

8. Doppler-free laser spectroscopy

F 8.1 Calculate the Doppler width of a spectral line with a wavelength of 589 nm for...

a) Sodium vapour at 1000 K.

$$(8.7) \Rightarrow u = 2230 \cdot \sqrt{\frac{T}{300\text{K}} \cdot \frac{1 \text{ a.m.u.}}{M}} \approx 849 \text{ m/s}$$

$$\frac{\Delta\omega_D}{\omega_0} = 1.7 \cdot \frac{u}{c}$$

$$\Delta\omega_D = 1.7 \cdot \frac{u}{c} \cdot \omega_0 = \left/ \omega_0 = 2\pi f \right/ = 1.7 \cdot \frac{u}{c} \cdot 2\pi f$$

$$\Delta f = \frac{\Delta\omega_D}{2\pi} = 1.7 \frac{u}{c} \cdot f$$

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta f}{f} \Leftrightarrow \Delta\lambda = \lambda \cdot \frac{\Delta f}{f} = \lambda \cdot \frac{1.7u \cdot f}{c \cdot f} = \boxed{\frac{1.7\lambda u}{c}}$$

Alltså:

$$\Delta\lambda = \frac{1.7\lambda u}{c} \approx \boxed{2.8 \text{ pm}} \quad \Delta\lambda$$

b) Molecular iodine (I_2) at 300 K.

$$u = 2230 \sqrt{\frac{300}{300} \cdot \frac{1}{2.127}} \approx \underline{\underline{140 \text{ m/s}}}$$

$$\Delta\lambda = \frac{1.7\lambda u}{c} = \boxed{0.47 \text{ pm}} \quad \Delta\lambda$$

F8.2 The two fine-structure components of the 2s-2p transition in lithium atom have wavelengths of 670.961 nm and 670.976 nm. Estimate the Doppler broadening.

$$\text{Rumstemperatur} \Rightarrow T = 300 \text{ K}$$

$$\text{Lithium} \Rightarrow M = 6.94$$

$$u = 2230 \cdot \sqrt{\frac{300}{300} \cdot \frac{1}{6.94}} \approx 846.5 \text{ m/s}$$

$$\frac{\Delta w_D}{w_D} = 1.7 \cdot \frac{u}{c}$$

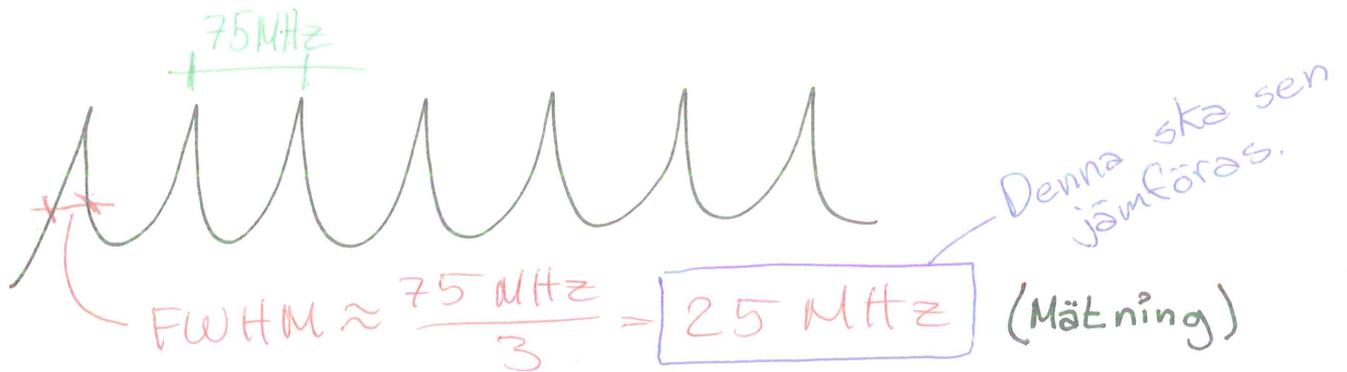
$$\Delta f = \frac{\Delta w}{2\pi} = 1.7 \cdot \frac{u}{c} \cdot f = 1.7 \cdot \frac{u}{c} \cdot \frac{1}{\lambda} = 1.7 \cdot \frac{u}{\lambda} = \boxed{2.14 \text{ GHz}} \Delta f$$

För att upplösa Zeemankomponenterna måste uppsplittningen vara 2.14 GHz. Den totala finstrukturuppsplittningen är ungefär 10 GHz, det går alltså att studera "svagt fält" utan att använda dopplerfria metoder.

8.3 Determine the line widths of the peaks and the frequency shift.

$T = 900 \text{ K}$, Strontium, $\lambda = 243 \text{ nm}$

spacing: 75 MHz .



Nu vill vi beräkna teoretiska dopplerbredden.

$$\left. \begin{array}{l} T = 900 \text{ K} \\ M = 88 \text{ a.m.u.} \end{array} \right\} \Rightarrow u = 2230 \sqrt{\frac{900}{300} \cdot \frac{1}{88}} \approx \underline{412 \text{ m/s}}$$

$$\frac{\Delta\omega_D}{\omega_0} \approx 1.7 \cdot \frac{u}{c} \Rightarrow \Delta\omega_D \approx 1.7 \cdot \frac{u}{c} \cdot \omega_0 = 1.7 \cdot \frac{u}{c} \cdot \frac{2\pi c}{\lambda}$$

Men vi är intresserade av $\Delta f_D = \frac{\Delta\omega_D}{2\pi}$

$$\Rightarrow \Delta f_D = \frac{\Delta\omega_D}{2\pi} = 1.7 \cdot \frac{u}{c} \cdot \frac{2\pi c}{\lambda} \cdot \frac{1}{2\pi} = \frac{1.7u}{\lambda} \approx \underline{2.9 \text{ GHz}} \Delta f_D$$

Nu vill vi beräkna divergensvinkeln, enligt Foot (se s. 153) är vinkeln (α) lika med förhållandet mellan Δf_D och FWHM.

$$\Rightarrow \alpha \approx 0.01 \text{ rad}$$

8.5 Hyperfine structure in laser spectroscopy.

$\Delta f_{\text{HFS}}(1s) = 1.4 \text{ GHz}$, och...?

$$A = \frac{2}{3} \mu_0 g_s \mu_B g_I \mu_N \frac{Z^3}{4\pi a_0^3 n^3} = \mu \cdot \frac{Z^3}{n^3} \propto \frac{1}{n^3}$$

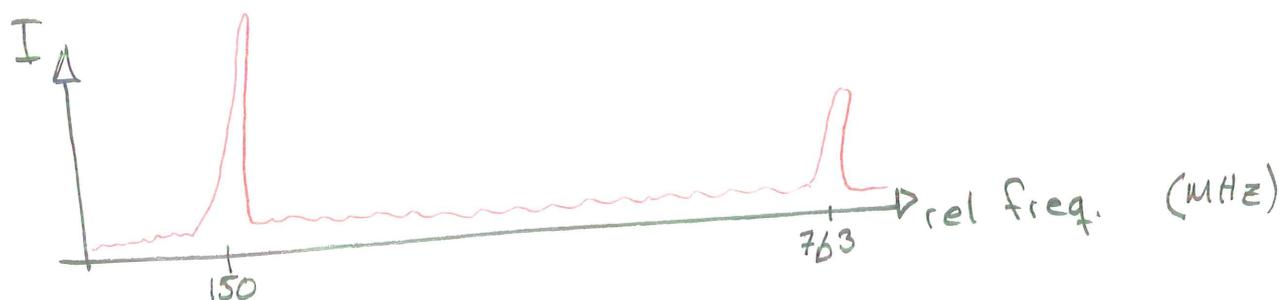
a) Determine the separation of the hyperfine sublevels in the $2s^2S_{1/2}$ level in hydrogen.

Eftersom $A \propto \frac{1}{n^3}$ så kommer A att minska med en faktor 2^3 då vi går från $n=1$ till 2.

$2^3 = 8$, stämmer med figurtexten... tror jag.

b) Show that the peaks in fig 8.11 have an expected separation of $\frac{7}{16} \Delta f_{\text{HFS}}(1s)$.

Fig 8.11



Givet: $\Delta f_{\text{HFS}}(1s) = 1,4 \text{ GHz}$

$$\frac{7}{16} \Delta f_{\text{HFS}}(1s) = \frac{7}{16} \cdot 1400 \text{ MHz} = 612,5 \text{ MHz}$$

612.5 MHz stämmer mycket väl med figuren!