High index and high frequency modulation spectroscopy

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Conventional frequency-modulation (FM) spectroscopy operates at low modulation index [1], and gives an optimum sensitivity for an optical depth (OD) of two. The signal decreases at higher OD as resonant absorption deplete the carrier component, which makes FM spectroscopy unusable. Here, we present a new sensitive FM spectroscopy technique applicable at arbitrary large OD. Using high modulation index, the sample is probed with detuned sidebands, while the carrier amplitude is brought to zero. When the modulation frequency becomes much larger than the Doppler width, these sidebands probe the wings of the absorption window dominated by the homogenous response of the vapour. Surprisingly, this method becomes Doppler-free and show high sensitivity at large OD (see Figure 1). We test this technique on the D2 line of a caesium vapour cell (OD up to 700), and find a good agreement with our model [2]. In future, this technique could be useful to study collisional shift, pressure broadening, and collective responses in dense atomic gases.

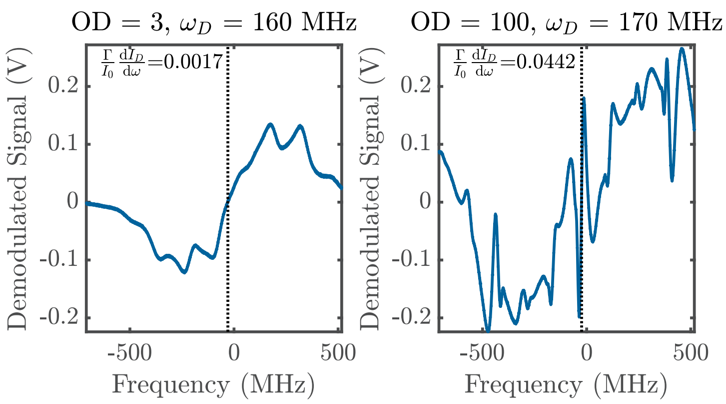

Figure 1. Experimentally measured signals at small and large OD. The non-dimensionalized slope at line center $\frac{\Gamma}{I_0}\frac{dI_D}{d\omega}$, which measures the sensitivity, is higher at large OD. For each figure, the blue solid line is the demodulated signal after the slope is optimized by changing the phase shift of the local oscillator. The line center is indicated by the vertical dotted line.

[1] Gary C. Bjorklund, Frequency-modulation spectroscopy: a new method for measuring weak absorptions and dispersions, Opt. Lett. **5**, 15 (1980).

[2] Chang Chi Kwong, Syed Abdullah Aljunid, Eng Aik Chan, Rustem Shakhmuratov and David Wilkowski, manuscript in preparation.