Spin Polarized Electrons and Molecular N_2 Fluorescence

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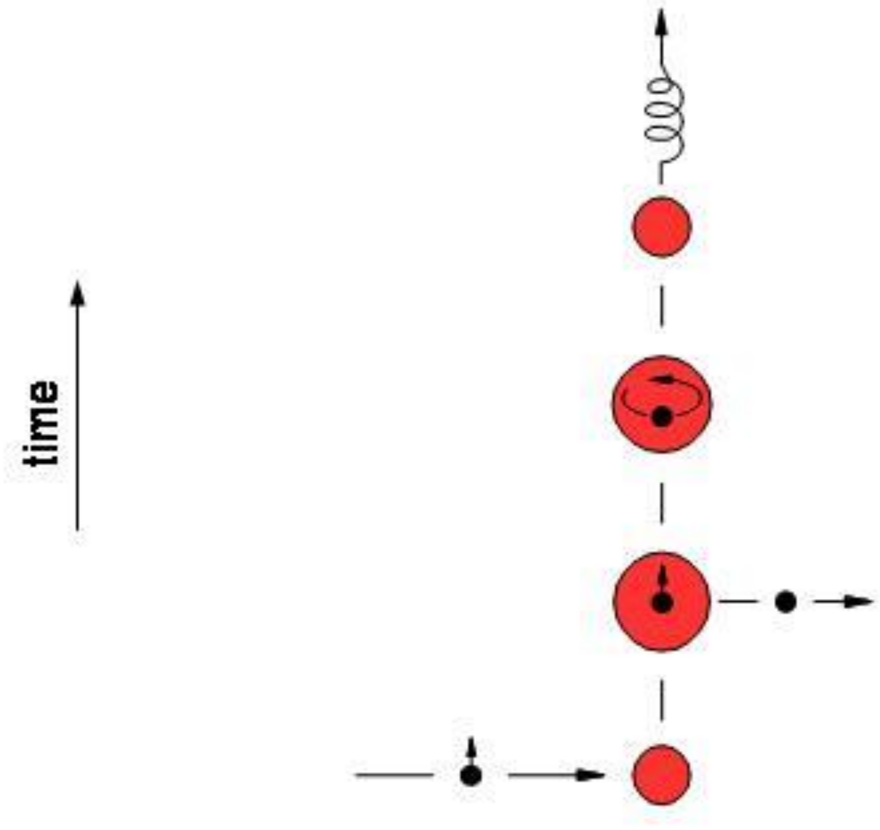
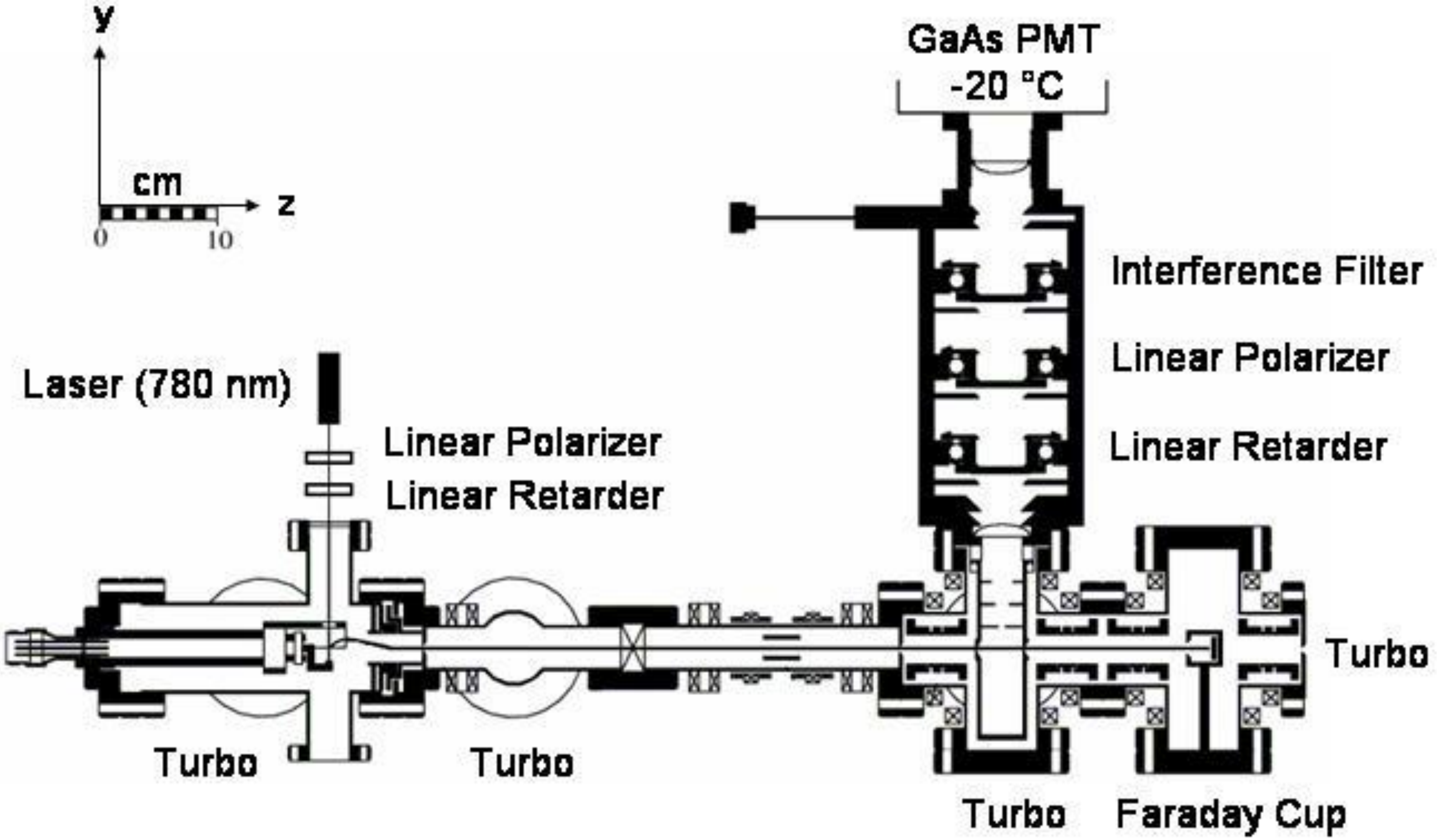
Spin and Radiation for Atoms or Molecules



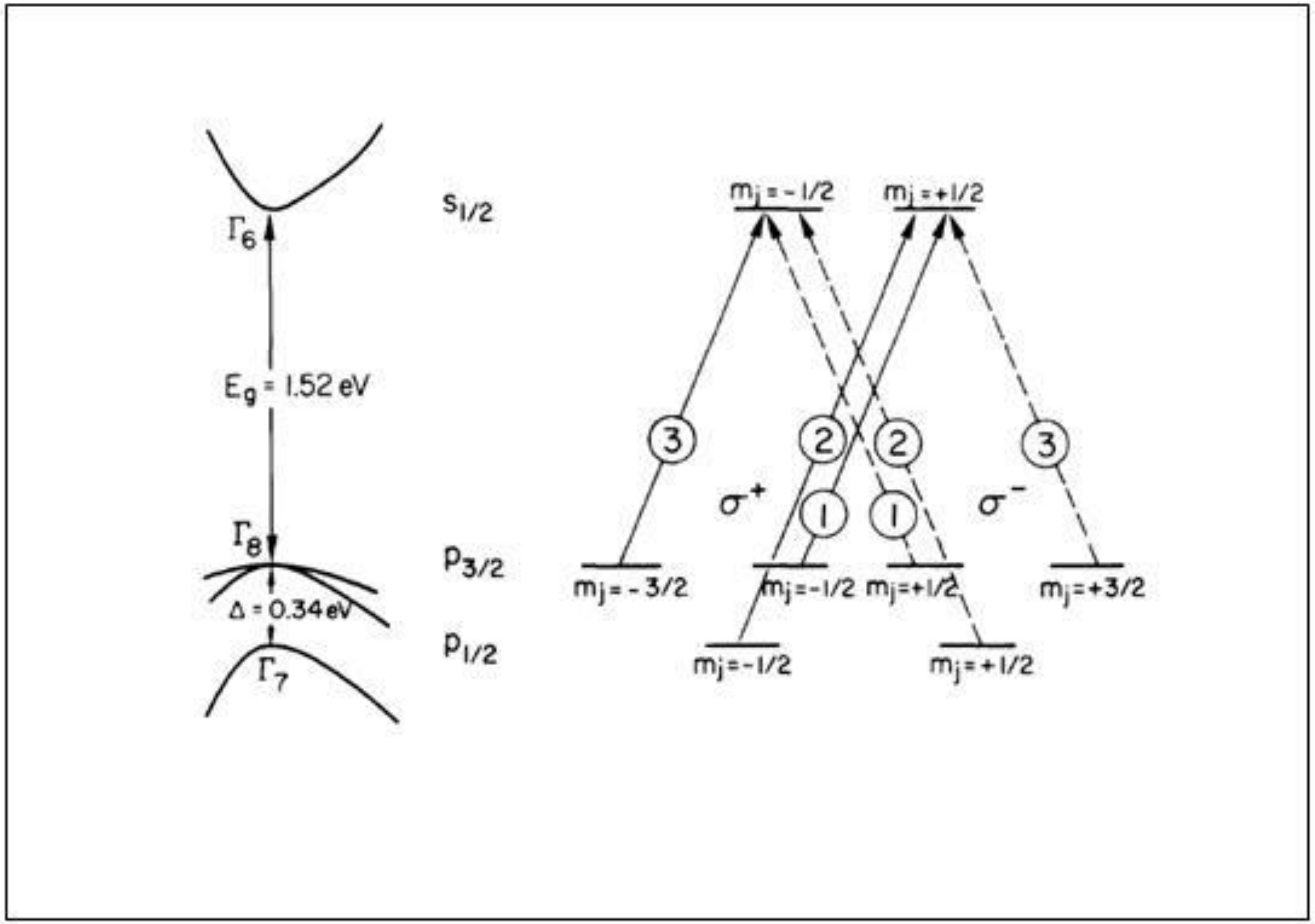
The Apparatus



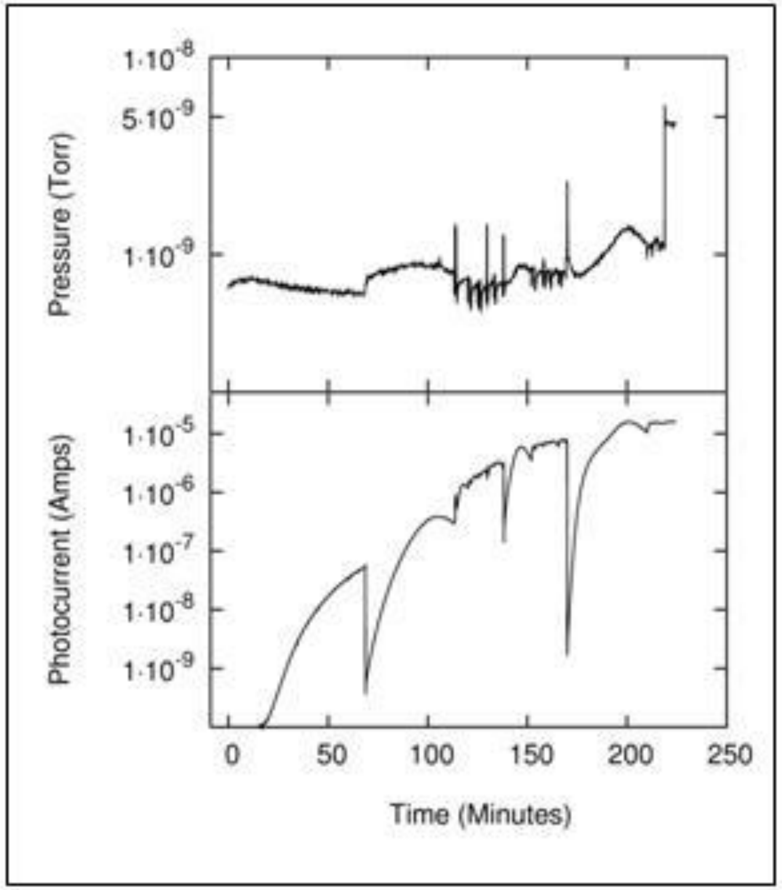
GaAs Polarized e^- Source

- Getting polarized electrons…
  - Chemically clean crystal and insert into vacuum chamber
  - Bake chamber and get a base pressure of $2x10^{-10}$ Torr
  - Heat clean crystal
  - Circularly polarized laser light (780 nm) is used to preferentially excite electrons of a particular spin
  - Cesium (Cs) and oxygen (O_2) are applied in layers to reduce the work function of GaAs so that it lies below the first conduction band (~4 eV).

GaAs Polarized e⁻ Source



GaAs Polarized e⁻ Source



- Emission current ~15 μA (but beam lifetime only ~1 day)
- Typical beam energy width of ~0.3 eV.
- Electron polarization measured 19.3 ± 0.7%

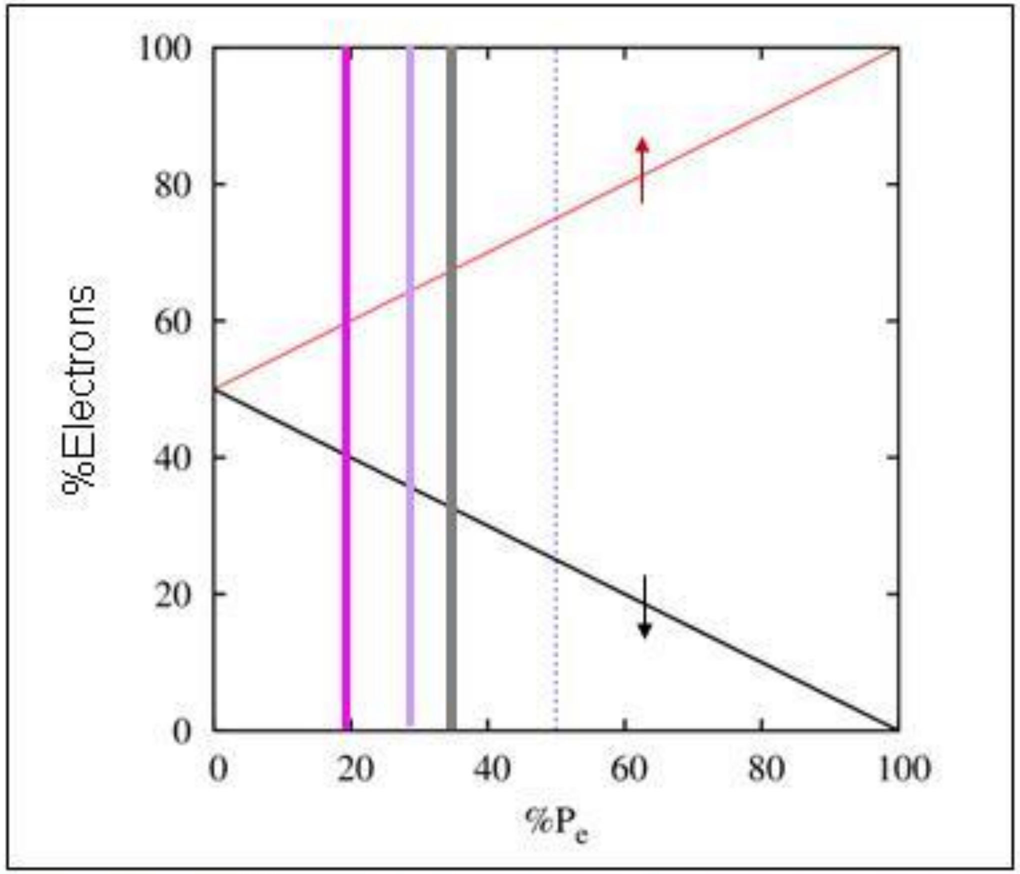
"Yo-yo" activation

Polarizations for electrons

Electron polarizations for a system of identical spin states ('pure') are defined as expectation values of the Pauli spin operators

$$\vec{P}_e = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow}\,\hat{y}$$

$$\approx 20\%$$



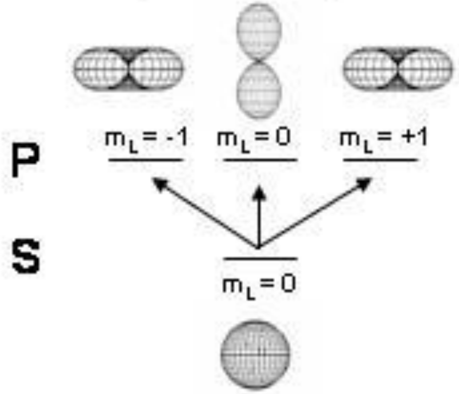
Helium Optical Polarimeter

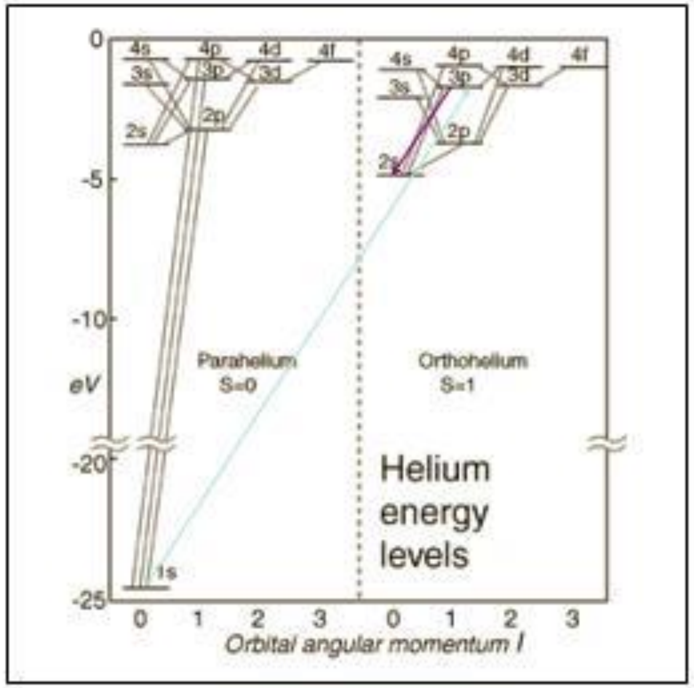
He: 1 $^1S_0$ excited→ 3 ^3P_J decays→ 2 ^3S_J (388.9 nm … 388±5 nm)
23 eV threshold; 23.6 eV cascade threshold.

Excitation timescale is 10^{-16} sec.

Decay timescale is 10^{-8} sec.

During this time weak spin orbit coupling affects the direction of L (i. e. the m_L projection), thus influencing the emitted photon's polarization.



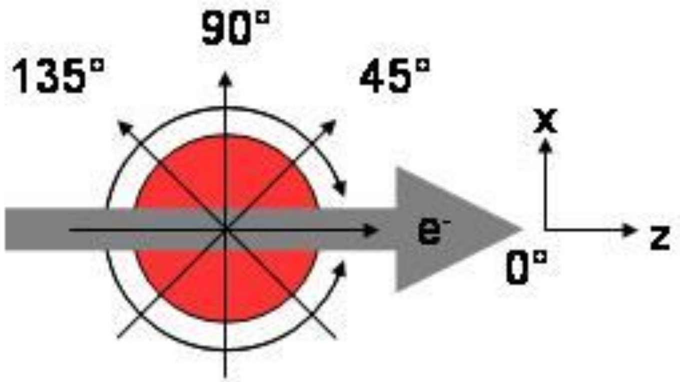


Stokes Parameters

To completely characterize the polarization of light a minimum of four parameters are required:

$$StokesVector\,\wp = \begin{pmatrix} I \\ IP_1 \\ IP_2 \\ IP_3 \end{pmatrix}$$

$$IP_1 = I_{0°} - I_{90°}$$
$$IP_2 = I_{45°} - I_{135°}$$
$$IP_3 = I_{RH} - I_{LH}$$



$$1 \geq P_{total} = \sqrt{P_1^2 + P_2^2 + P_3^2}$$

How to Measure Stokes Parameters

$$I' = \sum_{j=1}^{4} M_{1j} \wp_j$$

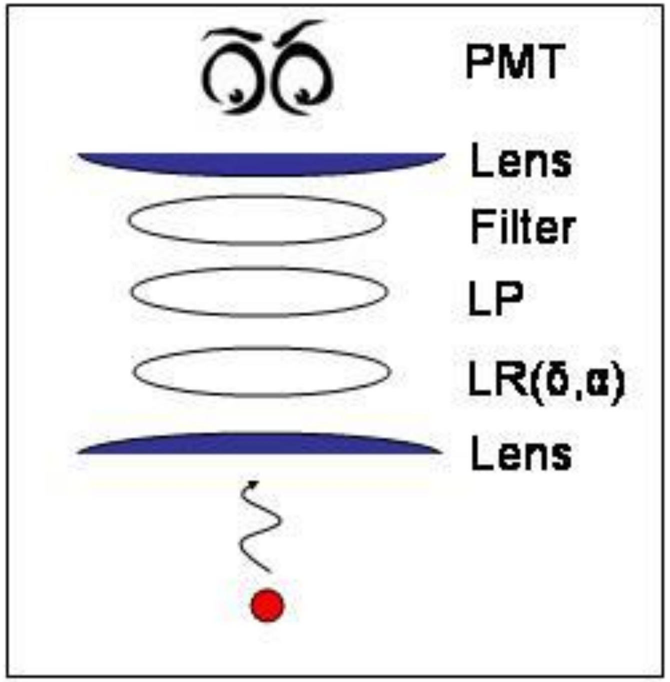
$$M = LP \times R(-\alpha) \times LR(\delta) \times R(\alpha)$$

$$LP = \frac{1}{2}\tau_{max} \begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

$$R(-\alpha) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 1 & cos(2\alpha) & -sin(2\alpha) & 0 \\ 0 & sin(2\alpha) & cos(2\alpha) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$LR(\delta) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & cos(\delta) & sin(\delta) \\ 0 & 0 & -sin(\delta) & cos(\delta) \end{pmatrix}$$

$$R(\alpha) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 1 & cos(2\alpha) & sin(2\alpha) & 0 \\ 0 & -sin(2\alpha) & cos(2\alpha) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$



$$\begin{aligned} [2/I\tau_{max}]\, I' = [1] & \\ & + [cos^2(2\alpha) + sin^2(2\alpha)cos(\delta)]\, P_1 \\ & + [sin(2\alpha)cos(2\alpha) - sin(2\alpha)cos(2\alpha)cos(\delta)]\, P_2 \\ & - [sin(2\alpha)sin(\delta)]\, P_3 \end{aligned}$$

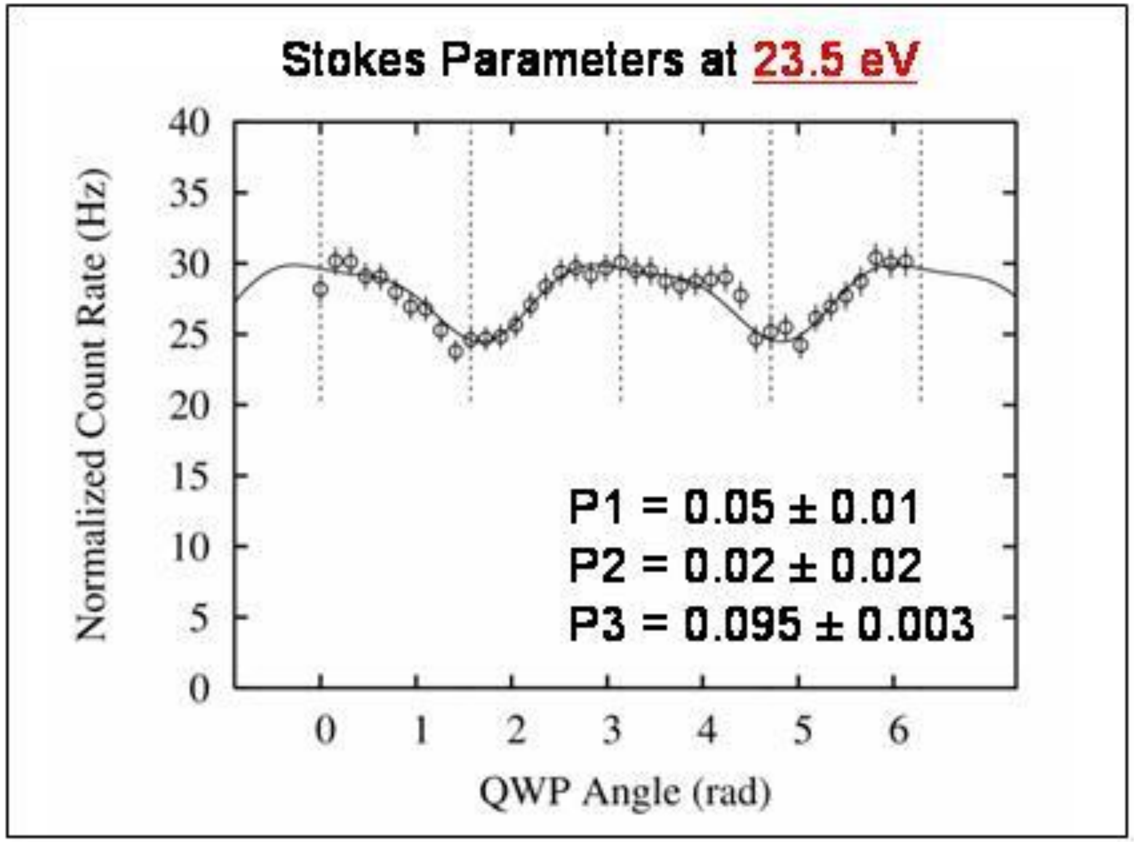
Helium Optical Polarimeter

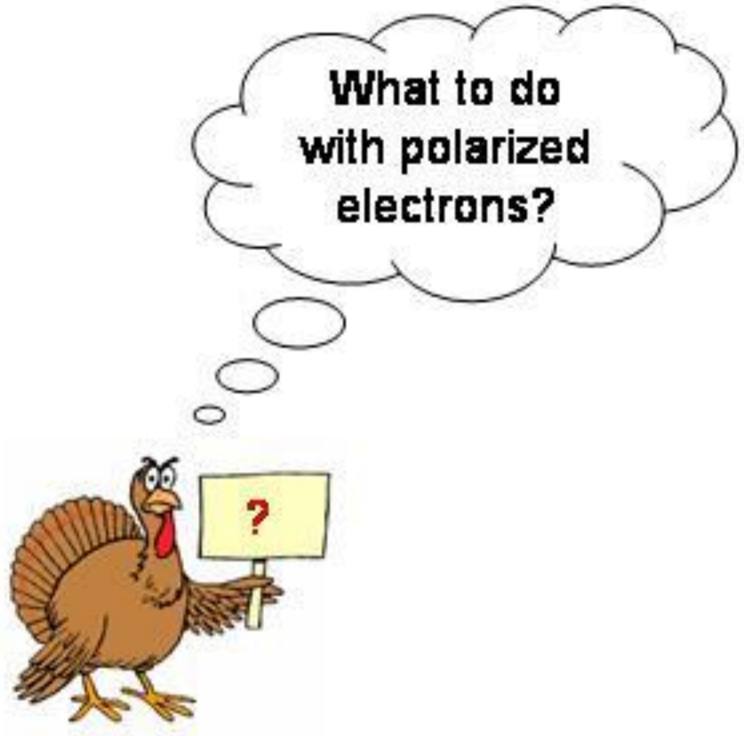
He: 1 $^1S_0$ excited→ 3 ^3P_J decays→ 2 ^3S_J (388.9 nm … 388±5 nm)

23 eV threshold; 23.6 eV cascade threshold.

$$P_e = \frac{6P_3}{(3 - P_1)} = .193 \pm 0.007$$

$$P_3 = AP_e = 0.49\, P_e$$




What to do
with polarized
electrons?
?

Why not try to experimentally observe spin transfer in molecules?

- **Adam Green observed significant spin transfer (P_3/P_e~%10) in H_2 molecular fluorescence**
- **It would be interesting to compare H_2 with another simple diatomic molecule: N_2**

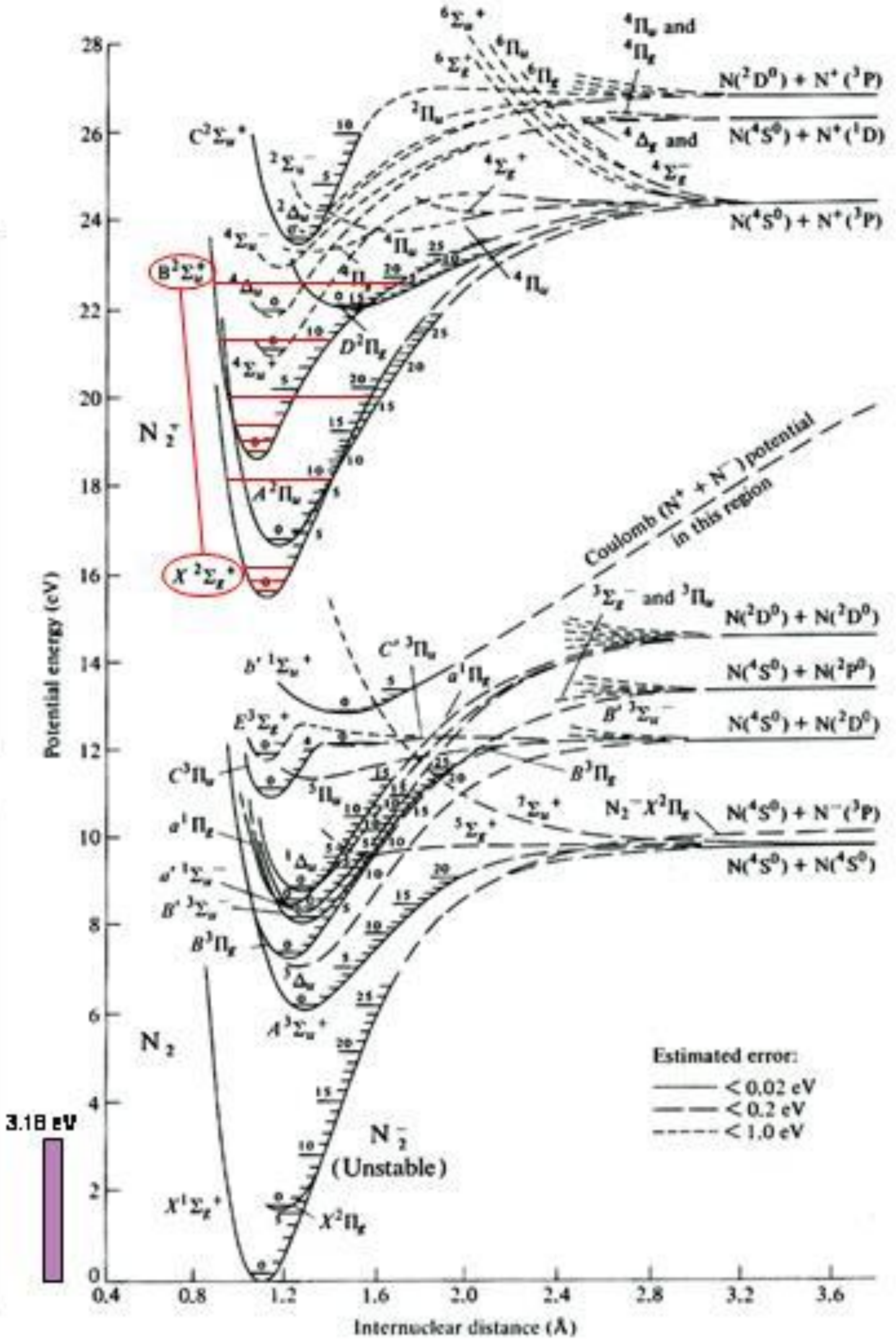
	H_2	N_2
Rotational Velocity	Faster	Slower
L-S coupling	Weaker	Stronger
Coupling of L with Molecular Axis	Spin Fixed in Lab Frame	Spin Follows Molecular Axis
P_3/P_e	Non-zero	Near-Zero

Process:	Timescale (sec.)
Excitation	10^{-16}
Molecular Vibration	10^{-14}
Molecular Rotation	10^{-13}
Spin Exchange	10^{-9}
Fluorescence	10^{-8}

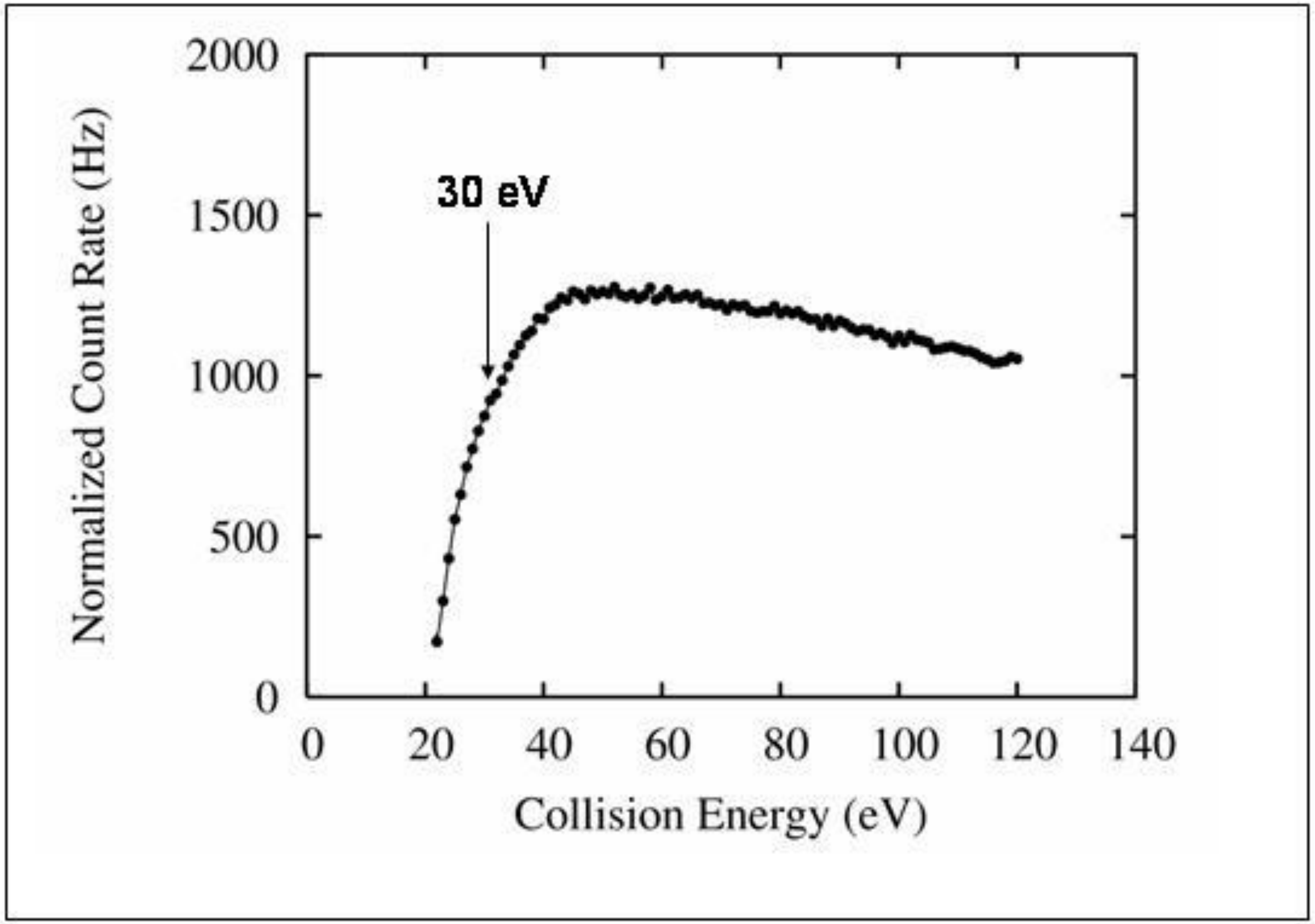
Using 388 ± 5 nm filter…

N_2	λ(Å)	I	V'	V''
$A^3\Sigma_u^+ - X^1\Sigma_g^+$	3855	3	3	13
$C^3\Pi_u - B^3\Pi_g$	3858	5	4	7
$A^3\Sigma_u^+ - X^1\Sigma_g^+$	3889	4	0	11
$C^3\Pi_u - B^3\Pi_g$	3895	7	3	6
$C'^3\Pi_u - B^3\Pi_g$	3925	4	0	8

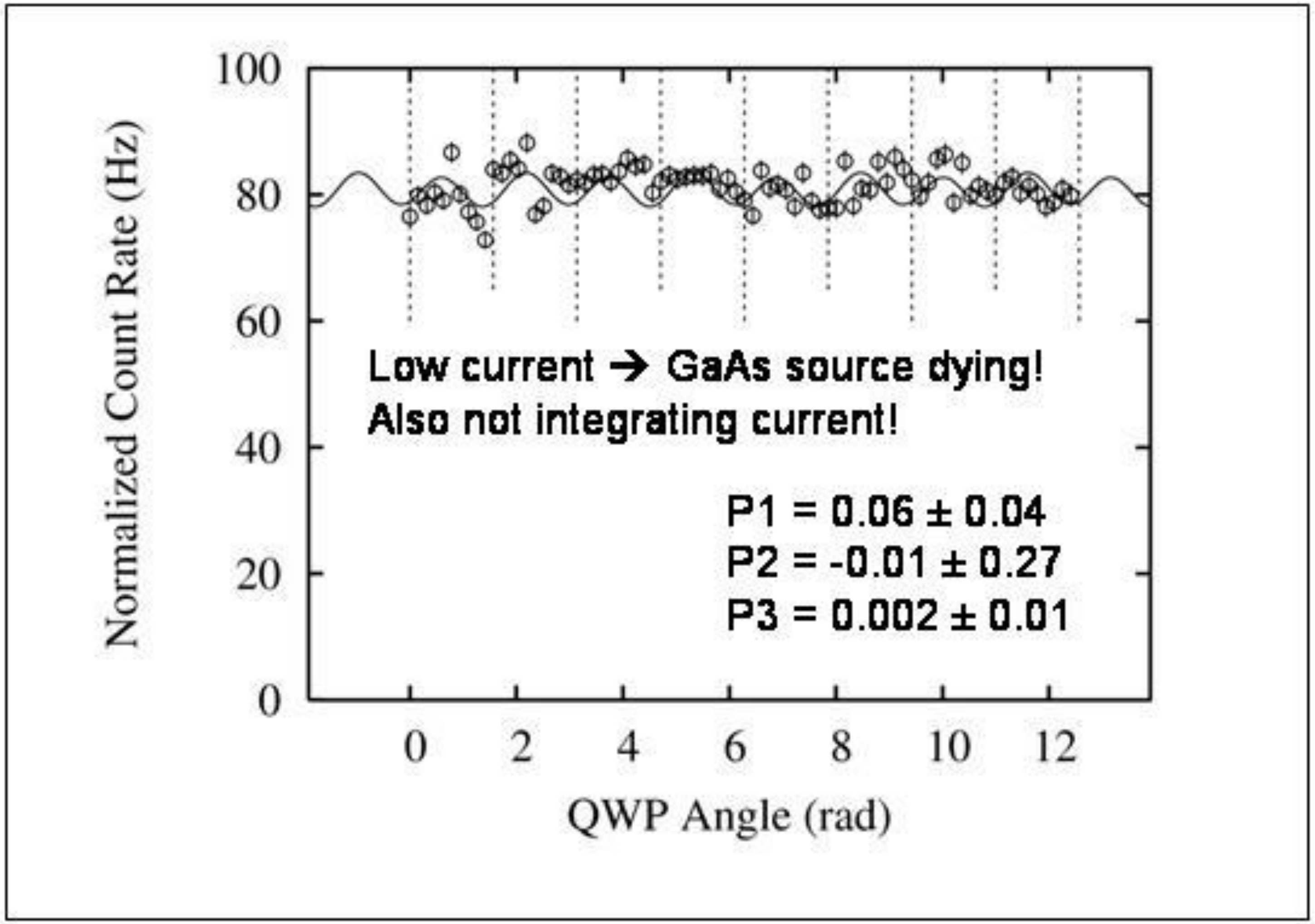
N_2^+	λ(Å)	I	V'	V''
$B^2\Sigma_u^+ - X_2\Sigma_g^+$	3857	4	2	2
	3875	6	10	10
	3884	3	1	1
	3892	6	19	16
	3914	10	0	0



N_2 excitation function with 388±5 nm filter



Stokes parameters at 30 eV



Summary / Fixes

- Now integrating current at 2 Hz
- Made differential pumping apertures smaller so source pressure remains low ($>5x10^{-8}$ Torr → $<5x10^{-9}$ Torr during run)
- Getting another diode laser for source…(current power only 1 mW)
- Getting Narrower N_2 Filter