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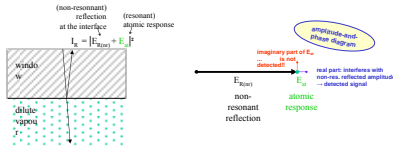
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SELECTIVE REFLECTION SPECTROSCOPY WITH A HIGHLY PARALLEL WINDOW: PHASE TUNABLE HOMODYNE DETECTION OF THE RADIATED ATOMIC FIELD

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the hidden side of the
selective reflection signal

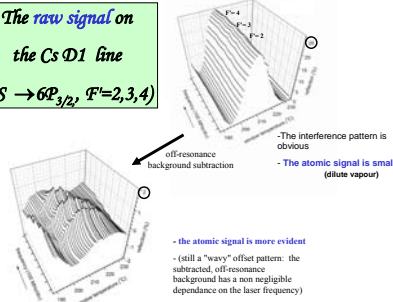
"ordinary" selective reflection



Observable = reflected intensity: $I_r = |E_{\text{refl}}|^2 = |E_{\text{inc}}|^2 \cdot |1 + 2\text{Re}(E_r/E_{\text{inc}})|^2$

- How to detect the imaginary part??** Some proposals have been made:
- Brewster incidence ($E_{\text{inc}}=0$)? (Khalilov et al. Soviet J. Q. E. 18(1991), 416)
 - the sub-doppler feature of SR spectroscopy is lost;
 - **multidielectric coating?** (short work by Vorontsov and Zapor. Opt. Commun. 118(1994), 315)
 - the coating may be damaged by the atomic vapour
 - **metallic coating?** (Chocroffier et al. Phys Rev E48(1993), 2001)
 - 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)
- 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)

assuming cell length \gg absorption length (no backward beam coming from z=0)

then

where the t_1 and r_1 's are the amplitude transmission and reflection coefficients and the backward atomic field is generated by the vapour atomic polarisation:

Defining the atomic response, $\chi_a = \frac{\hbar \rho_{21} E \exp(i\phi)}{1 - r_{21} \exp(2i\phi)}$ and assuming the absence of saturation and non-linearity, we get $(\nabla \cdot \mathbf{E}; \text{homogeneous and Doppler widths})$

$$\chi_a = \frac{\Delta \omega_a}{\hbar \Gamma} \sum_{\mu} |\mu\rangle \langle \mu| \int_{-\infty}^{\infty} \frac{\exp(-i\omega' t)}{i(\omega - \omega' + i\Gamma)}$$

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:

then:

- $\text{Re}(E_{\text{refl}})$ does not interfere with $E_{\text{inc}} + E_{\text{refl}}$ → not detected
- $\text{Im}(E_{\text{refl}})$ interferes with $E_{\text{inc}} + E_{\text{refl}}$ → DETECTED!

- the $\text{Im}(E_{\text{refl}}) \times (E_{\text{inc}} + E_{\text{refl}})$ 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 $\lambda=852\text{nm}$:

$\Delta T = 30^\circ\text{C} \leftrightarrow 2\pi$ change of the interference

(see Adler et al. Appl Phys B71 (2000), 561 for the use of the "temperature tuning" of the windows for reflection-loss free vapour cells)

Conclusion

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

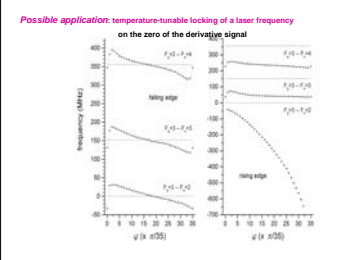
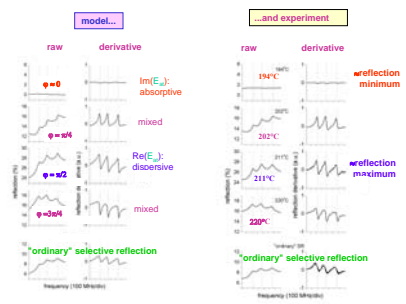
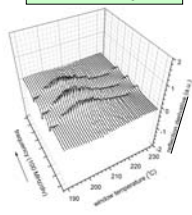
By using a "temperature tunable" window, one can detect at will

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

SNR 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

