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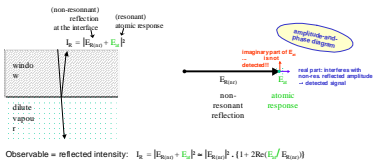
SELECTIVE REFLECTION SPECTROSCOPY WITH A HIGHLY PARALLEL WINDOW: PHASE TUNABLE HOMODYNE DETECTION OF THE RADIATED ATOMIC FIELD

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

the hidden side of the
selective reflection signal

"ordinary" selective reflection

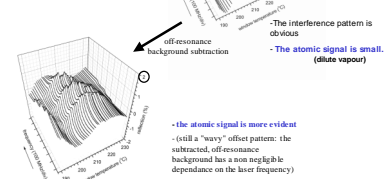


Observable = reflected intensity: $I_{refl} = |E_{refl}|^2 = |E_0 + E_p|^2 = (1 + 2\text{Re}(E_0^* E_p) + |E_p|^2)$

How to detect the imaginary part?? Some proposals have been made:

- Brewster incidence ($E_{refl} \perp E_0$) (Mandelstam et al. Soviet J. Opt. 1969, 416)
- the non-dispersive feature of SR spectroscopy is best;
- multi-electric coating (these work by Venturoli and Fregoni (Opt Commun 198(1994) 315))
→ the coating may be damaged by the atomic vapour
- metallic coating (Chouhrouh et al. Phys Rev E 63(1999) 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 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)
 $\frac{\partial E_{refl}}{\partial z^2} + 2ik \frac{\partial E_{refl}}{\partial z} = -(\epsilon^2 - \epsilon_0) P(z)$

assuming cell length \gg absorption length (no backward beam coming from $z=0$)
then $E_{refl} = \frac{P(z) \exp(i\phi)}{1 - \epsilon^2 \exp(2i\phi)}$ (ordinary reflection from a parallel interface with $\epsilon = n_2/n_1$)
 $+ \frac{P(z) \exp(i\phi)}{1 - \epsilon^2 \exp(2i\phi)}$ (the atomic contribution)

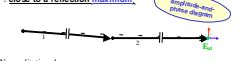
(where the n_1 and n_2 are the amplitude transmission and reflection coefficients) and the backward atomic field is generated by the vapour atomic polarisation:
 $E_{refl} = 2ik \int_0^L P(z) \exp(2ikz) dz$

Defining the atomic response, by $\frac{P(z) \exp(i\phi)}{1 - \epsilon^2 \exp(2i\phi)}$ and assuming the absence of saturation and non-linearity, we get (F, F_0 : homogeneous and Doppler widths):
 $\mathcal{D}^2 = \frac{P(z) \exp(i\phi)}{1 - \epsilon^2 \exp(2i\phi)}$

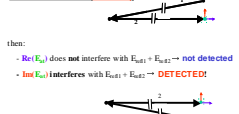
selective reflection with a parallel window (qualitative approach)

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

- close to a reflection maximum:



- close to a reflection minimum:



- the $\text{Im}(E_{refl}) \times (E_{refl} + E_{refl})$ signal changes sign around refl. minimum

The experiment

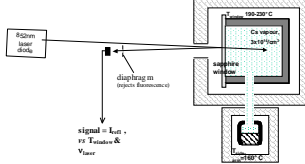
How to change the interference condition in the window?

very easily, by changing the window temperature

For 0.5 mm sapphire window and $\lambda=852\text{nm}$:

$\Delta T = 30^\circ\text{C} \Rightarrow \Delta z$ 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 parameters) on the size and the temperature dependence of the spectra.

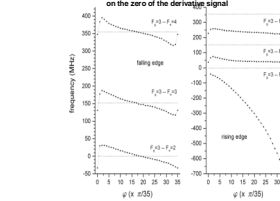
By using a "temperature tunable" window, one can detect at will

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

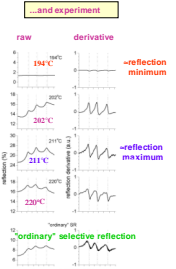
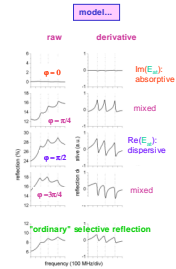
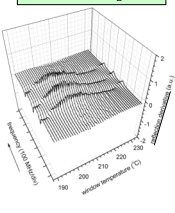
SR is better near the reflection minimum.

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

Possible application: temperature-tunable locking of a laser frequency on the zero of the derivative signal



The raw and derivative signals



zoom at...

The minimum reflection regime

