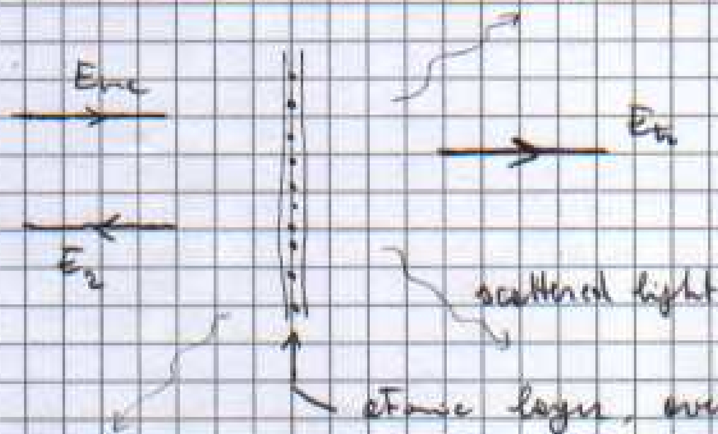
The optical density of a 2D atomic sheet

(Added 2011)



atomic layer, average density n_{2D}
+ fluctuations due to atomic discrete nature
(accounts for scattered light)

simplest model

$$\chi_0(\omega) = \frac{f}{\omega_0^2 - \omega^2 - i\omega\Gamma_e}$$

where $f = \frac{e^2}{m} n_{2D}$ oscillator strength per unit area

Γ_e = radiative decay into modes other than orthogonal to plane

harmonic oscillator model

$$\Gamma_e = \frac{4}{3}\frac{\omega_0^3}{\hbar c^3} d^2 = \frac{4}{3}\frac{\omega_0^3}{\hbar c^3} \underbrace{\left[e\sqrt{\frac{\hbar}{m\omega_0}}\right]^2}_{d^2} = \frac{2e^2\omega_0^2}{3mc^3}$$

$$E_t = \frac{1}{1 - \frac{2\pi n\omega}{c}\,\frac{f}{\omega_0^2 - \omega^2 - i\Gamma\omega}}\,E_{inc}$$

<u>for low optical thickness</u> :

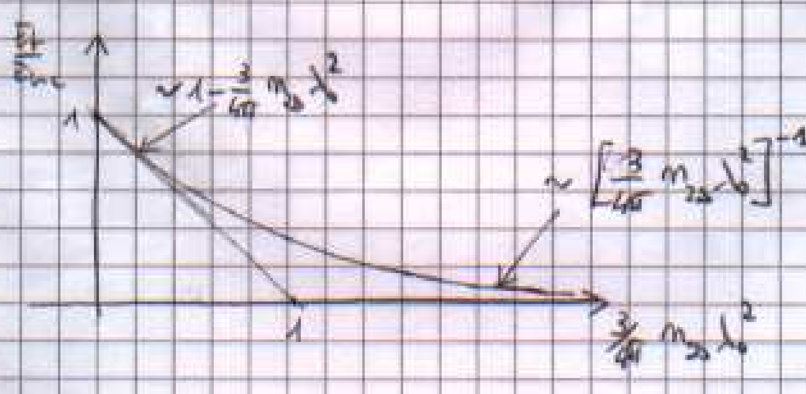
$$E_t \simeq 1 + \frac{2\pi n\omega}{c}\,\frac{f}{\omega_0^2 - \omega^2 - i\Gamma\omega}$$

* off resonance requires $\left|\frac{2\pi\omega}{c}\,\frac{f}{\omega_0^2 - \omega^2 - i\Gamma\omega}\right| \ll 1$

* on resonance $\omega = \omega_0$: $\frac{3}{4\pi}\, n \lambda_0^2 \ll 1$

<u>Resonant absorption</u> for $\omega = \omega_0$:

$$E_t = \frac{1}{1 + \frac{3}{4\pi} n_{2D} \lambda_0^2}\,E_{inc}$$



<u>NOTE</u>: at high optical thickness there is <u>NO</u> exponential decay !!
[i.e. not Lambert-Beer law]

Comparison with expt in Dalibard's group PRA **82**, 013609 (2010).

characteristic density $\frac{3}{4\pi} n_{2D} \lambda_0^2 = 1$

$$\Longrightarrow n_{2D} = \frac{4\pi}{3\lambda_0^2} = 6{,}88\,\mu m^{-2}$$ for Rb, $\lambda_0 = 780$ nm

Correcting for 0,25 factor in optical coupling

$$\hookrightarrow n_{2D}^{eff} = \frac{1}{0{,}25} n_{2D} = 27{,}7\,\mu m^{-2}$$

Optical density $OD = \sigma n_{2D}$ with σ = absorption cross section

$$\sigma = \frac{3}{2\pi} \lambda_0^2$$

For Rb: $\sigma = 0{,}3\,\mu m^2$, $\sigma_{eff} = 0{,}25 \cdot \sigma = 0{,}075\,\mu m^2$

In terms of optical density:

$$E_t = \frac{E_{inc}}{1 + \frac{1}{2} OD} \quad ; \quad I_t = \frac{I_{inc}}{\left(1 + \frac{OD}{2}\right)^2} \simeq 1 - OD + O(OD^2)$$