Absorption line shape analysis beyond the bandwidth detection limit: application to the Boltzmann constant determination

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In recent years, there has been a growing interest toward precise and accurate observations of spectral line shapes, for the purpose of either applications (atmospheric sounding, isotope research, chemical analysis in the gas phase) or fundamental studies (molecular collisions, fundamental metrology, tests of quantum mechanical calculations). An interesting example is the recent implementations of Doppler broadening thermometry for the aims of an optical determination of the Boltzmann constant. In this latter field, accuracies in the 10^{-5} range have been demonstrated [1, 2]. To this purpose, a careful error budget analysis is required, but the bandwidth detection limit has not been considered in details, so far [3].

A theoretical model of the influence of the detection bandwidth properties on observed line shapes will be described [4]. In case of a continuous evolution of the laser frequency, the line shape can be set in a quasi-analytical form that easily highlights consequences on the retrieval of the line center frequency and broadening parameter or on line asymmetry. For the sake of completeness, these results have been extended via numerical simulations to the case of a step-by-step frequency evolution.

This model has been accurately validated thanks to experiments performed with laser spectrometers in Paris 13 and Naples 2 laboratories [4]. In order to get robust tests, quite unusual bandwidth misadjustments were used. Resulting frequency shifts, extra broadenings and line asymmetries were perfectly taken into account by the model, leading to line parameters in very good agreement with those resulting from well-designed experiments.

Finally, the influence of detection bandwidth properties on frequency and Doppler width measurements will be discussed in details, including a comparison of several filter designs (1^{st} and 2^{nd} orders). A particular emphasis will be given to the detection bandwidth adjustments required for the 10^{-6} precision that is targeted by the Boltzmann constant experiments.

References

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