Estimation of CaH density in beam

July 2010

We observed peak absorption $1.59 \times 10^{-}3$ of CaH after double passing the laser through the beam (See Fig. 1). If we can both measure the transverse spectrum and use the fluorescence detection to know the spacial spread of the beam (sending a sheet of detection laser from longitudinal direction), we can know the spectral line shape and interaction length between laser and beam. Therefore, we can use the same method we used for in cell absorption to determine the density in the beam.

However, the beam signal was weak so that we didn't have good measurements for either spectral line shape or spatial spread. In order to calculate the density and number of CaH in the beam, we need to estimate the absorption cross section, σ, and interaction length, z.

Fig. 2 shows our cell geometry. We assume our beam origins from a point source from the center of the cell. The divergence of the beam, θ, is set by the cell aperture size and the distance from the source to the aperture, d.

$$\tan(\theta) = \frac{D/2}{d} = 0.15. \tag{1}$$

Therefore, the interaction length between the beam and laser is $2z$ and z is given by

$$z = 2L \tan(\theta) \sim 1.4cm. \tag{2}$$

From eq. (9.10) in Demtröder, we learn the the transverse linewidth of the beam should be narrower than the linewidth in the cell.

$$\Delta\omega_{D\star} = \Delta\omega_D \sin(\theta), \tag{3}$$

where $\Delta\omega_{D\star}$ is the linewidth of the beam.

Therefore, the spectral line shape of the beam is given by

$$g(\omega)\star = \frac{1}{\sqrt{\pi}\Gamma\star} e^{-\frac{(\omega-\omega_0)^2}{\Gamma\star^2}}, \tag{4}$$

where $\Gamma\star = \frac{2\pi}{\lambda}\sqrt{\frac{2k_BT}{m_{CaH}}}\sin(\theta)$. The absorption cross section for the locked laser can be written as

$$\begin{aligned}\sigma(\omega = \omega_0 + \gamma/2)\star = \frac{1}{4}\lambda^2\frac{1}{\sqrt{\pi}}(\frac{\gamma}{\Gamma\star})e^{-\frac{1}{4}\frac{\gamma^2}{\Gamma\star^2}}(\frac{1}{1+S_0}) \\ \sim 1.05\times 10^{-10}cm^2,\end{aligned} \tag{5}$$

where we use $S_0 = \frac{I}{I_0} = 0.4$ and assume the temperature in cell is 6K. With interaction length and absorption cross section, we can use the Beer's law to calculate density.

$$\begin{aligned}I = I_0 e^{-n\star\sigma z} \\ \Rightarrow n\star = 5.4\times 10^6(1/cm^3),\end{aligned} \tag{6}$$

We can also estimate the total number of CaH out of the beam.

$$N_{beam} = A\sum f(t)\delta t = Av\sum n(t)\delta t, \tag{7}$$

where $A = \pi(\frac{z}{2})^2$ is the area of the beam at which we detected, $v = \sqrt{\frac{2k_bT}{m_{CaH}}}$ is the forward velocity of beam. We can use matlab to do the summation between $t = -0.9ms$ to $t = 6.5ms$ and get the total CaH number $\sim 1.7\times 10^8$. Since the total CaH number in cell $N_{cell} = n_c \times V \sim 10^9(cm^-3)\times 5^3(cm^3) \sim 10^{11}$, the extraction efficiency of our cell is around 10^{-3}.

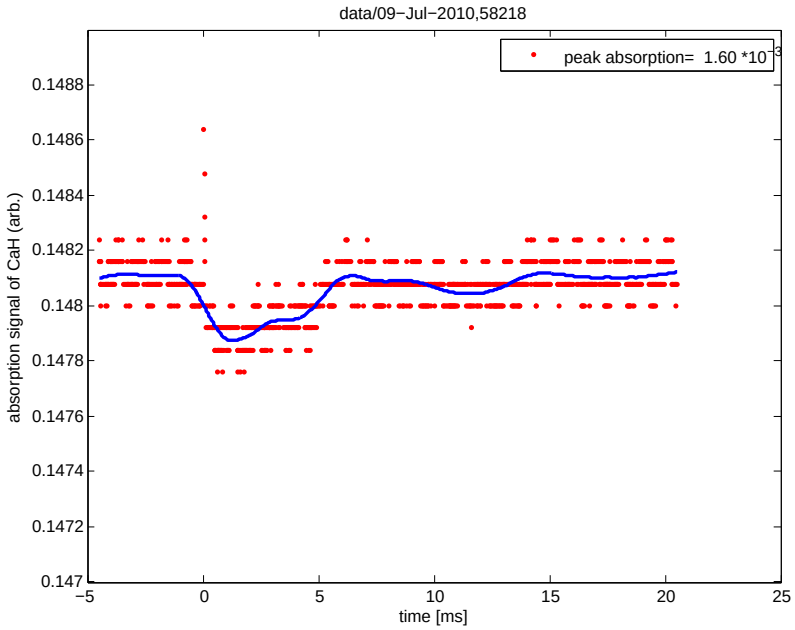

Figure 1: Absorption signal of CaH in beam.

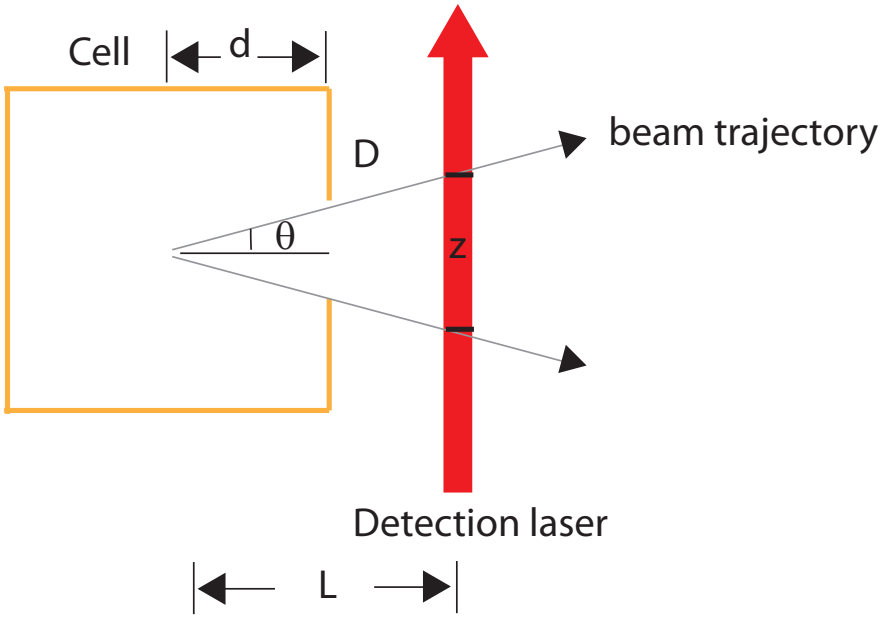

Figure 2: Schematic of cell: cell length 2d=5 cm, center of cell to detection position L=4.75 cm, cell aperture diameter D=0.3", and z is the interaction distance.