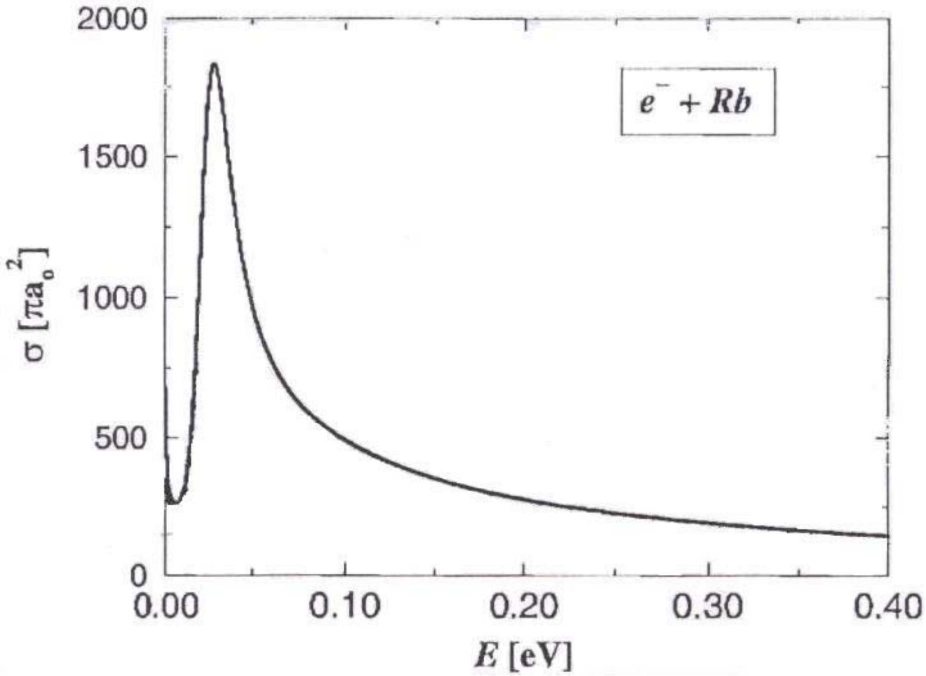


Improvements: LMA laser; side-pi pumping

The Good News: 50μA of current (@ 3% polarization)

The Bad News: Stringent requirement for high percentage of discharge in excited states; ΔE ~ 6 eV

Answer: use ground state atoms



*Fabrikant and Thumm, JPB **40**, 1245 (1999)*

$$e^- + Rb \rightarrow e^- + Rb$$

Require (at 5 eV) that $\sigma_{ex} n_{Rb} \ell \sim 1$

$\rightarrow \quad n_{Rb} \sim 10^{14}\ \mathrm{cm}^{-3}$

Other (Electron) Spin Filters

Ann.Phys. **2**, 465 (1993)

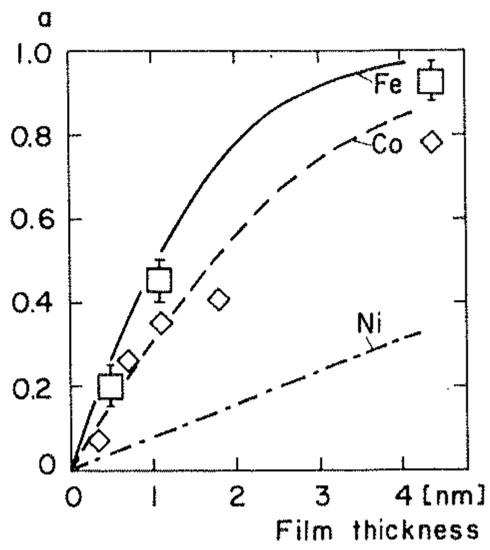
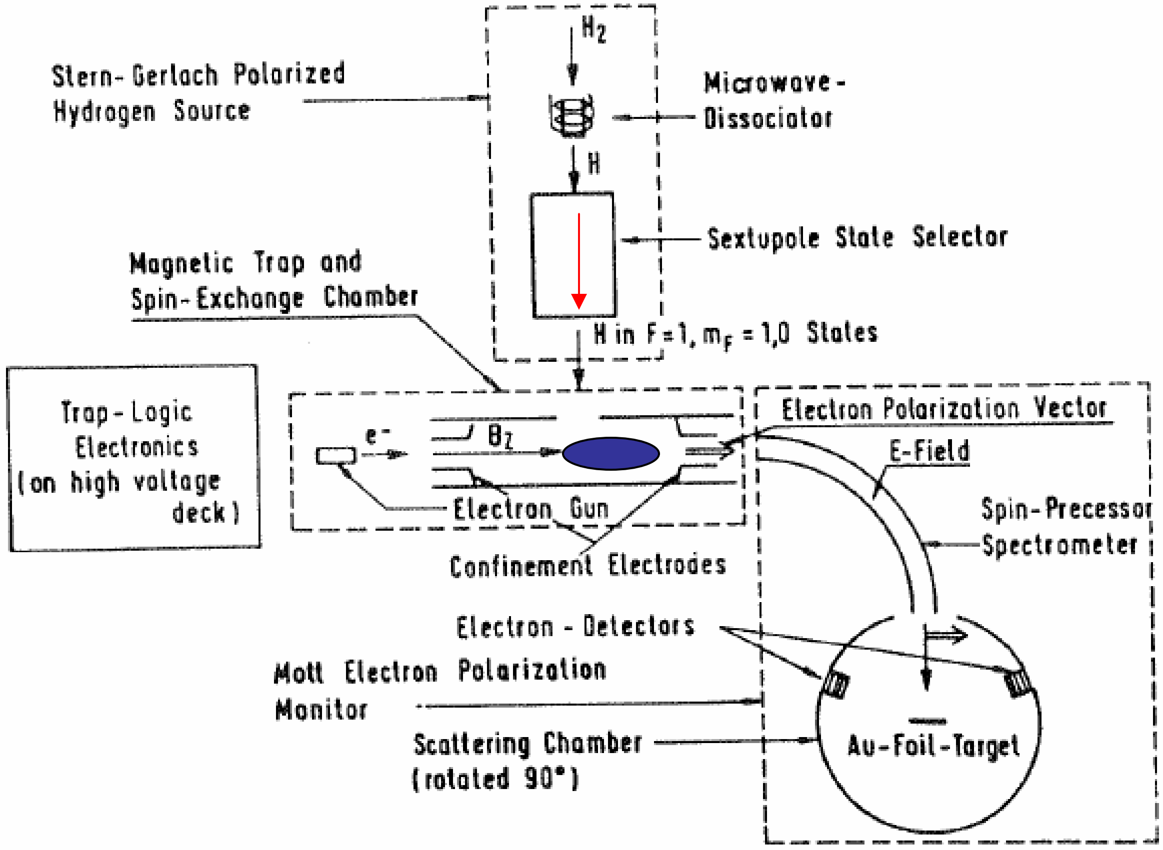


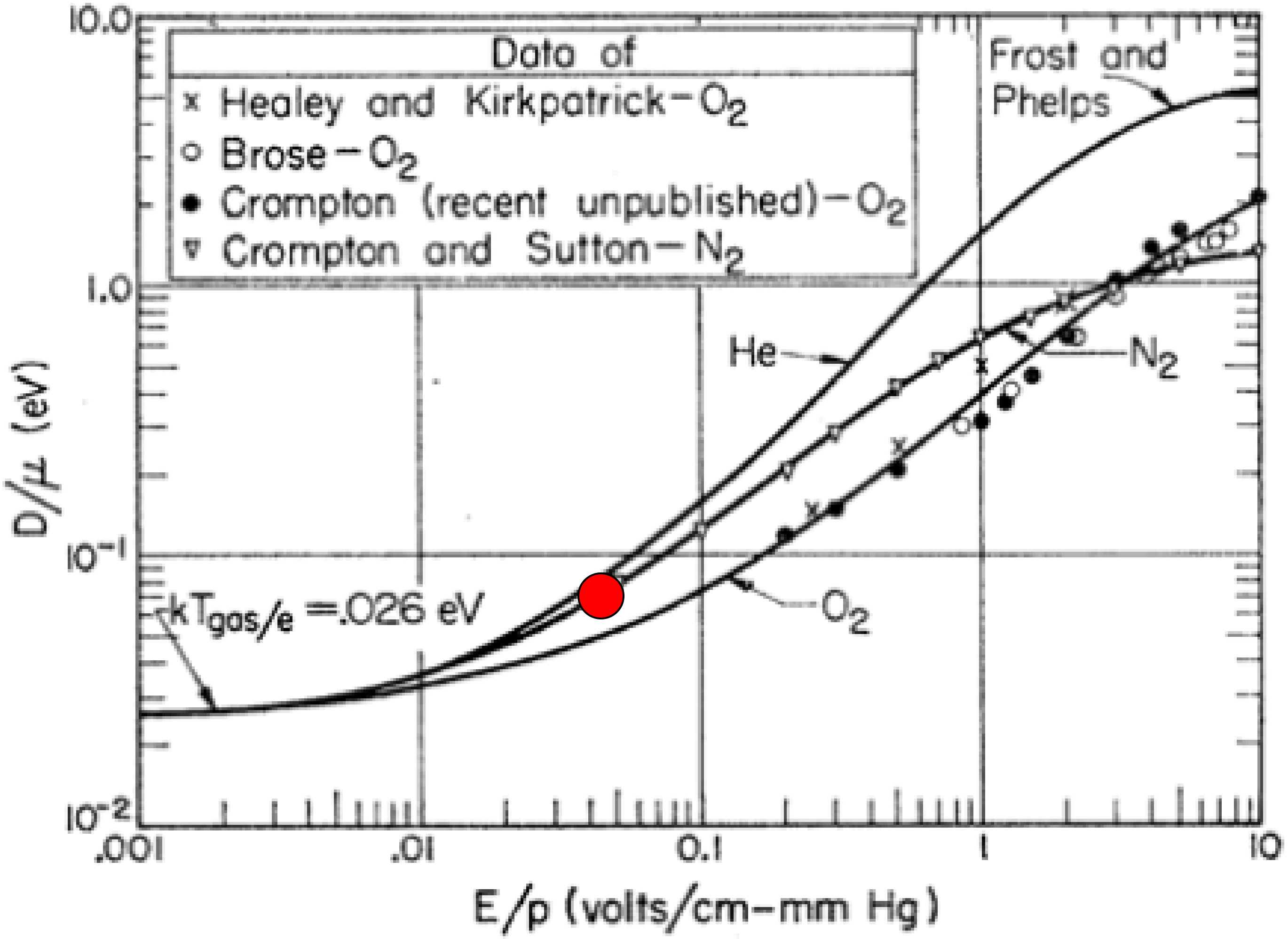
Fig. 4 Transport spin polarization $\mathbf{a}(x)$ vs. thickness x of the ferromagnetic material for Fe, Co and Ni. The calculated curves are for $T = 0$ K, whereas the data points were obtained at $T = 300$ K. Squares denote Fe data, diamonds Co.

See also work on neutron spin filters by Gentile, Chupp, Cates etc…

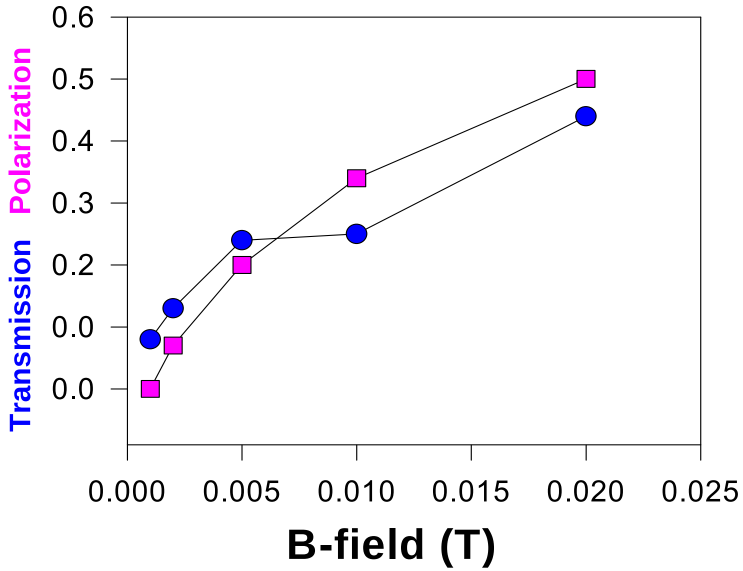
An early spin-exchange source

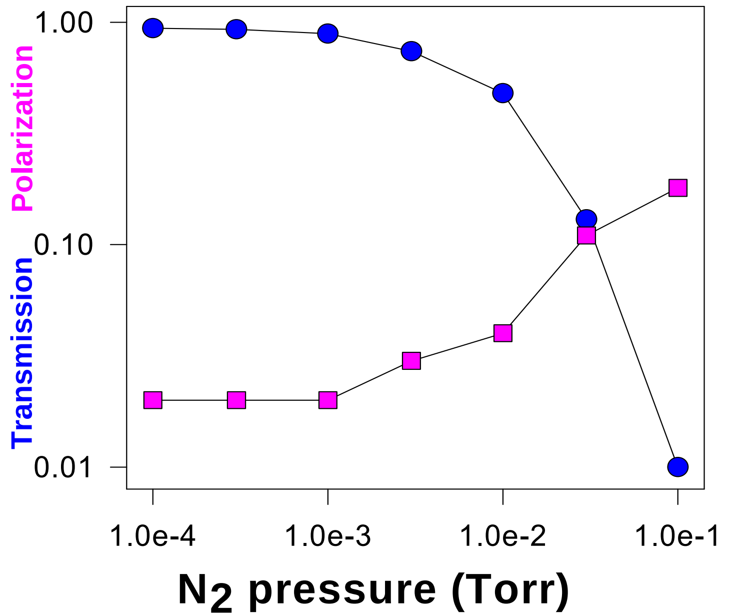


*Krisciokaitis-Krist and Tsai, NIM 83, **45** (1970)*



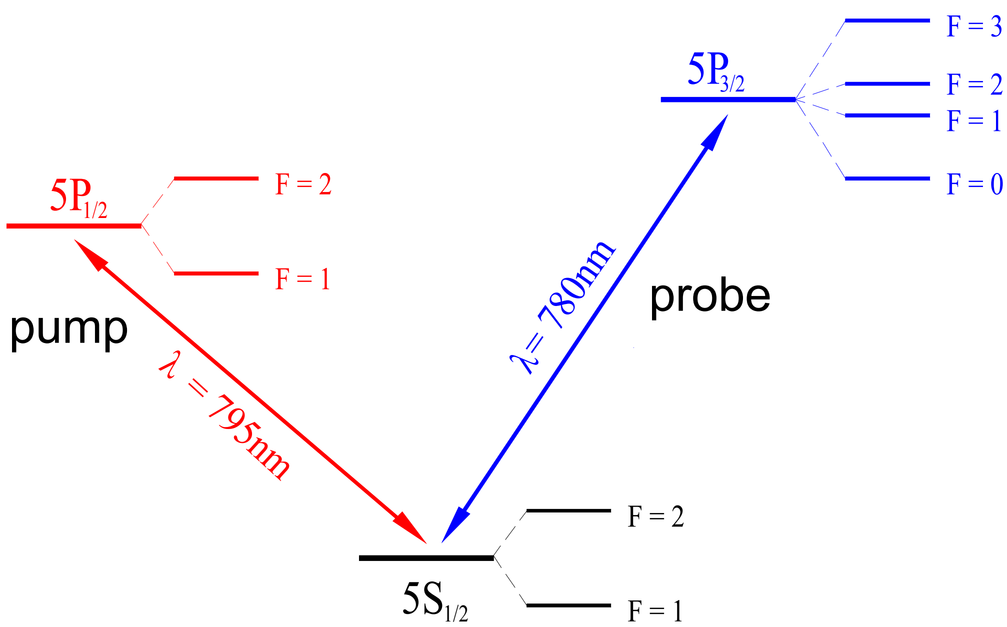
Chanin *et alii*, PR **80**, 67 (1962)

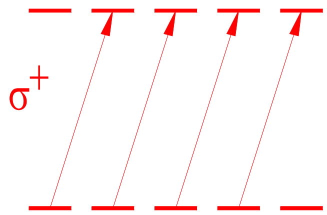


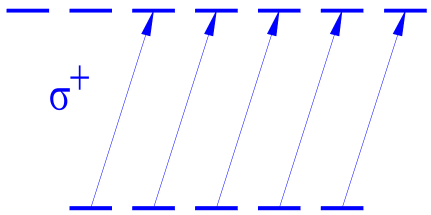


Some model calculations for n_{RB} = 3 x 10^{14} cm^{-3}

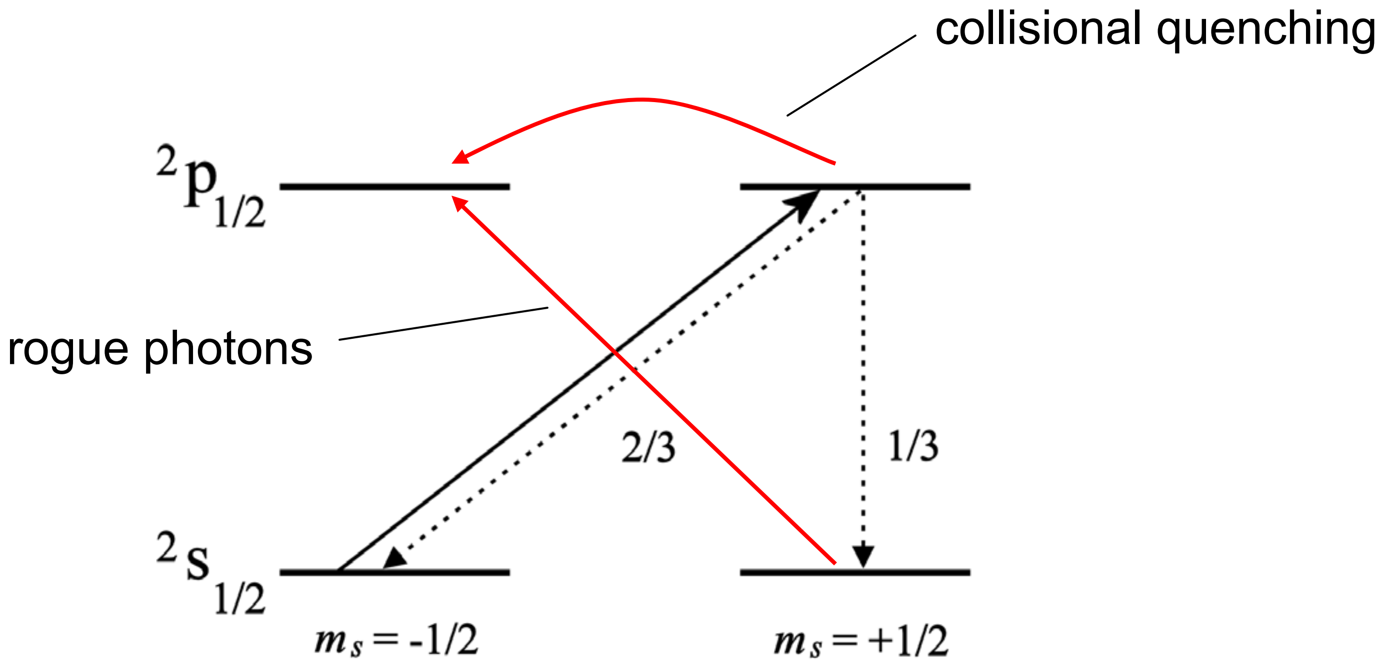
Rb optical pumping



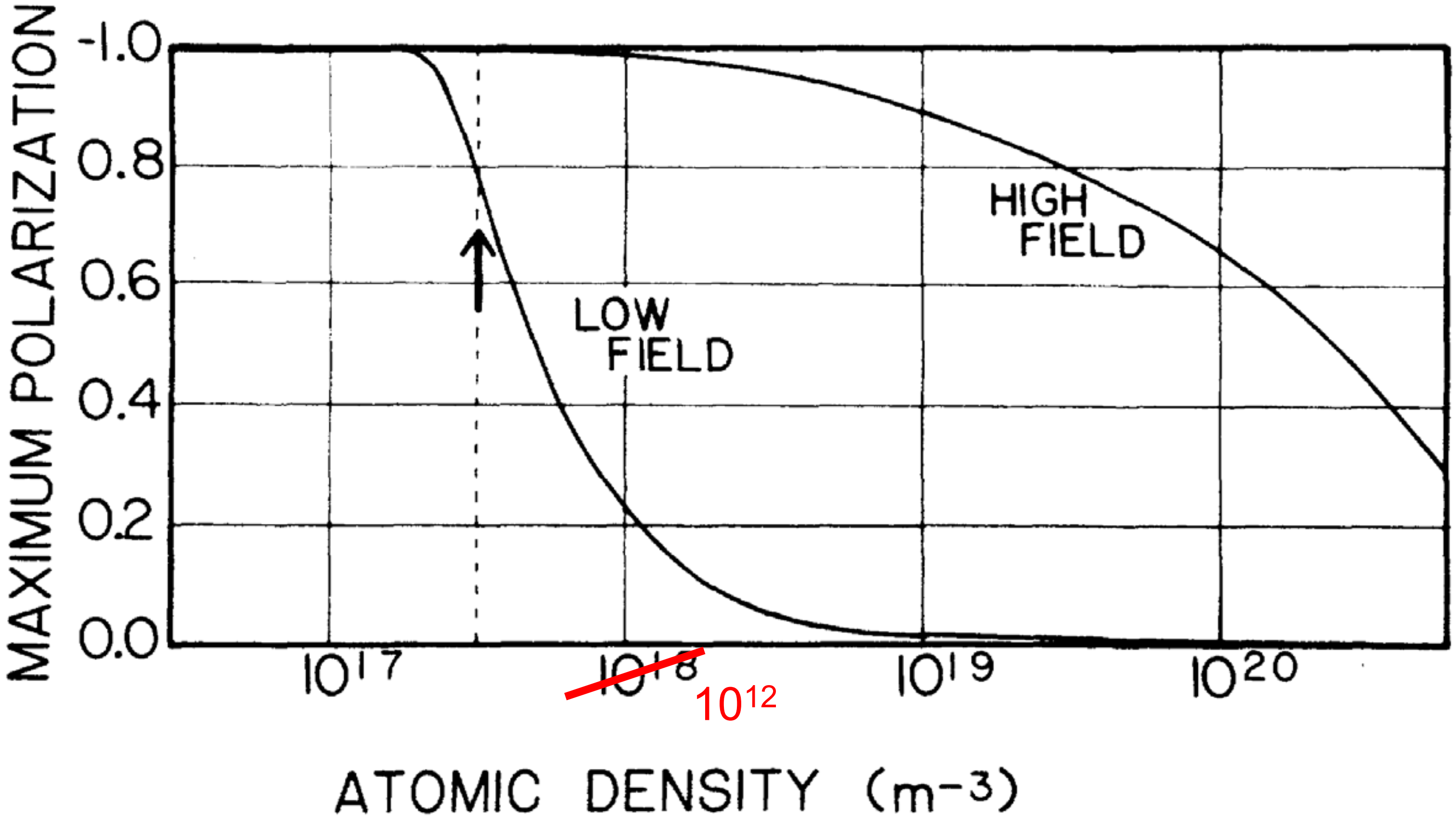




Rb optical pumping and radiation trapping

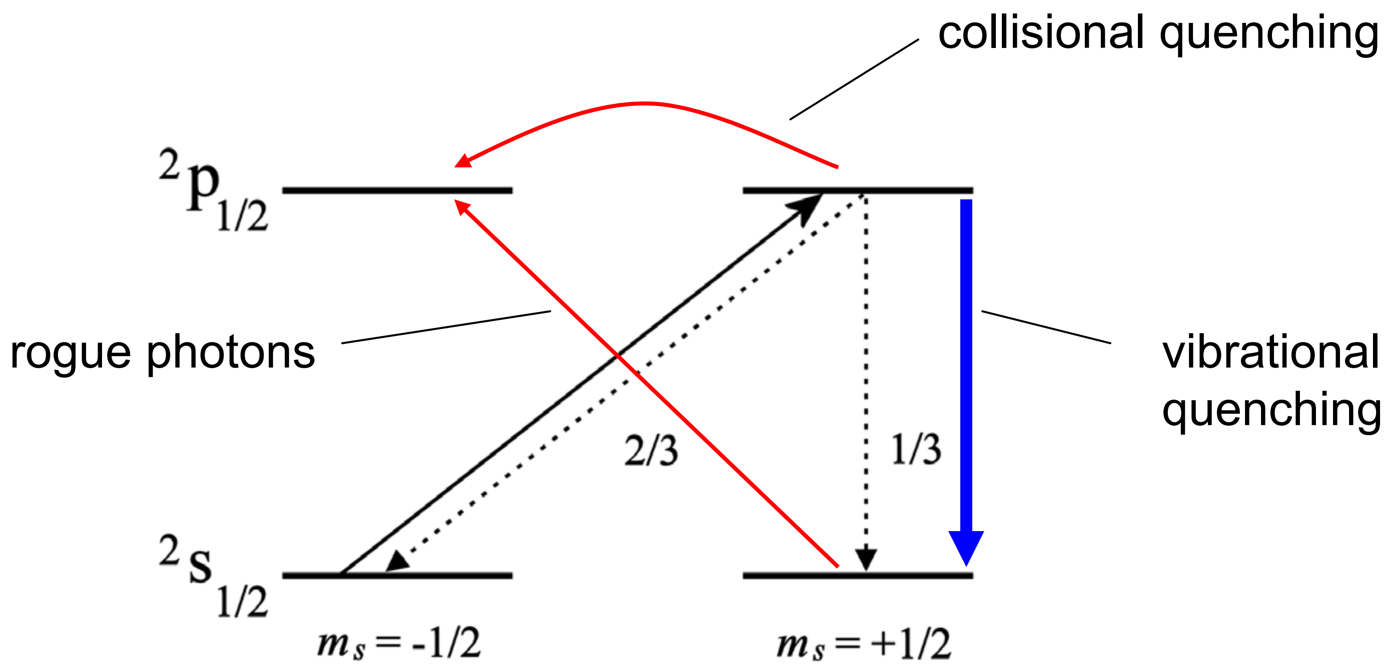


One solution: Gausses

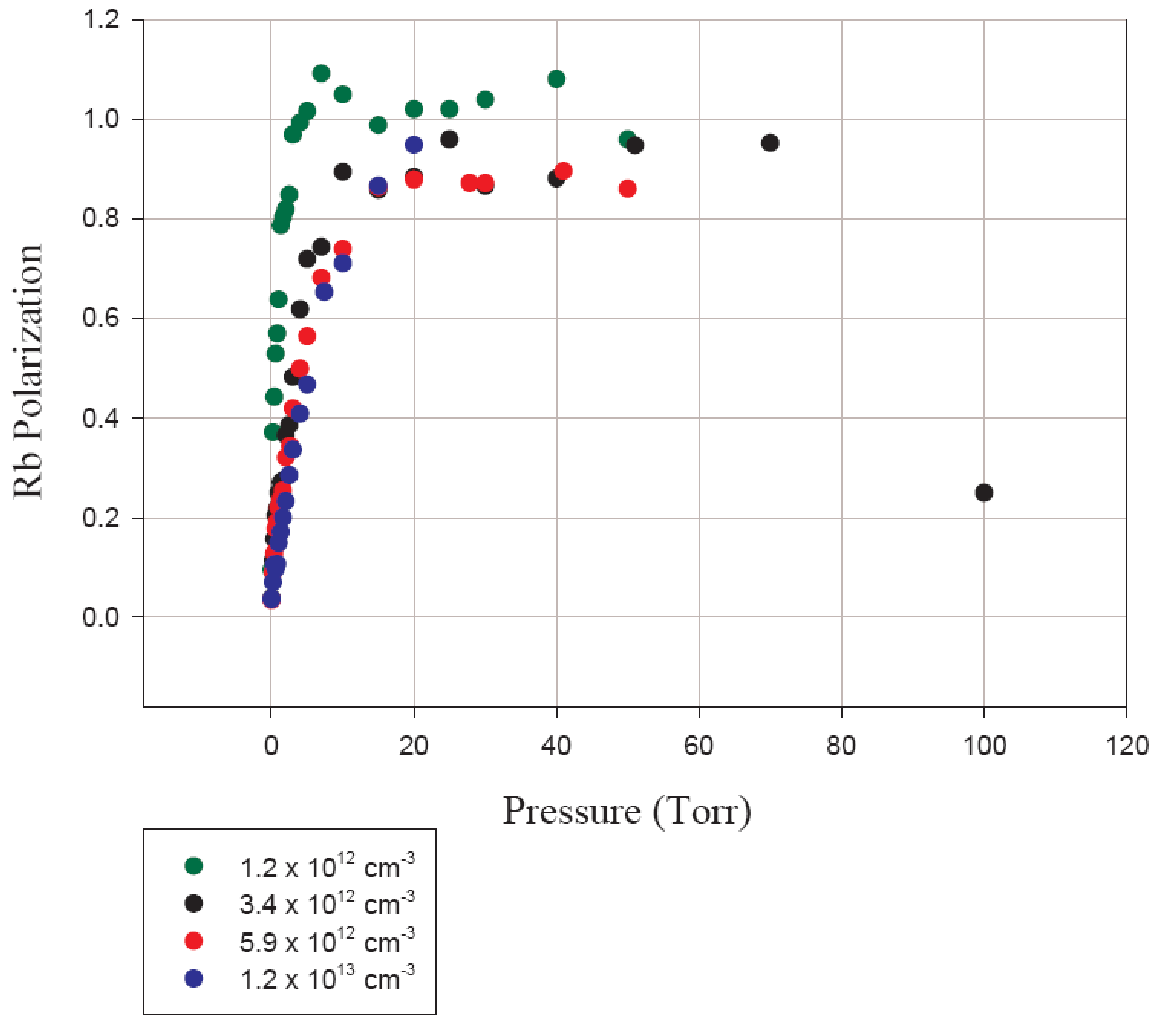


Tupa et al., *PRA* ***33****, 1045 (1986);* ***36****, 2142 (1987)*

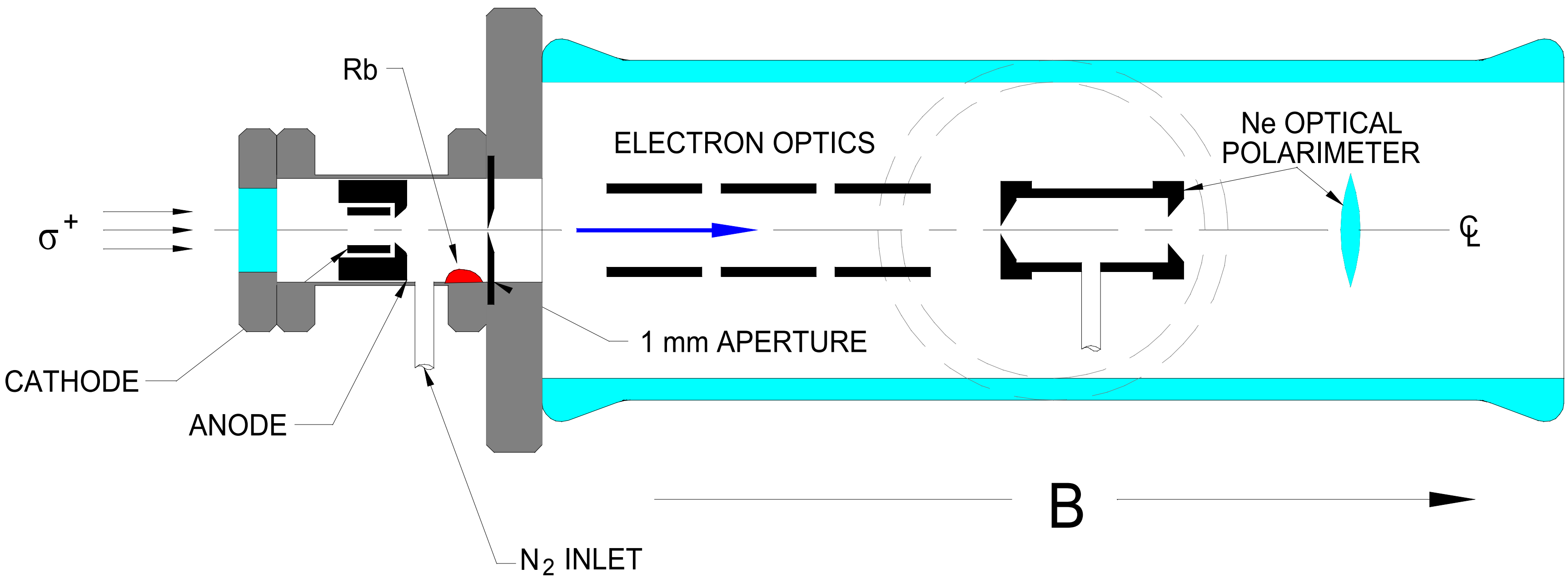
Another Solution: Add Buffer Gas

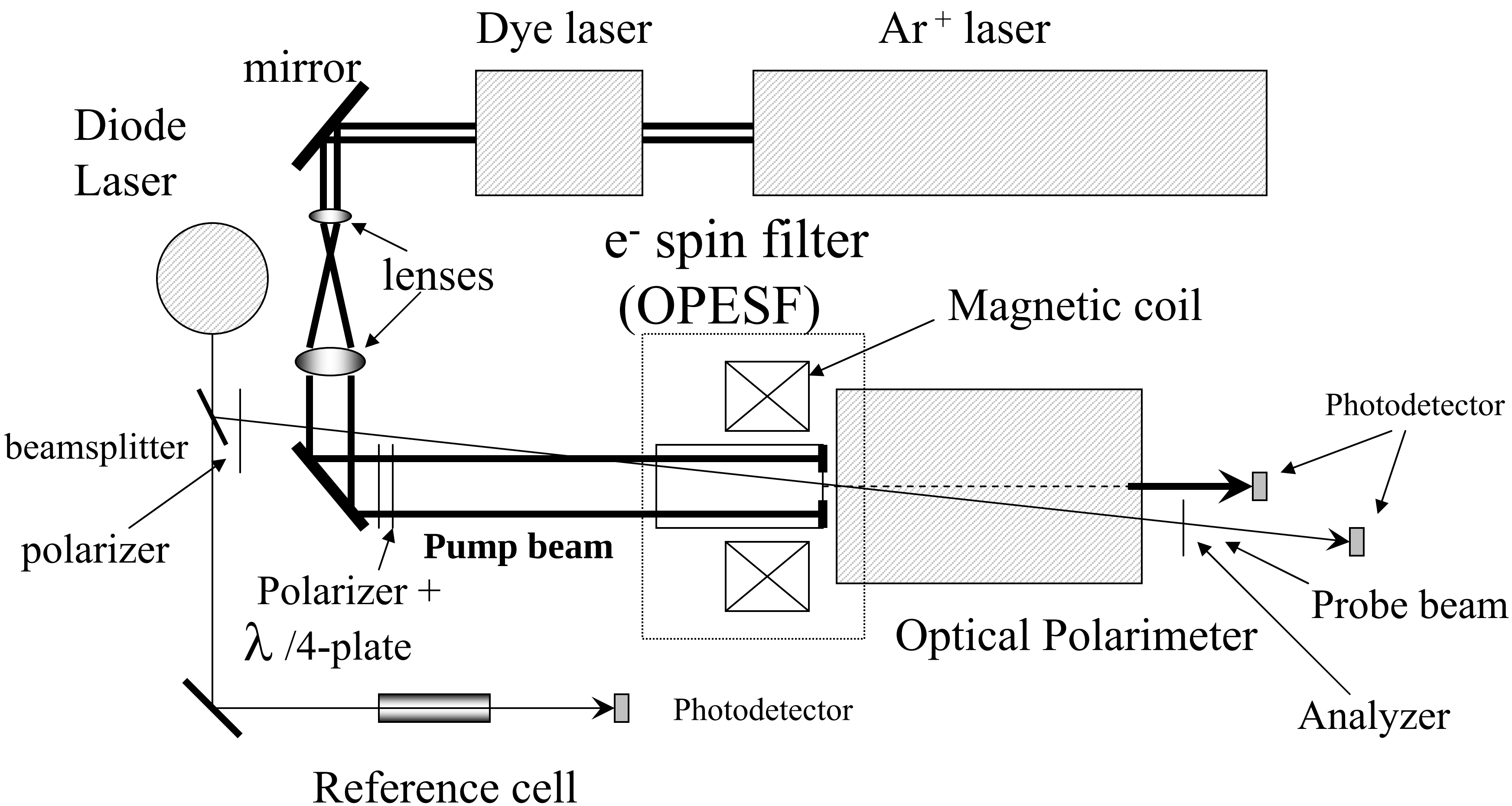


Rb optical pumping with N_2



First attempt




Dye laser
Ar + laser
mirror
Diode
Laser
lenses
e- spin filter
(OPESF)
Magnetic coil
Photodetector
beamsplitter
polarizer
Pump beam
Polarizer +
λ /4-plate
Probe beam
Optical Polarimeter
Analyzer
Photodetector
Reference cell

Probe data

$$n_{Rb} = \frac{8\pi(\Delta\phi)\delta^2}{l\Gamma\lambda^2\mu_B B}$$

$$P_{Rb} = \frac{56\pi(\Delta\phi)\delta}{3n_{Rb}l\Gamma\lambda^2}$$

- $\Delta\Phi$ = optical rotation of probe
- δ = probe beam detuning
- l = path length
- λ = D2 wavelength
- Γ = D2 natural width

Results

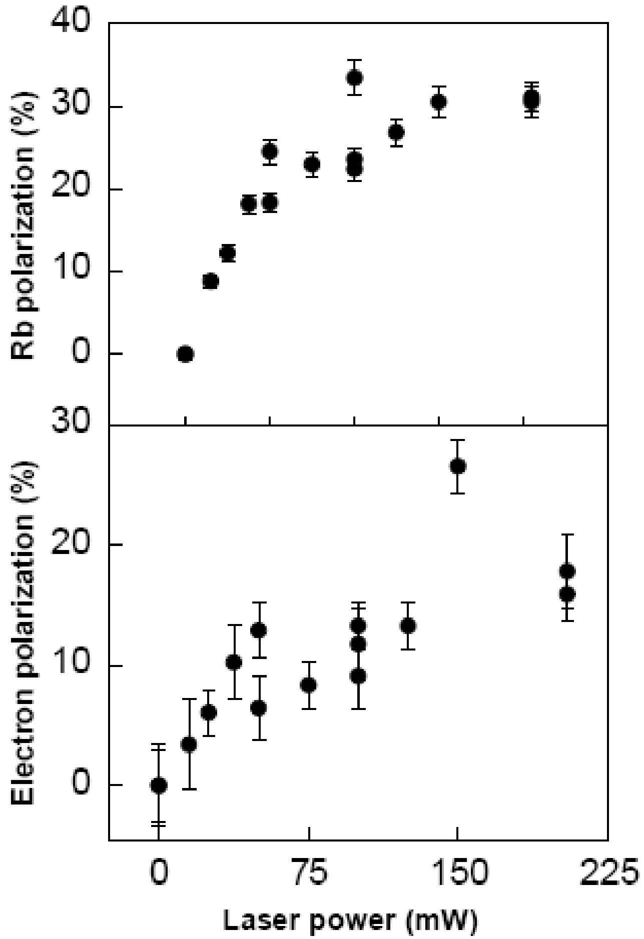


FIG. 3. Rb and electron polarization vs pump laser power with $n_{Rb} = 7 \times 10^{11}$ cm^{-3} and a nitrogen buffer pressure of 0.4 Torr. The extracted electron current is 2 μA. Error bars indicate statistical uncertainty only.

Batelaan *et alii*, PRL 82, 4216 (1999)

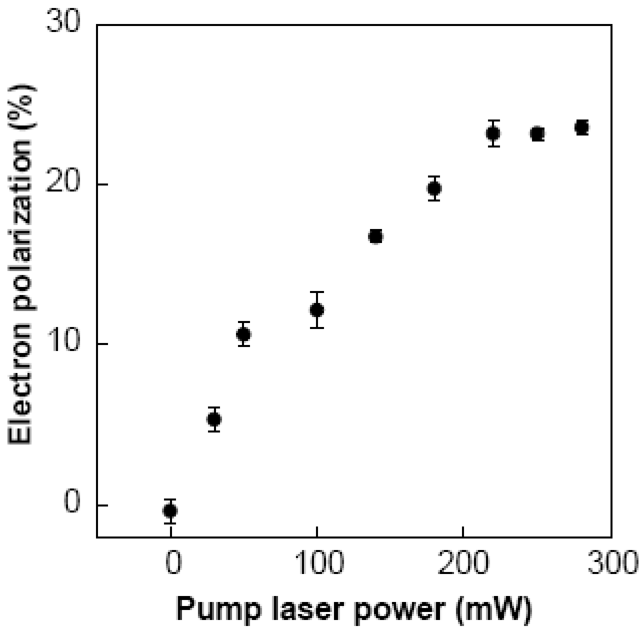


FIG. 4. Electron polarization vs pump laser power with $n_{\mathrm{Rb}} = 3 \times 10^{12}\ \mathrm{cm}^{-3}$ and a helium buffer pressure of 2 Torr. The extracted electron current is between 4 and 5 μA.

Figure of Merit = $P^2 I$ = 0.28 μA

¡Nitrogen - the wonder buffer!

- *provides the electrons*
- *narrows their energy spread*
- *thermalization increases* σ_{ex}
- *increases path length, l*
- *vibrational quenching*
- *diffusion barrier*
- *broadens absorption profile*

v.2

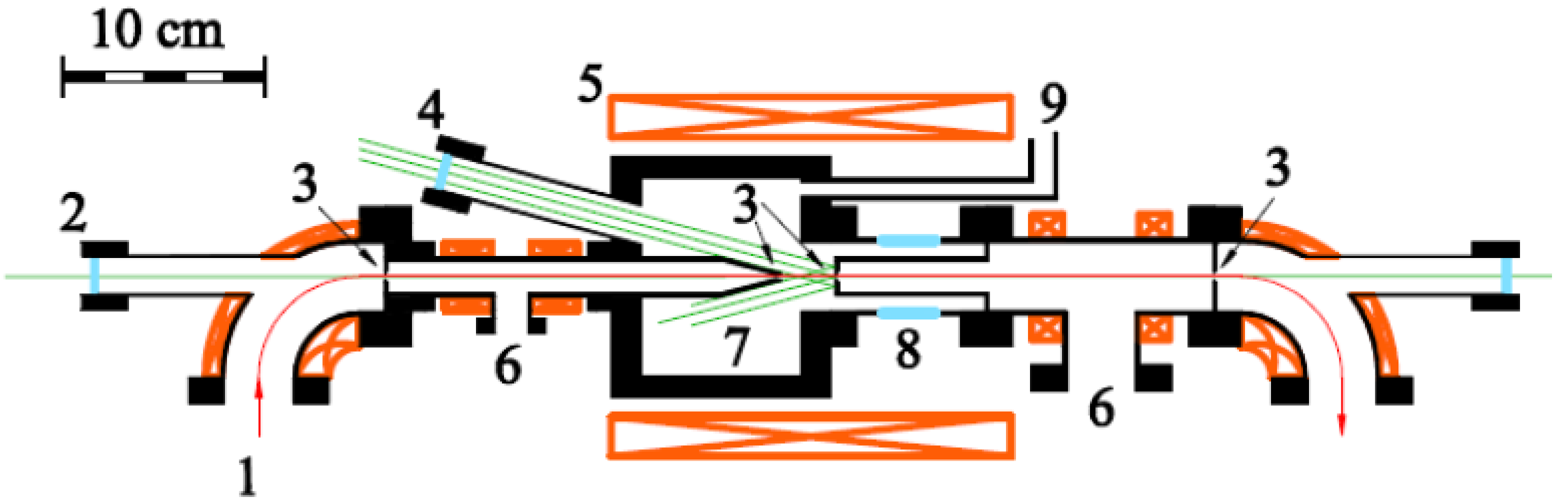


Figure 8. Spin filter apparatus showing (1) incident electron beam; (2) probe laser; (3) differential pumping and beam-defining aperture; (4) pump beam; (5) solenoidal magnet; (6) differential pumping port; (7) spin-exchange chamber; (8) insulating break; (9) buffer gas inlet.

Problem

Pump beam is most efficient at entrance point, where the electrons that will ultimately be polarized aren't.

High magnetic field side-pumping scheme

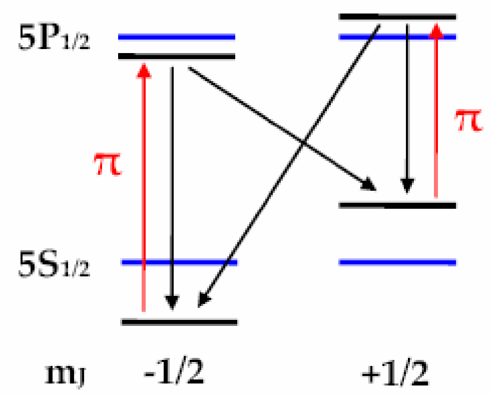
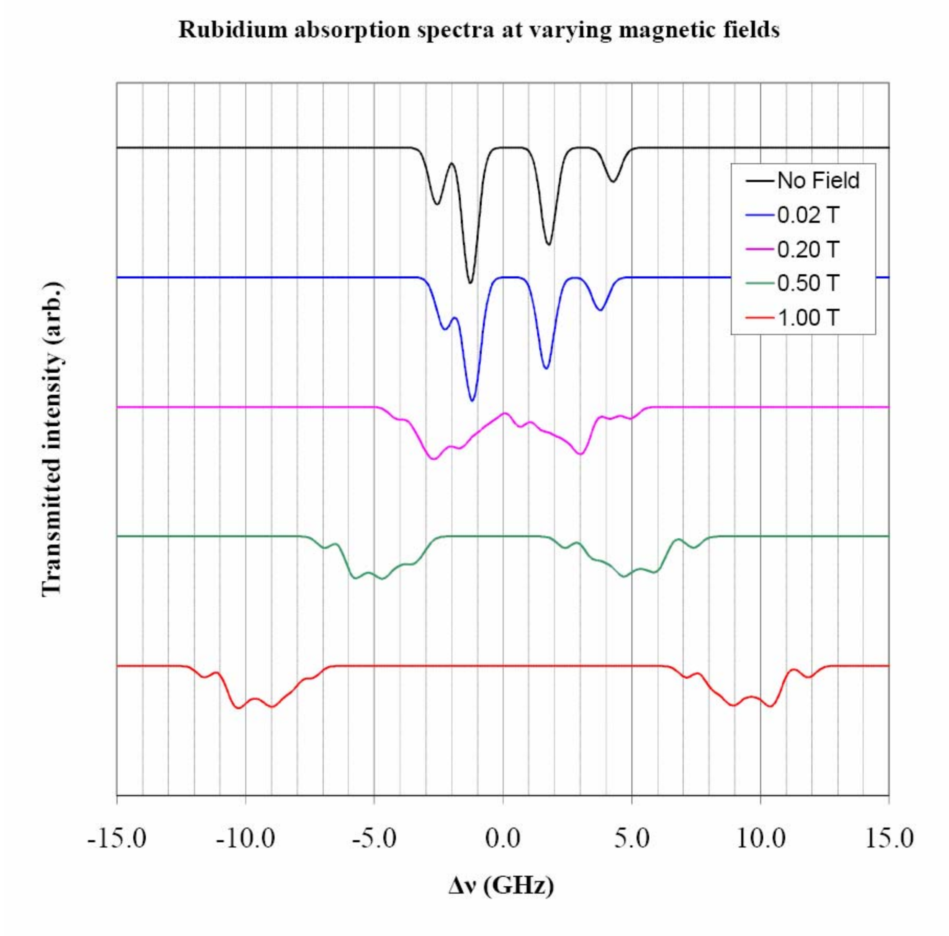


Figure 9. The pumping (red arrows) and decay (black arrows) transitions are shown for optical pumping with linearly-polarized light in a strong magnetic field.

*Martin, Walker, Anderson, and Swenson, NIM A **335**, 233 (1993)*

Rb absorption *vs*. B-field



Side-pumping geometry

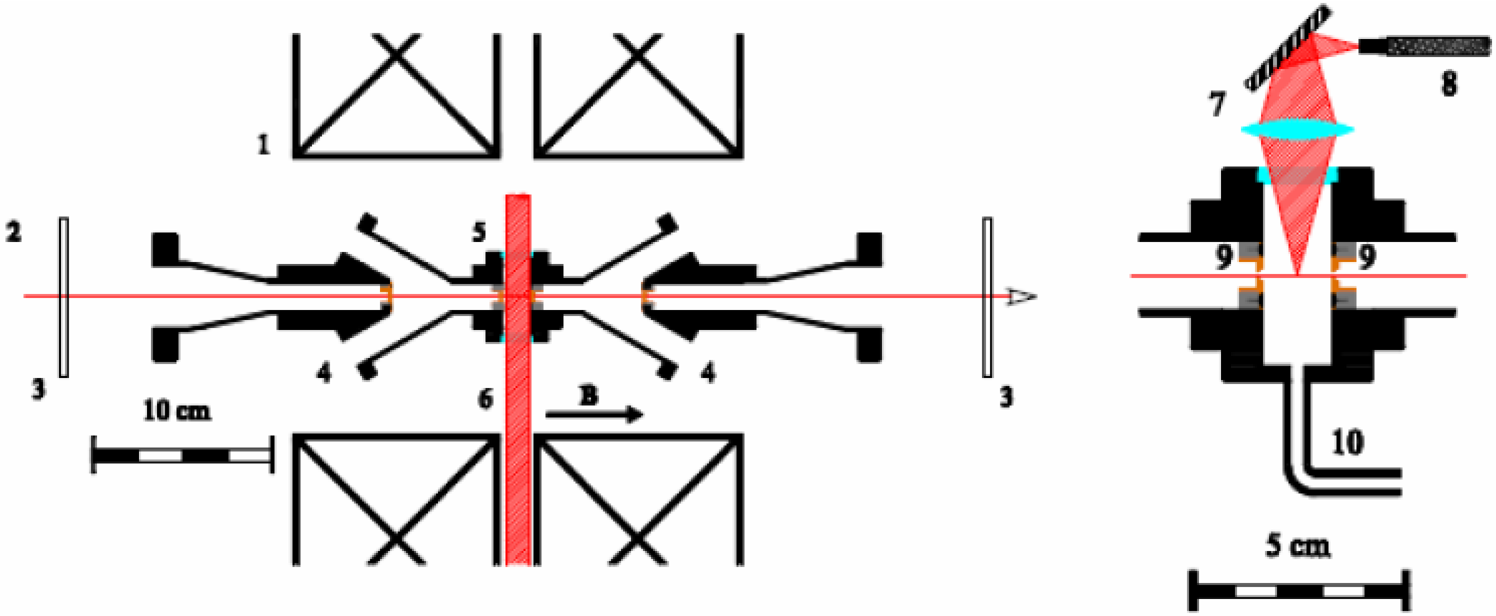
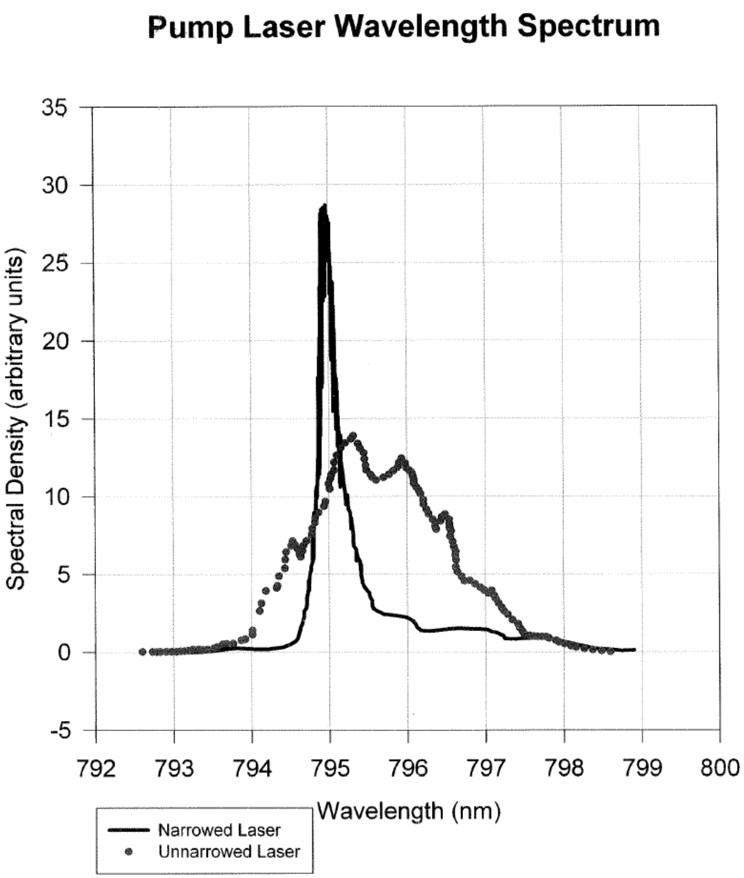


Figure 10. Proposed apparatus for transverse optical pumping and electron/alkali spin exchange. Shown schematically are (1) magnetic coils to create the longitudinal field; (2) probe laser beam; (3) linear polarizer; (4) differential pumping ports; (5) spin exchange/pumping cell (see close-up at right); and (6) pump laser. At right is a close up of the pumping cell showing (7) resonance fluorescence collection optics routing fluorescence light into (8) a fiber optic; (9) differential pumping apertures that also establish the drift field in the cell; and (10) a port for introducing Rb vapor and buffer gas.

Possibilities for the future



T. Walker et al.