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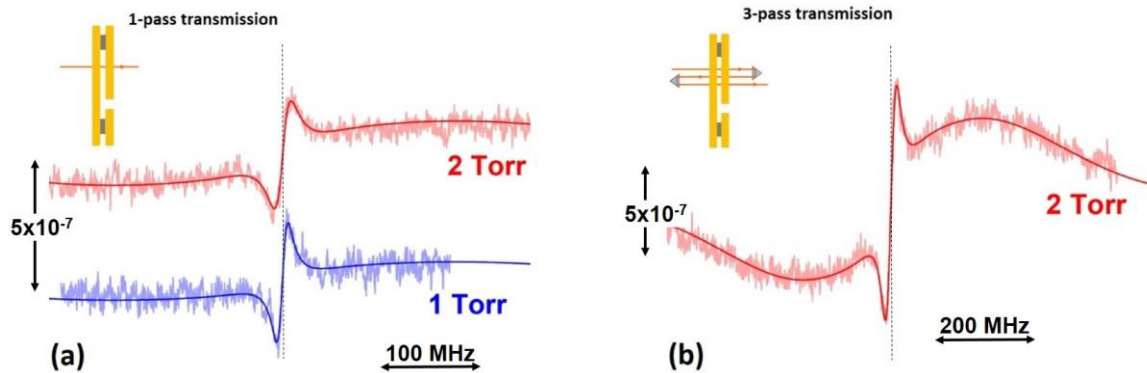
# Thin Cell Spectroscopy at Telecommunication Wavelengths: Towards Acetylene based Compact Frequency References

G. Garcia Arellano<sup>1</sup>, H. Mouhanna<sup>1</sup>, F. DuBurck<sup>1</sup>, B. Darquié, D. Bloch<sup>1</sup>, I. Maurin<sup>1</sup>, A. Laliotis<sup>1</sup>

*1. Université Sorbonne Paris Nord, Laboratoire de Physique des Lasers, CNRS UMR 7538, 99 Av. J-B Clément, 93430 Villetaneuse, France*

Molecules are ideal candidates for frequency referencing applications offering a comb of extremely narrow rovibrations (linewidth essentially proportional to pressure) throughout the mid and near infrared spectrum. The telecommunications window (around 1.5 $\mu\text{m}$ ) is the most important region for such applications, where references are typically provided by saturated absorption spectroscopy of C<sub>2</sub>H<sub>2</sub> or HCN in voluminous macroscopic cells. Driven by the telecommunications market, fiber components have now reached a high level of technological maturity allowing the interface of molecular gases with photonic devices for the realization of compact transportable standards. In answer to this demand, compact hollow core photonic crystal fibres (HCPCF) were filled with molecular (acetylene) gas [1] and chip based waveguides were ‘cladded’ with molecules [2] for the purpose of frequency referencing. Such compact platforms remain of macroscopic length, while a full interpretation of the spectra is a challenge that still needs to be tackled.

Thin cells (of thickness comparable to the excitation wavelength) are an alternative platform for such applications, providing simple high-resolution spectroscopy due to the coherent Dicke narrowing [3], without resorting to nonlinear schemes. Probing sub-wavelength confined molecules is challenging compared to atoms due to small transition probabilities. However, we have already demonstrated the feasibility of these measurements by selective reflection spectroscopy inside a macroscopic cell [4].



**Fig. 1** (a) Frequency modulated thin cell transmission for different acetylene pressures. (b) Frequency modulated multipass transmission for 2Torr acetylene pressure. The cell thickness is  $5.35 \pm 0.02 \mu\text{m}$ , uniform for all 3 passes inside the cell. The solid lines represent theoretical fits.

In our experiment, we have used a thin cell (thickness  $5.35 \mu\text{m}$  corresponding to  $7\lambda/2$ ) filled with acetylene gas and performed sub-Doppler spectroscopy of the  $\nu_1 + \nu_3$  rovibrations at 1530nm in the linear regime. Fig.1.a shows Frequency Modulated thin-cell transmission spectra for different acetylene pressures. Solid lines represent the prediction of a model that includes the transient effects due to collisions with the cell walls and Fabry-Perot cavity effects [5]. The theoretical curves were fit to the experiment to extract the collisional linewidth (collisional broadening of  $\sim 8\text{MHz/Torr}$ ). The agreement between theory and experiments shows that thin cells are well adapted for frequency referencing and fundamental physics measurements. Multipass techniques could significantly increase the signal amplitude. In Fig.3b we show the expected (x3) signal amplification for a 3-pass configuration.

Further increasing the thin-cell signal could allow direct stabilization of a telecommunication laser, whose frequency stability can be tested against an absolute reference. We are also working towards fabricating a new generation of thin cells of nanometric thickness suited for studies of the Casimir-Polder interaction with molecules. We acknowledge financial support from the ANR project SQUAT (Grant No. ANR-20-CE92-0006-01).

## References

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