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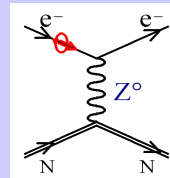
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# SYMMETRY DISCRIMINATION AND MEASUREMENTS OF PARITY VIOLATING AND MAGNETOELECTRIC DICHROISMS IN A Cs VAPOUR

J. Guéna, M. Lintz and M.-A. Bouchiat,

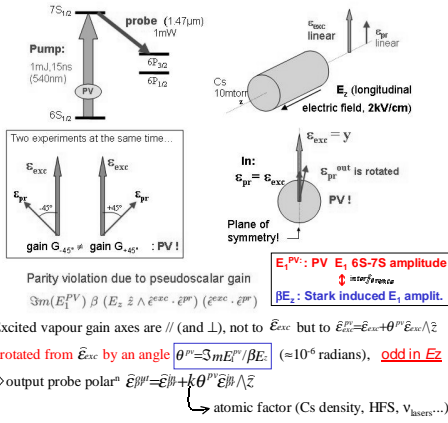
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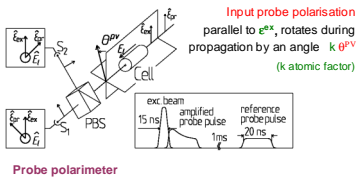
Particle physics...  
...at low energies!

## PRINCIPLE OF THE EXPERIMENT

### EXCITATION AND DETECTION



### POLARIMETRIC METHOD OF MEASUREMENT ...and CALIBRATION



Polarimeter imbalance  $\Rightarrow$  left-right asymmetry

$$A_{LR}(\theta^{PV}) \equiv (S_x - S_y) / (S_x + S_y) = 2k \theta^{PV}$$

Calibration: rotating  $e^{exc}$  by  $\theta^{cal} \Rightarrow$  probe rotation  $k \theta^{cal}$

$$A_{LR}(\theta^{cal}) = 2k \theta^{cal}$$

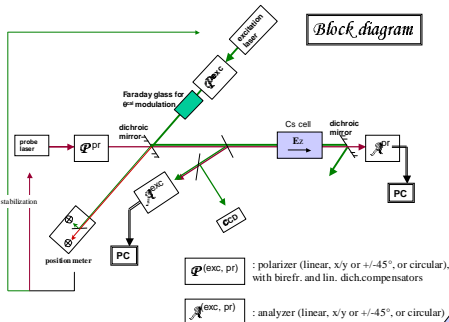
$$\theta^{PV} = [A_{LR}(\theta^{PV}) / A_{LR}(\theta^{cal})]_{\theta^{cal}}$$

### Selection criteria of the PV rotational invariant

Criteria	Selection of	against	Period
$D = \frac{S_x - S_y}{S_x + S_y}$	Imbalance between R-L configurations	intensity, population	each pulse
$\Delta D = D^{amp} - D^{ref}$	Atomic imbalance	non atomic	1 ms
$\pm \theta^{cal}$	imbalance $D^{cal}$	CALIBRATION	0.4s
$E_z$ -odd	PV effect (main signature)	most PC $E_z$ effects (Stark-Stark)	0.8s
Tilt ( $\theta^{out}$ -odd)	True polarization effect	instrumental defects (EMI, geometrical)	6s
$\theta^{PV}$ $\begin{cases} \parallel E^{exc} \\ \perp E^{exc} \end{cases}$ -even	Linear dichroism (Atomic alignment)	optical rotation (e.g. Faraday)	12s
$\theta^{exc}$ -isotropic	Rotational invariant (cf "cylindrical symmetry")	stray transverse $B_z, E_z$ field effects	2 mn

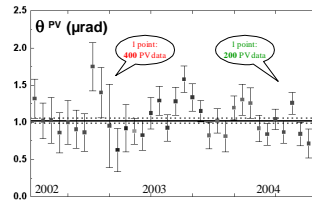
1 PV data

### IMPLEMENTATION of the EXPERIMENT



## PRESENT RESULTS

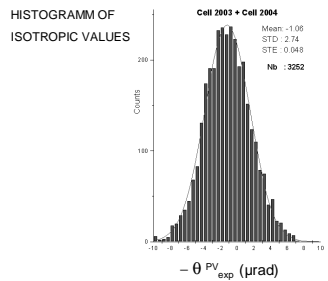
### EVOLUTION OF THE RESULTS (6 different cells)



Since first results (PRL, 2003), S/N improved by 3.3

$\Rightarrow$  acquisition time for S/N=1 reduced by 10

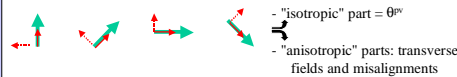
Current average result (at 1.74kV/cm):  $\theta^{PV} = 1.019 \pm 0.034$  ( $\mu$ rad)  
agrees with Boulder's more precise result



## CYLINDRICAL SYMMETRY DISCRIMINATION AND THE MAGNETO-ELECTRIC EFFECTS

The experiment is invariant under rotations of  $(\hat{E}_{exc}, \hat{E}_{pr})$  around  $\hat{k} // \hat{E}$

4 Polarization config<sup>ns</sup>: 0°, 45°, 90°, 135°



But is the isotropic part free from systematics arising from  $E_z$ ,  $B_z$  fields or misalignments?

The case of transverse E and B fields:

Ideal situation: pure longitudinal E field (and probe polarization  $\hat{E}_{pr} // \hat{E}_{exc}$ )  
 $\Rightarrow$  (Stark) Parity-conserving alignment with axes  $\hat{E}_{exc}$  and  $\hat{E}_{exc} \wedge \hat{E}_{exc}$

$\Rightarrow$  no imbalance in output probe polarimeter

$\pm$  transverse E field

- $\rightarrow$  adds new Stark alignment, with revolution symmetry around  $\hat{k}$
- $\rightarrow$  yet, no imbalance

$\pm$  transverse B field

- $\rightarrow$  Larmor precession of the  $E_z$ -induced alignment
- $\rightarrow$  this new rotated alignment is detectable by the probe
- $\rightarrow$  non-zero polarimeter imbalance:

$$A_{LR}(\theta^{PV}) = \frac{D(\theta^{PV})}{D(\theta^{cal})} \theta^{cal}$$

$E_x, B_z$  measured and reduced in dedicated sequences  $\rightarrow \theta_{\text{sys}} \leq \theta^{PV} / 10$ , corrected

This is a P-conserving "Jones Dichroism" (i.e. with axes at 45° from  $\hat{k}$ ) due to the transverse  $E_x$  and  $B_z$  fields

Magneto-electric optical effects have also been observed in liquids, yet with a  $B_z = 15$  T and  $E_z = 1.7$  kV/cm

Here it is easily observed with  $B_z = 1$  G,  $E_z = 10$  V/cm in a dilute vapor, and fully understood

The case of a transverse E field and a pump-probe misalignment

a probe misalignment  $\hat{k}$  is equivalent to a rotation of angle/direction of the probe with respect to the exc beam  
 $\rightarrow$  is given by the above formula except for the replacement

$$E_z \rightarrow E_x$$

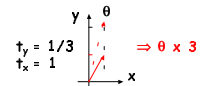
## HOW TO AMPLIFY THE PV EFFECTS?

### PASSIVE AMPLIFICATION

Polarization Magnifier at cell output :

Passive Amplification of the Polarization Tilt

dichroic component with axes x (transmission = 1) and y (transmission  $T_y < 1$ )



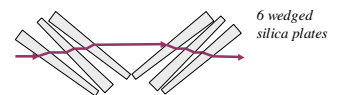
But... 9 x less photons detected :

photon shot noise also increased X 3 !

To gain in S/N we increase the probe intensity

How to make a polarisation magnifier ?

6 brewster plates... with no two surfaces parallel ! (interference + linear birefringence  $\rightarrow$  birefringence)



### ACTIVE AMPLIFICATION

...by the atomic medium itself!

Excited vapour  $\equiv$  anisotropic amplifier ( $\eta$ : gain anisotropy)

$\rightarrow$  exponential growth of both

probe intensity and left-right asymmetry vs. optical density

$$A_{LR} \equiv 2 \theta^{PV} x [\exp(\eta A) - 1]$$

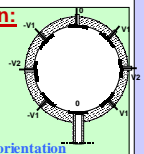
$$= 2 (E_z^{PV} / \beta E_z) x [\exp(\eta A) - 1]$$

where  $A = \text{Ln}(I^{out} / I^{in})$  : optical density,  $\propto E_z^2$

$\rightarrow$  Increase  $E_z$  at will? ...But cell is long (8cm)

$\rightarrow$  high endcap potentials  $\rightarrow$  discharges at  $E_z > 1.8$  kV/cm

Exploiting further  $A_{LR}$  amplification: a new PV proposal in transverse E field



$\rightarrow$  observable = PV excited-state orientation

The PV orientation is transverse

- $\rightarrow$  apply transverse B field  $\rightarrow$  longitudinal PV orientation
- $\rightarrow$  probe circ. dichroism, detected using circular analyser

Advantages of the transverse field configuration:

- Larger excitation rate (involves scalar polarisability  $\alpha \approx 10 \beta$ ),
- Longer interaction length is possible without discharges.

Cylindrical symmetry restored by rotating E and B fields by 45° steps

$\rightarrow$  predicted quantum-noise limit improves by a factor 10, or even more in the triggered superradiant regime!

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