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► **To cite this version:**

Aram V. Papoyan, G. G. Grigoryan, S. V. Shmavonyan, David Sarkisyan, Jocelyne Guéna, et al..  
SELECTIVE REFLECTION SPECTROSCOPY WITH A HIGHLY PARALLEL WINDOW: PHASE  
TUNABLE HOMODYNE DETECTION OF THE RADIATED ATOMIC FIELD. 8th EPS conference  
on atomic and molecular physics, 2004, Rennes, France. pp.4-84. hal-00002633v2

**HAL Id: hal-00002633**

**<https://hal.science/hal-00002633v2>**

Submitted on 27 Aug 2004

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# SELECTIVE REFLECTION SPECTROSCOPY WITH A HIGHLY PARALLEL WINDOW: PHASE TUNABLE HOMODYNE DETECTION OF THE RADIATED ATOMIC FIELD

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(to be published in *Eur. Phys. J. D*)

the hidden side of the  
selective reflection signal

### Ordinary selective reflection

Observable = reflected intensity:  $I_R = |E_{Rtot} + E_{A2}|^2 = |E_{Rtot}|^2 \cdot (1 + 2\text{Re}(E_A/E_{Rtot}))$

- **Brewster incidence** ( $E_{Rtot} \perp \vec{k}$ ) (Mandelstam et al. Soviet J. Opt. 1969, 416)
  - the real dispersive feature of SR spectroscopy is lost;
- **multi-electric coating** (these work by Venturoli and Fregoni (Opt Commun 198(1994) 314))
  - the coating may be damaged by the atomic vapour
- **metallic coating** (Chouhrouh et al. Phys Rev E 63(1998) 2801)
  - considerable attenuation of the atomic signal, due to the required metal thickness

### The raw signal on the Cs D1 line

$(6S \rightarrow 6P_{3/2}, F=2, 3, 4)$

- The interference pattern is obvious
- The atomic signal is small... (dilute vapour)
- off-resonance background subtraction
- the atomic signal is more evident - (still a "wavy" offset pattern: the subtracted, off-resonance background has a non negligible dependence on the laser frequency)

### The model

- Continuity equations at the two boundaries between the three media:
  - air,  $n_1=1$
  - (sapphire) window,  $n_2=1.76$
  - vapour,  $n_3=1$
- Maxwell equations for the propagation of the backward atomic field in the vapour (without using the slowly varying envelope approximation)
  - field envelope:  $\frac{\partial E(z,t)}{\partial z^2} + 2ik \frac{\partial E(z,t)}{\partial z} = -(\delta^2 \epsilon) P(z)$
  - atomic polarisation:  $\dot{P} = -(\delta^2 \epsilon) P(z)$  (no backward beam coming from  $z=0$ )
- assuming cell length  $\gg$  absorption length
  - then:  $E_{\text{backward}} = \left[ \frac{P(z) \exp(2i\phi)}{1 - P(z) \exp(2i\phi)} \right] E_0$  (ordinary reflection from a parallel interface with  $\phi = \pi, 3\pi, 5\pi, \dots$ )
  - +  $\frac{P(z) \exp(i\phi)}{1 - P(z) \exp(2i\phi)} E_0$  ( $E_{\text{atomic}}$  contribution)
- (where the  $n_1$  and  $n_3$  are the amplitude transmission and reflection coefficients) and the backward atomic field is generated by the vapour atomic polarisation:  $E_{\text{atomic}} = 2ik \int_0^L P(z) \exp(2ikz) dz$
- Defining the atomic response, by  $\frac{P(z) \exp(2i\phi)}{1 - P(z) \exp(2i\phi)}$  and assuming the absence of saturation and non-linearity, we get ( $F, F_0$ : homogeneous and Doppler widths):  $\mathcal{D}^2 = \frac{P_0}{h} \frac{1}{\Gamma} \frac{1}{P_0} \frac{1}{P_0} \frac{\exp(-\frac{F^2}{F_0^2})}{\exp(-\frac{F^2}{F_0^2})}$

### selective reflection with a parallel window

depending on the relative phase between the two NR reflected beams, two opposite regimes are expected:

- close to a reflection maximum:
  - SR signal still displays **real part** of the atomic response
  - then:  $\text{Re}(E_A)$  does not interfere with  $E_{R1} + E_{R2}$  → **not detected**
  - $\text{Im}(E_A)$  interferes with  $E_{R1} + E_{R2}$  → **DETECTED!**
- close to a reflection minimum:
  - the  $\text{Im}(E_A) \times (E_{R1} + E_{R2})$  signal **changes sign** around refl. minimum

### The experiment

How to change the interference condition in the window?  
very easily, by **changing the window temperature**

For 0.5 mm sapphire window and  $\lambda=852\text{nm}$ :  
 $\Delta T = 30^\circ\text{C} \Leftrightarrow \Delta z$  change of the interference

from Adler et al. Appl Phys B71 (2000), 555 for the use of the "temperature tanky" of the windows for reflection-free vapour cells

### Conclusion

The **model** and **experiment** agree very well (no fitted parameter) on the size and the temperature dependence of the spectra.

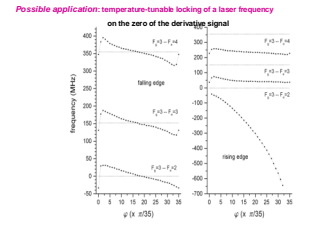
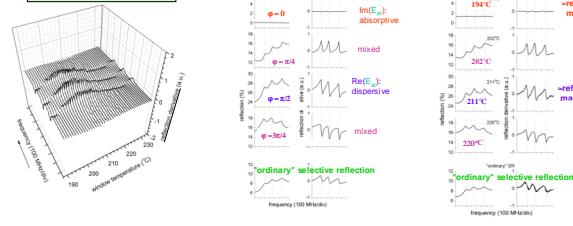
By using a "temperature tunable" window, **one can detect at will**

- the **real** (dispersive) part
- or the **imaginary** (absorptive) part of the atomic response.

SIN is better near the reflection minimum.

Changing from one regime to the other is obtained **very easily**, just by **changing the window temperature by a few degree C**.

### The raw and derivative signals



### zoom at...

### The minimum reflection regime

