Electrons on thin helium films

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The two-fraction model and cyclotron resonance measurements

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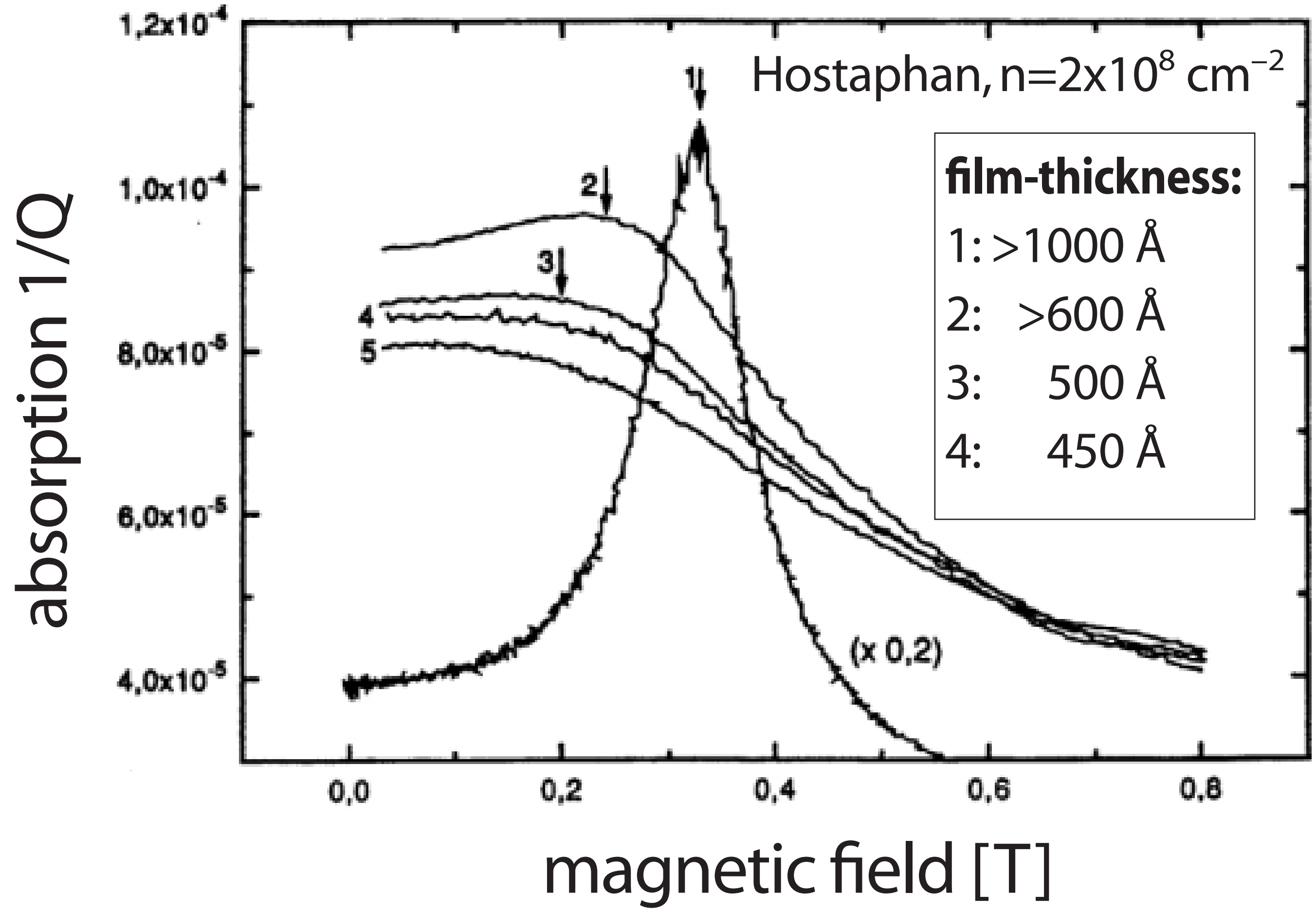
Motivation …

Measurements of cyclotron resonance of a 2DES on thin helium films show a behaviour which can not be explained with the free electron model.



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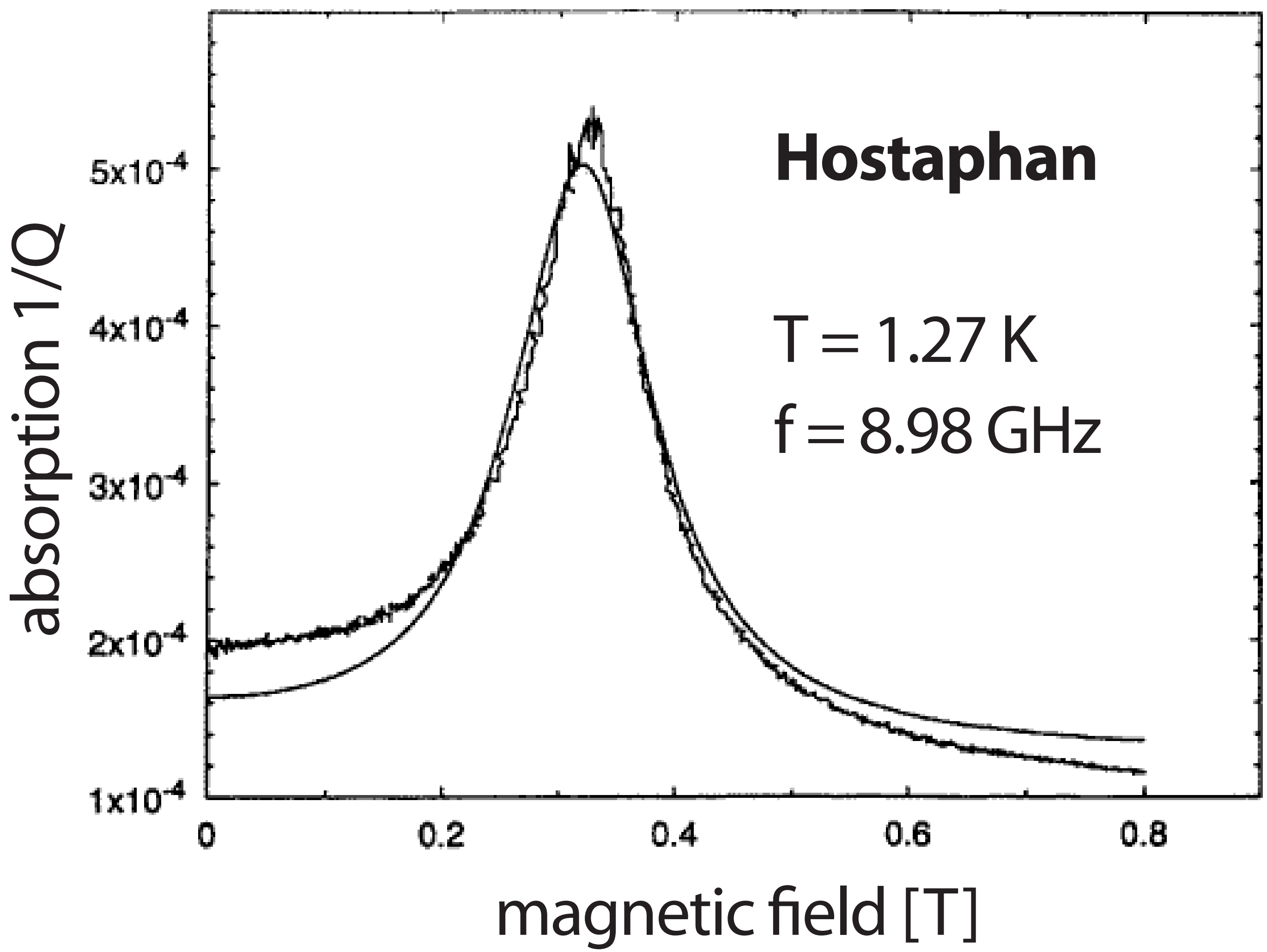
… Motivation

When one tries to fit the cyclotron resonance data with the free electron model, it is not possible to fit both sides of the curve simultaneously. ➡ localized electrons contribute



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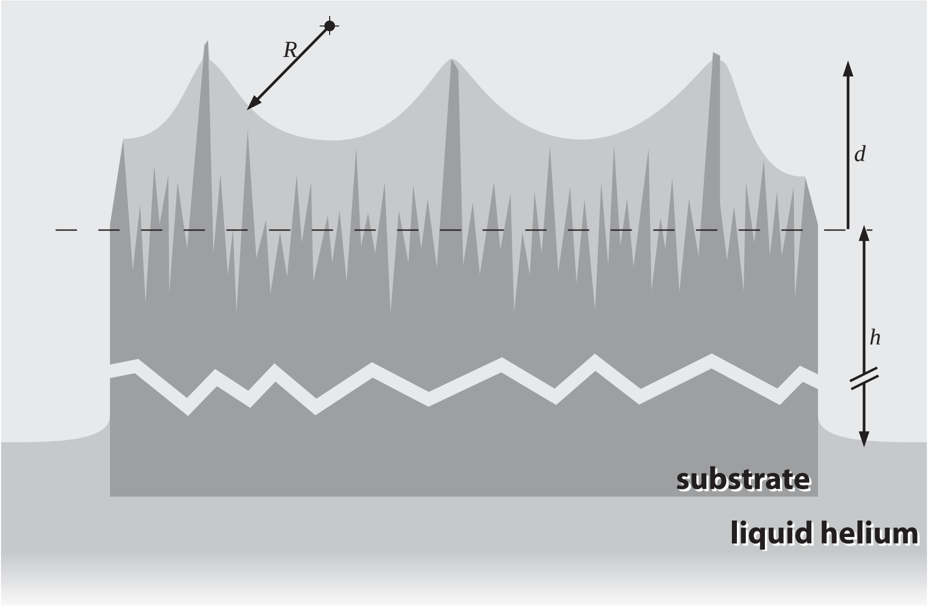
Modelling the adsorbed helium film . . .



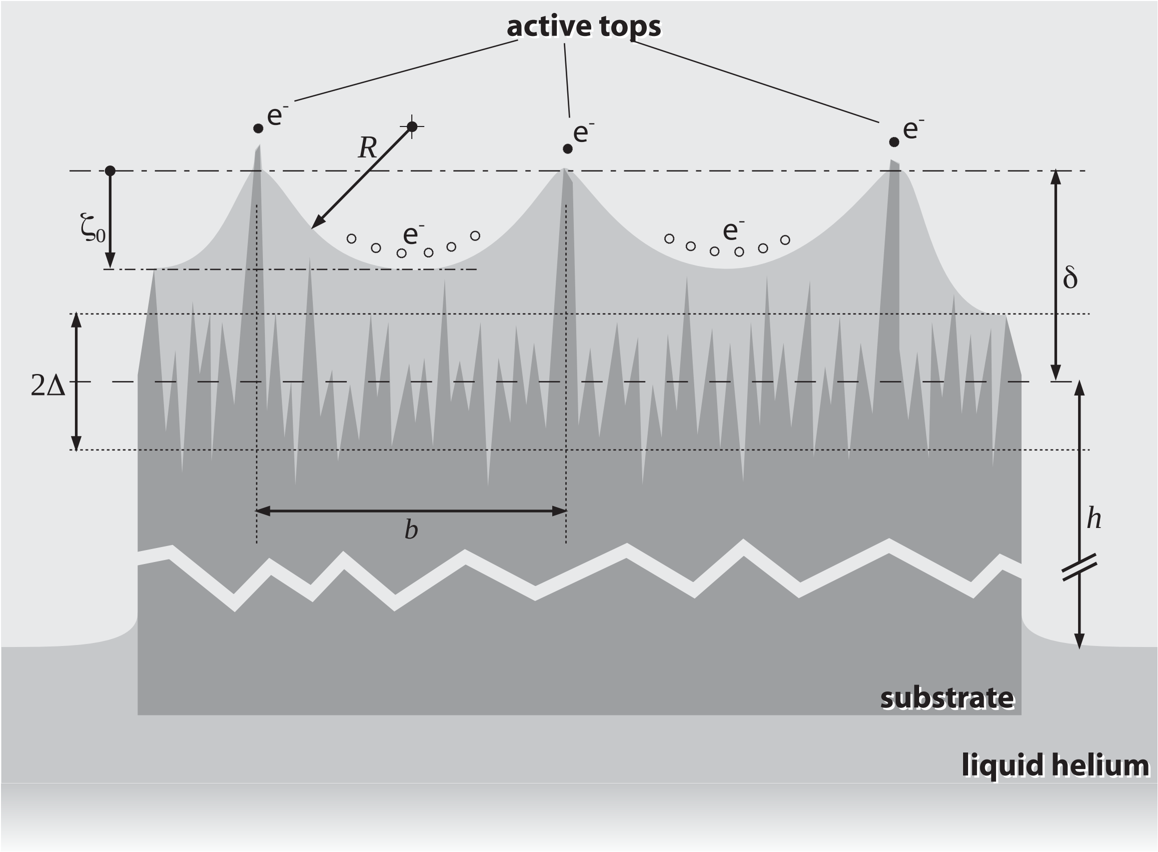
The **helium film thickness** *d(x)* can be deduced from:

$$\sigma_{lv} \frac{d''(x)}{[\ 1 + (d')^2\ ]^{3/2}} - \rho g \delta(x) + \frac{C_3}{d^3(x)} = \rho g h$$

The **radius of curvature** of the capillary condensed film is then:

$$\frac{2\sigma_{lv}}{R} \simeq \rho g h$$

. . . and the substrate roughness



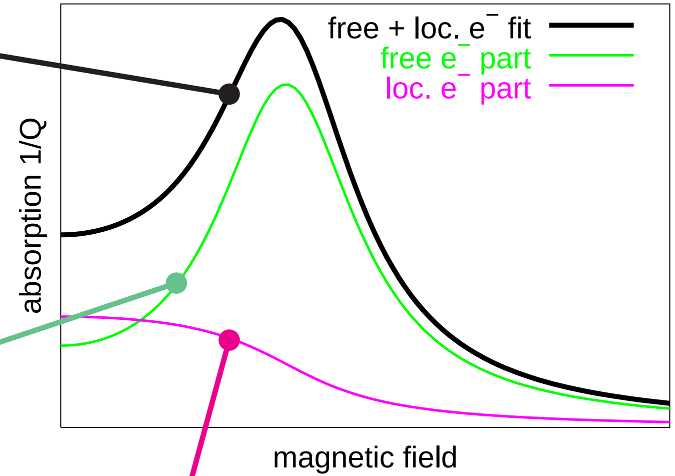
roughness distribution: $$G(\delta) = \frac{1}{\sqrt{2\pi\Delta^2}} \exp\left[-\frac{\delta^2}{2\Delta^2}\right]$$

lateral correlation length : $$\langle \delta(x), \delta(x-x') \rangle = \Delta^2 \exp\left(-\frac{x'^2}{2\eta^2}\right)$$

Modelling the CR absorption

The total absorption is then the sum of the absorption of localized and free electrons:

$$Q^{-1} = Q_e^{-1} + Q_l^{-1}$$



with

$$Q_e^{-1} \propto n_e \frac{1+z+x}{(1-z+x)^2+4z}$$

$$Q_l^{-1} \propto n_l \frac{\arctan \frac{\sqrt{z}}{1+x+\sqrt{xz}} + \arctan \frac{\sqrt{z}}{(1+x)\sqrt{z}-z\sqrt{x}} + c(z,x)}{2\sqrt{z}}$$

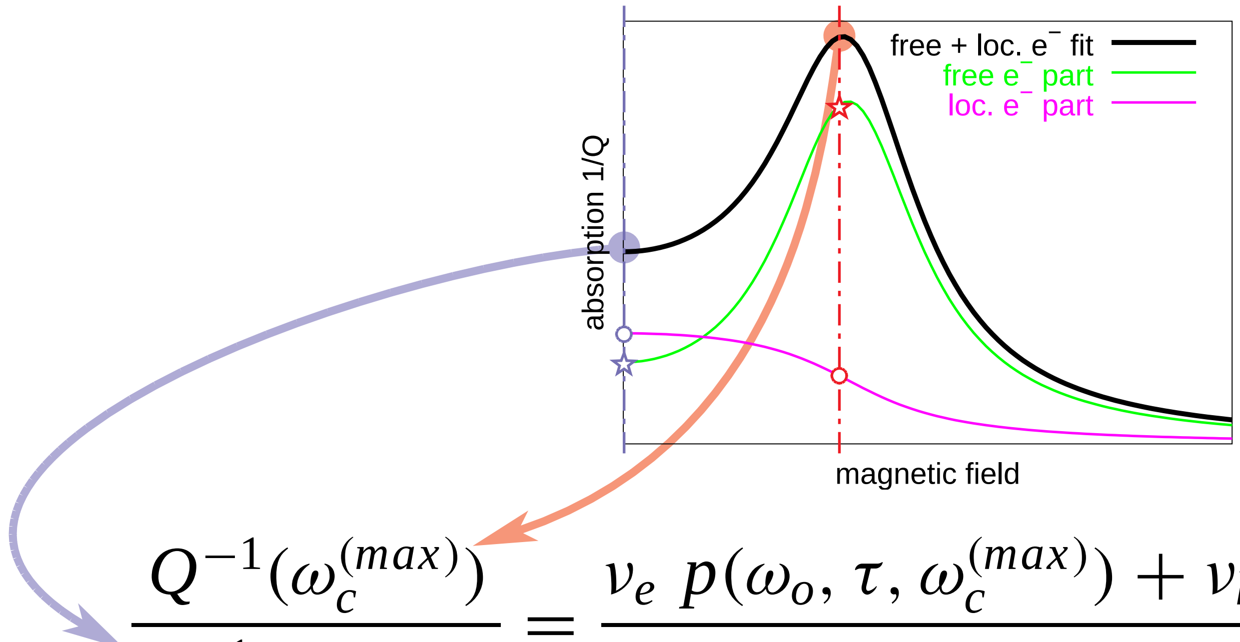
and $z = \omega^2 \tau^2$, $x = \omega_c^2 \tau^2$

Calculating the fractions

use only fractions of densities

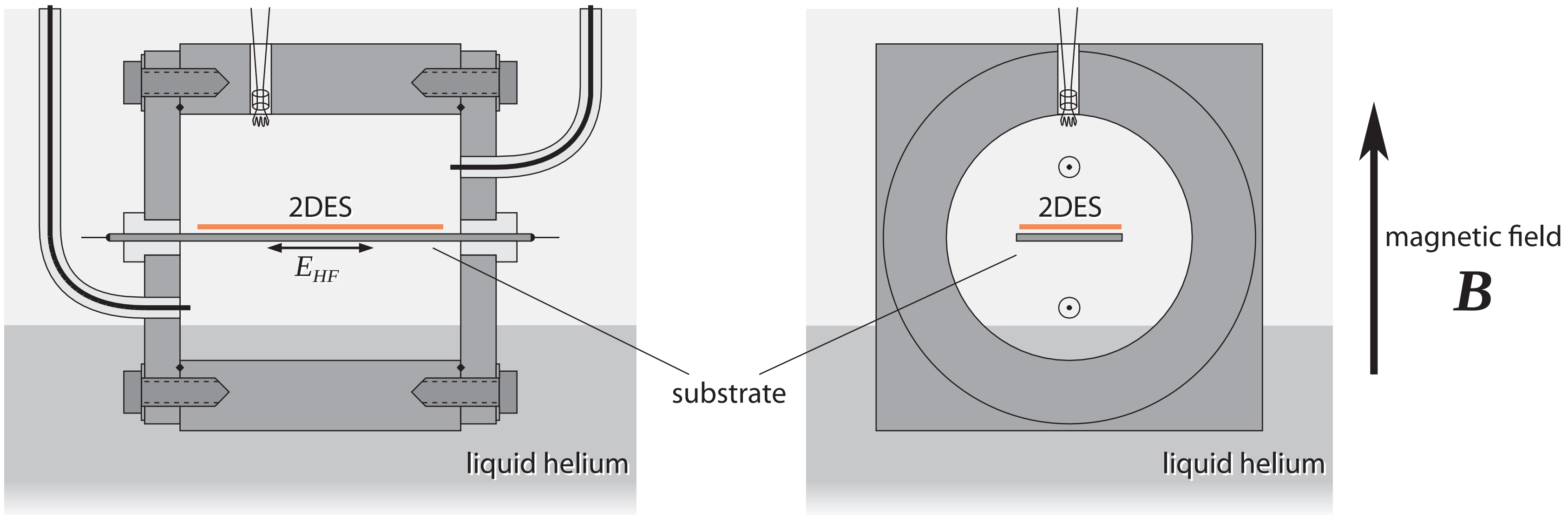
$$\nu_e = \frac{n_e}{n_s} \qquad \nu_l = \frac{n_l}{n_s} \qquad \nu_e + \nu_l = 1$$

the fractions are calculated with two points on the fit



$$\frac{Q^{-1}(\omega_c^{(max)})}{Q^{-1}(\omega_c = 0)} = \frac{\nu_e \; p(\omega_o, \tau, \omega_c^{(max)}) + \nu_l \; q(\omega_o, \tau, \omega_c^{(max)})}{\nu_e \; p(\omega_o, \tau, 0) + \nu_l \; q(\omega_o, \tau, 0)}$$

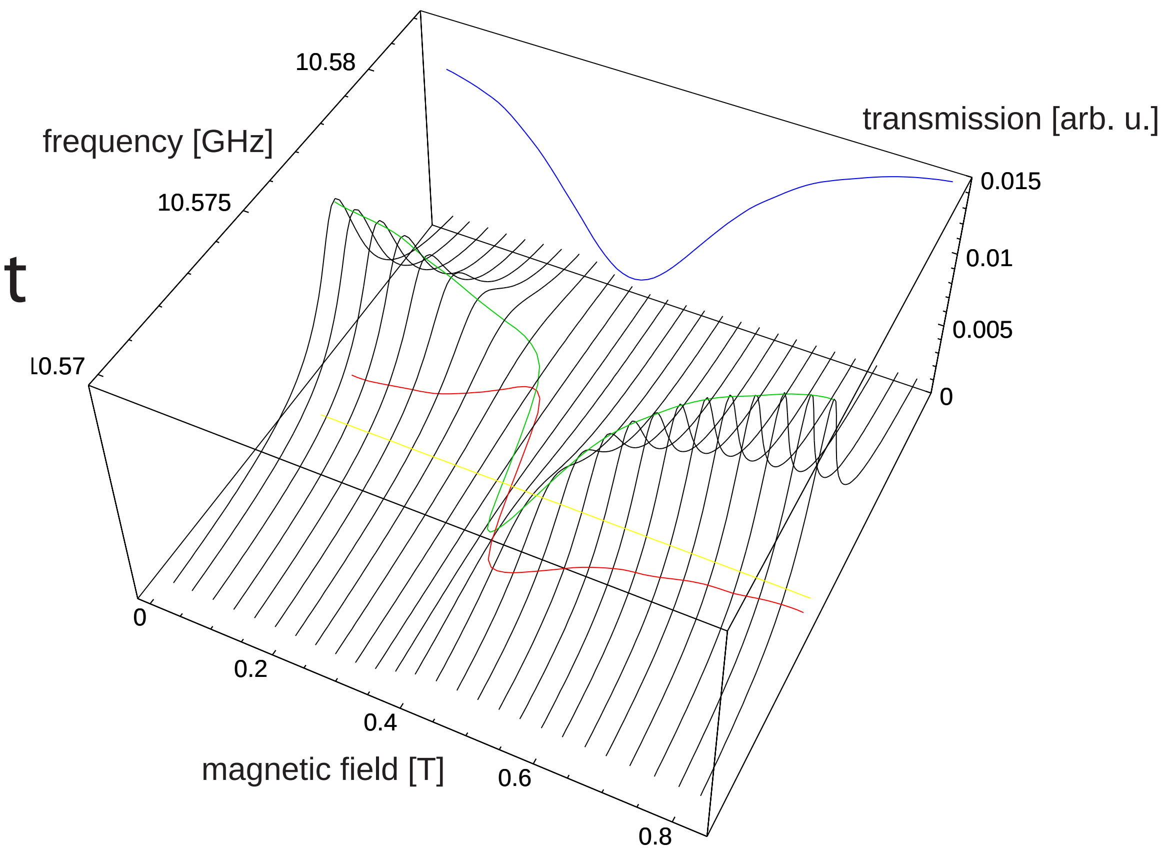
Experimental setup

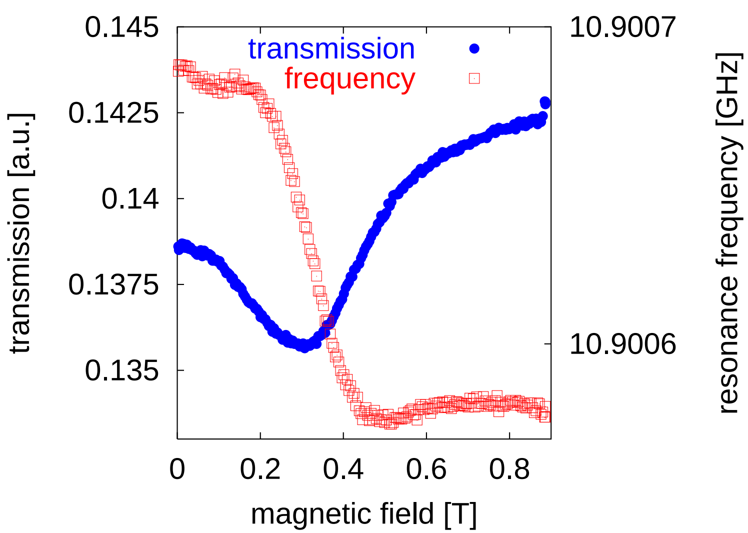


measuring frequency:	around 9 GHz
electron densities:	$10^{12} – 10^{15}$ m^{-2}
magnetic field:	0 – 1 T
helium-film thickness:	10 – 100

How the experiment works

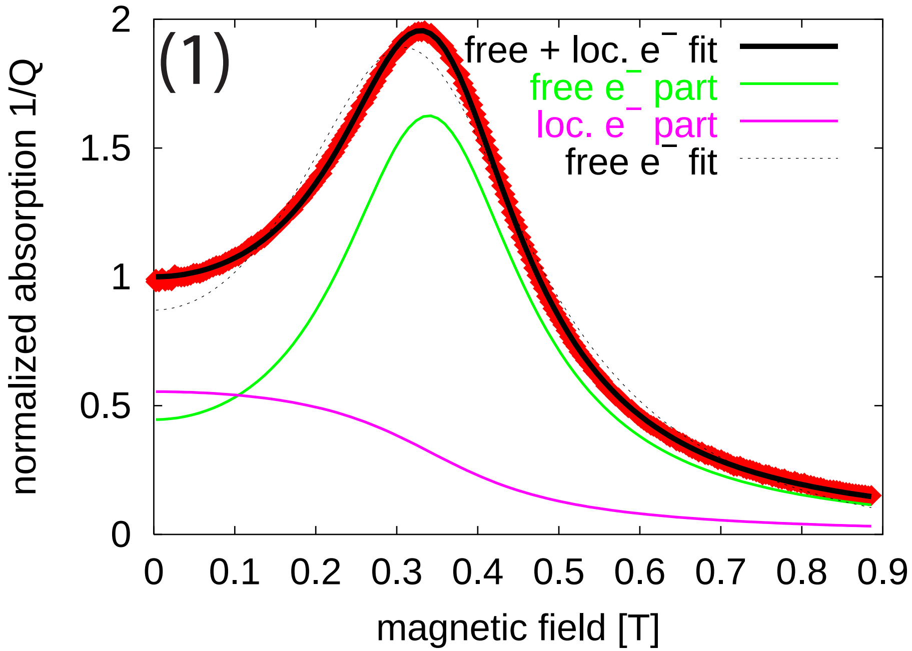
magnetic field is swept and the frequecy dependent transmission is recorded



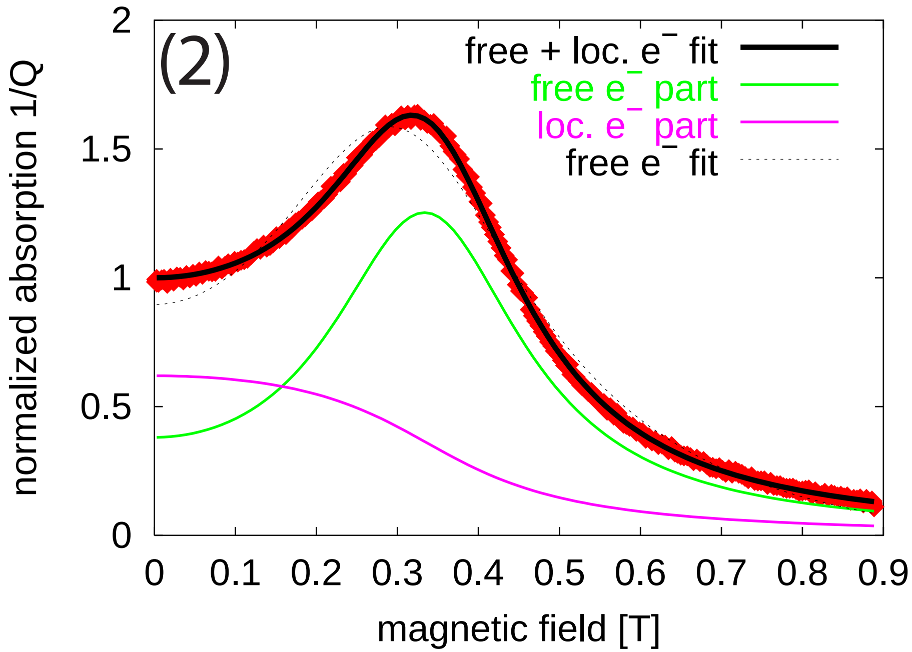


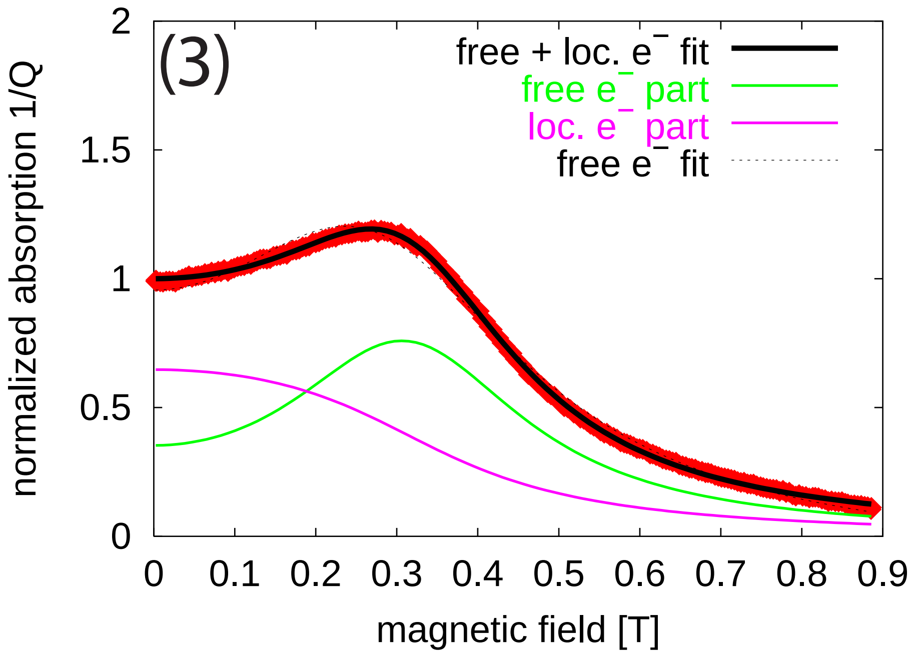
frequency and **amplitude** of the microwave resonance are the measured parameters

Experimental Results

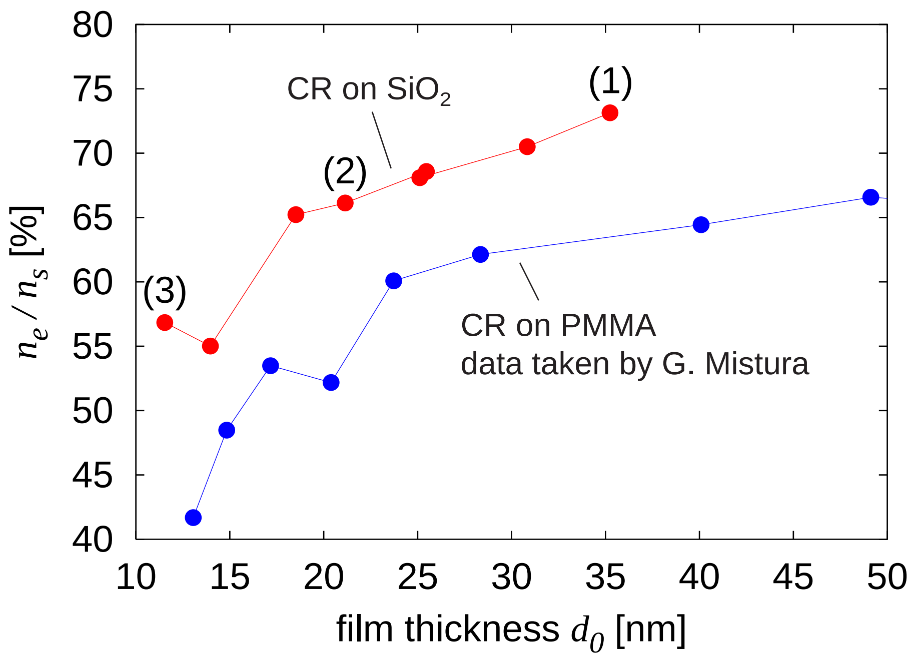


decreasing helium-film thickness





Analyzing the data



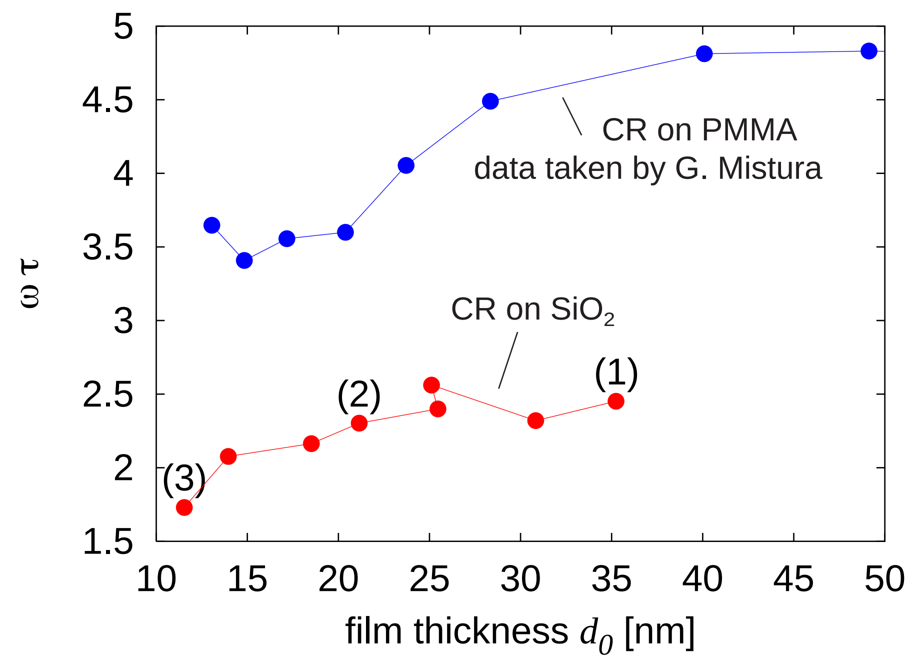
qualitative behaviour:

SiO_2 substrate is smoother

but: offset to 100% n_e/n_s

dip in both curves

difference due to temperature and different measurement frequencies



Conclusions & Outlook

two-fraction model explains the behaviour of a 2DES on thin helium films:

- origin of the CR-line **asymmetry is understood**
- **quantitative analysis of the electron fractions** is possible.
- model provides a method to **characterize a substrate surface** used in the measurements

experimental Outlook:

- explore wider range of film thicknesses
- resolve the vicinity of the dip more precisely

theoretical Outlook:

- refine theory for quantitative data analysis
- consider special properties of the cavity