Peter Frayne
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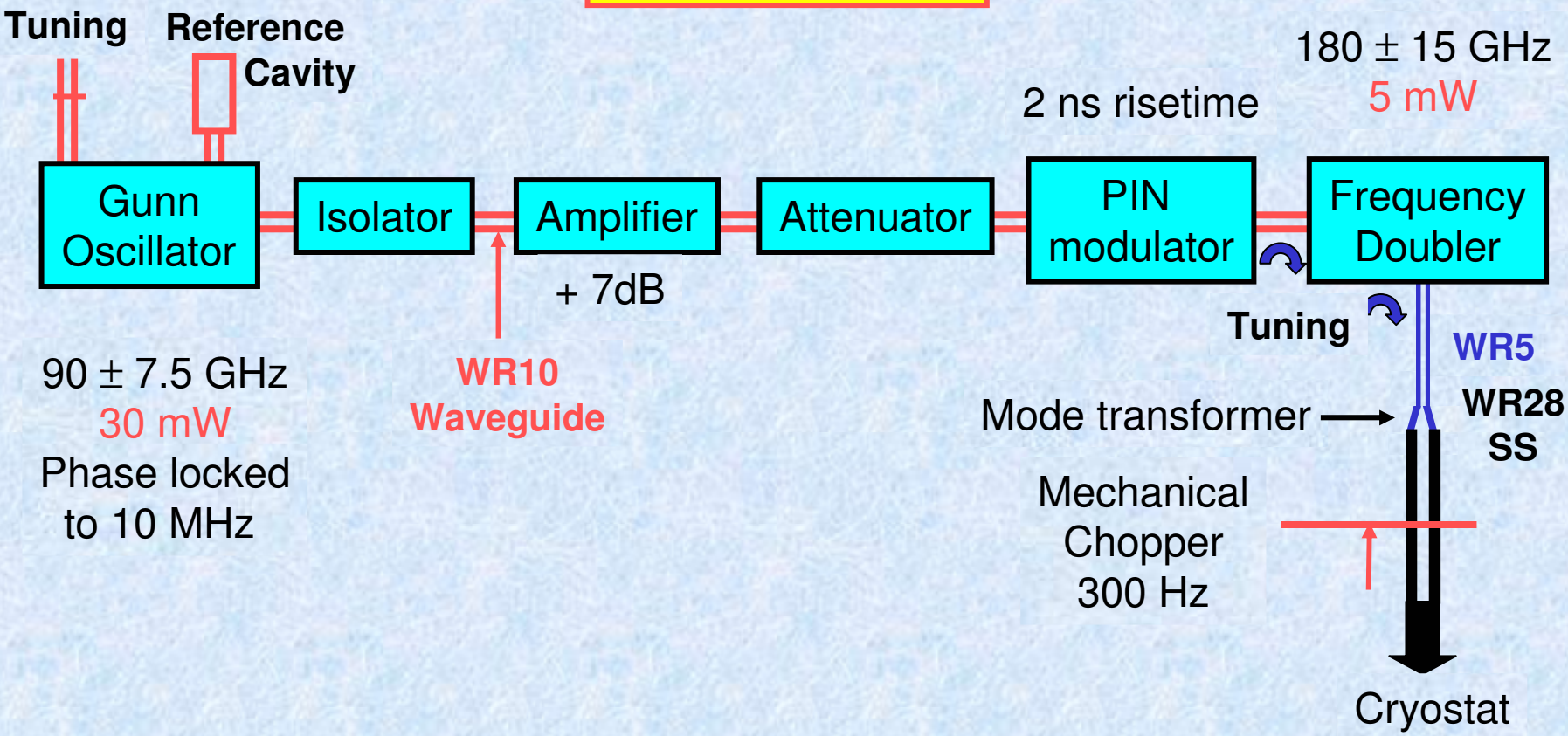
Rydberg resonance
190 GHz
E_z = 10.7 kV/m



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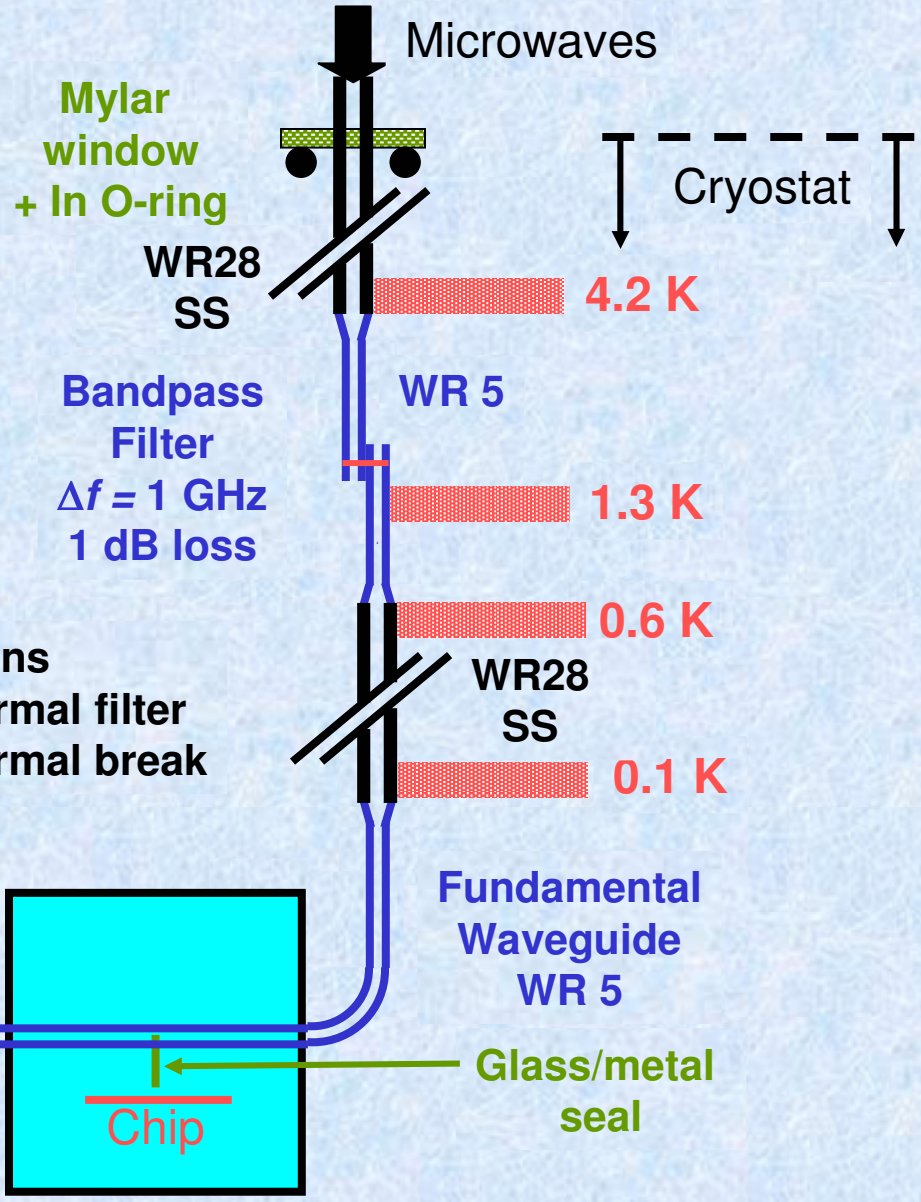
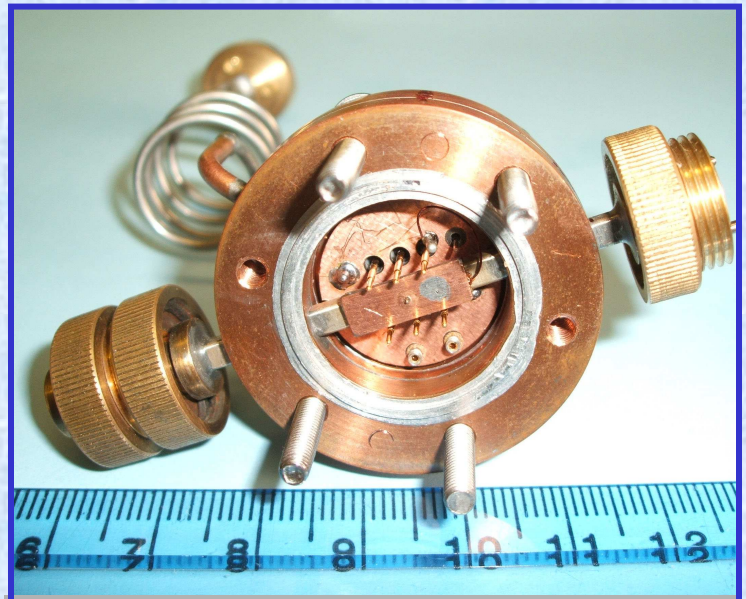


Microwave Components and Cell

Thermal break in fundamental mode waveguide - two back-to-back waveguide tapers (WR-05 to WR-28) with needle point mountings

Band-pass filter (WR-05) for removing thermal radiation complete with coupling horns to overmoded waveguide (WR-28)

Fundemental mode 'Swan-Neck' coupling piece for microwave cell



Upper microwave cell showing waveguide and coupling pin

Low Microwave Power

- Stark tuning resonance $f_{12}(E_z)$
- Linewidth $\gamma(T)$
- Temperature dependent resonance $f_{12}(T)$

High Microwave Power

- Absorption saturation
- Power broadening
- Absorption hysteresis

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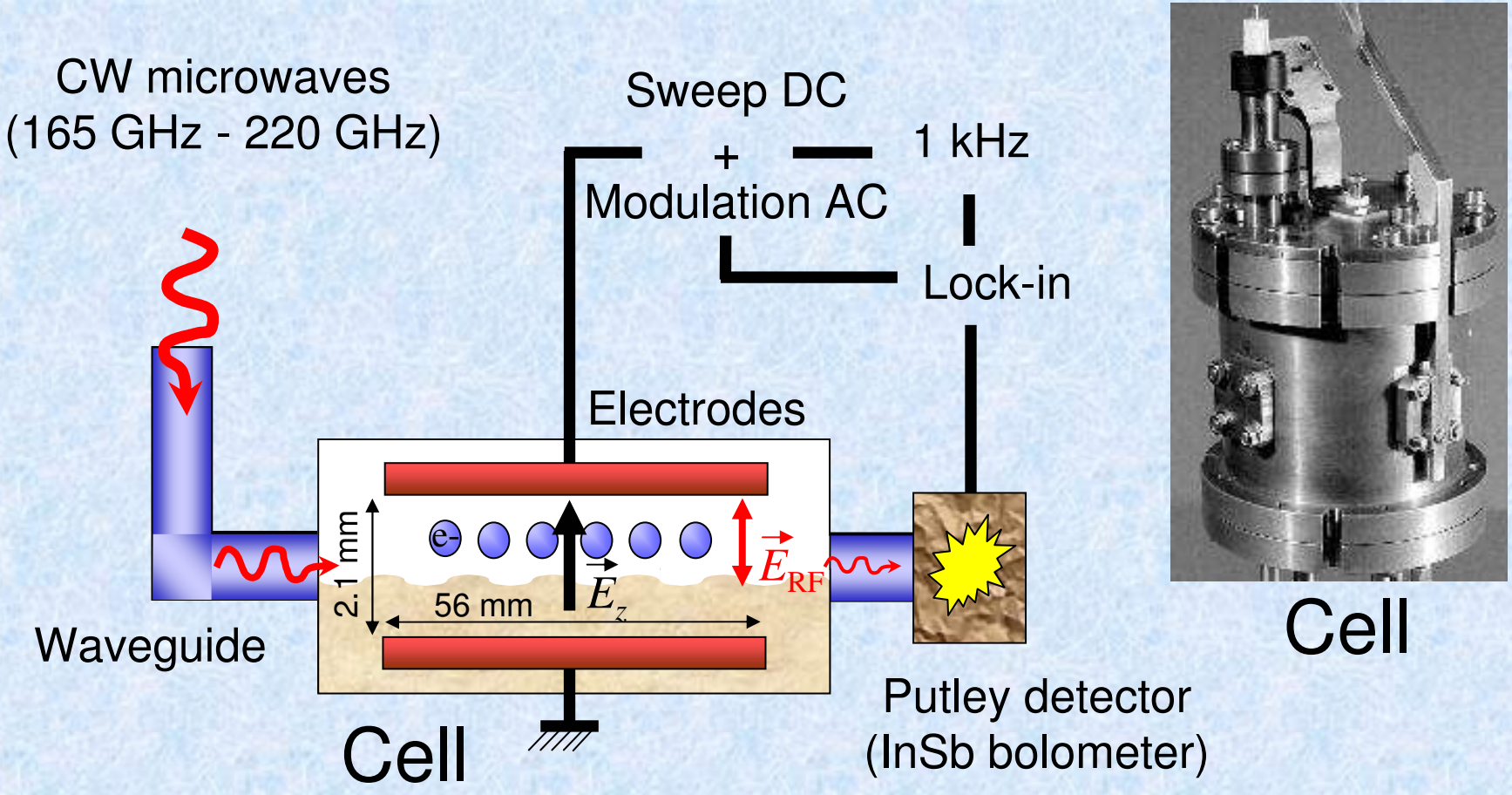
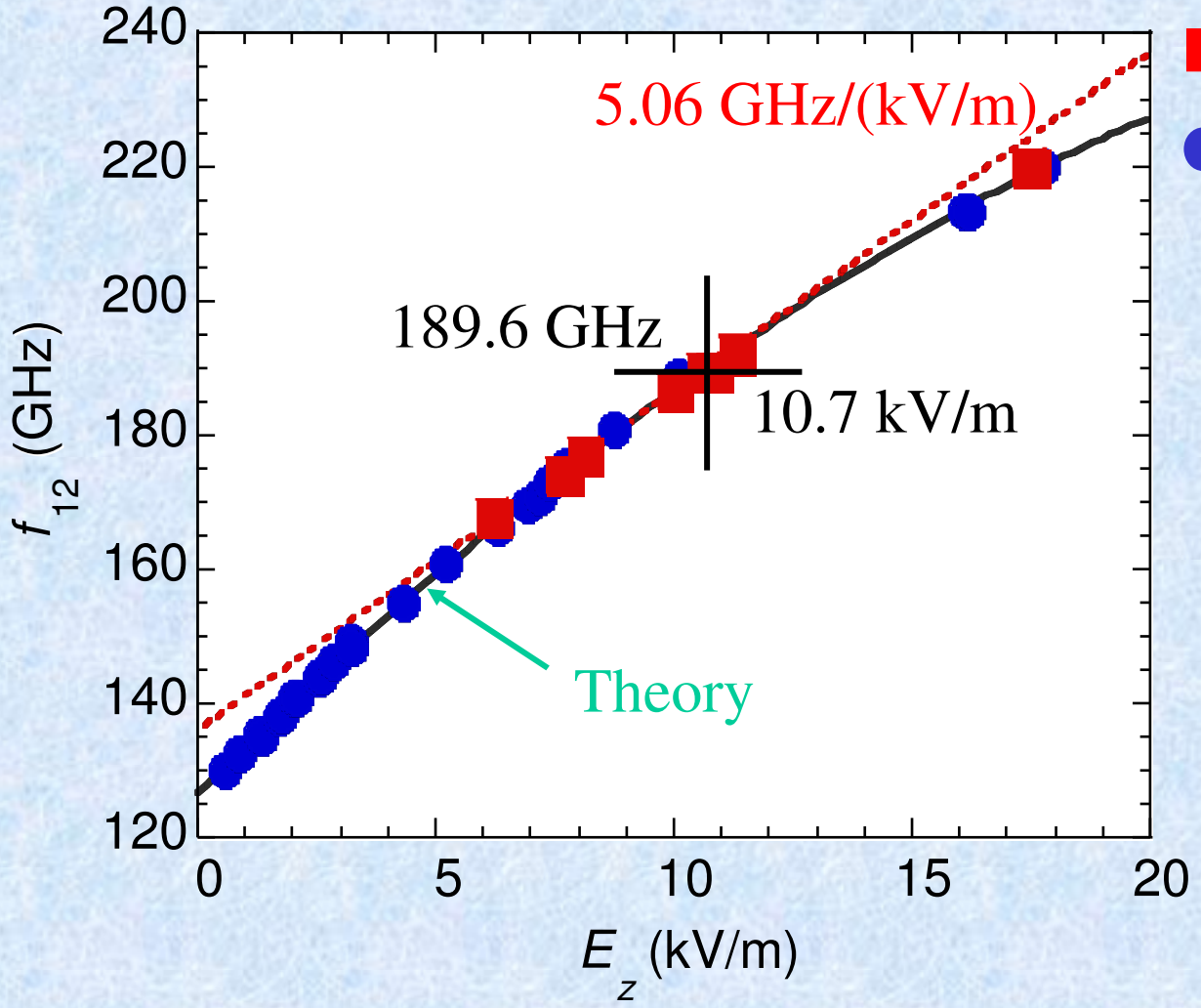

CW microwaves
(165 GHz - 220 GHz)
Sweep DC
+
Modulation AC
1 kHz
Lock-in
Electrodes
e-
2.1 mm
56 mm
$\vec{E}_z$
$\vec{E}_{RF}$
Waveguide
Cell
Putley detector
(InSb bolometer)

Cell

Ground state to first excited Rydberg state

Resonant frequency f_{12} increases with E_Z



Our results

Brown, Grimes, Zipfel, 1976

1.5 K
Low power

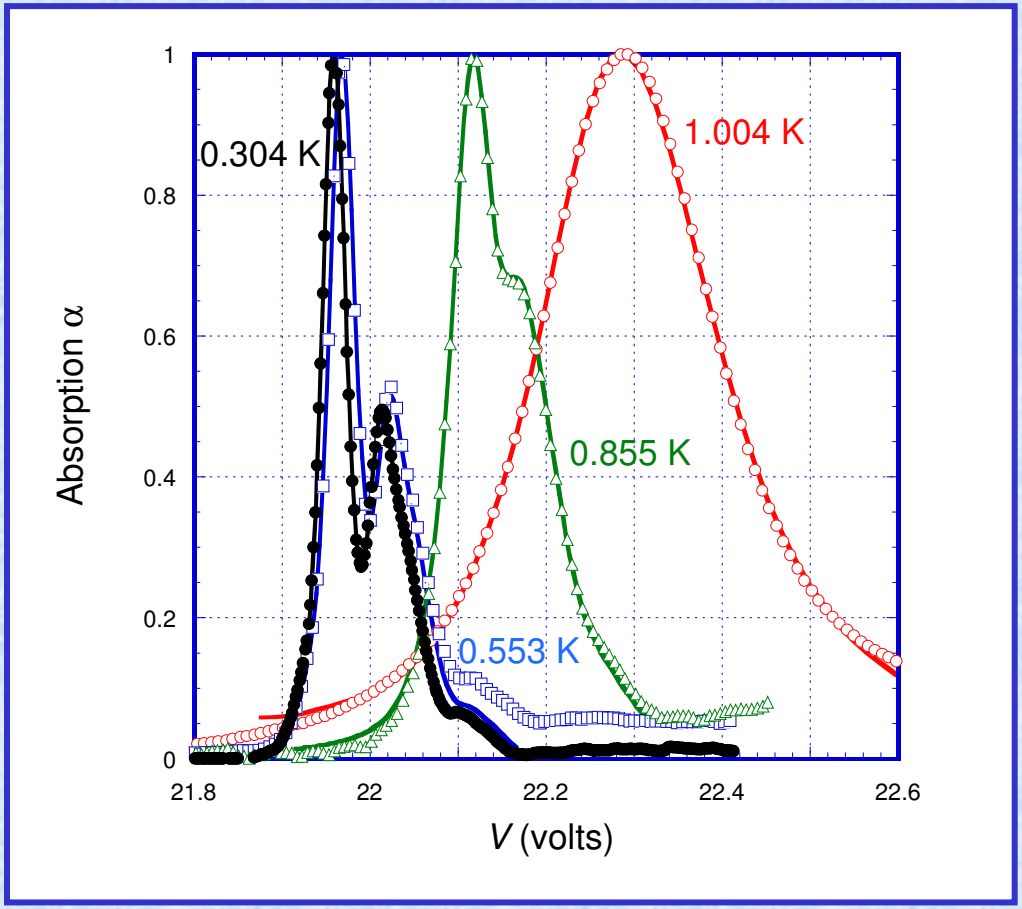
Temperature dependent absorption

Low temperatures
Inhomogenous broadening

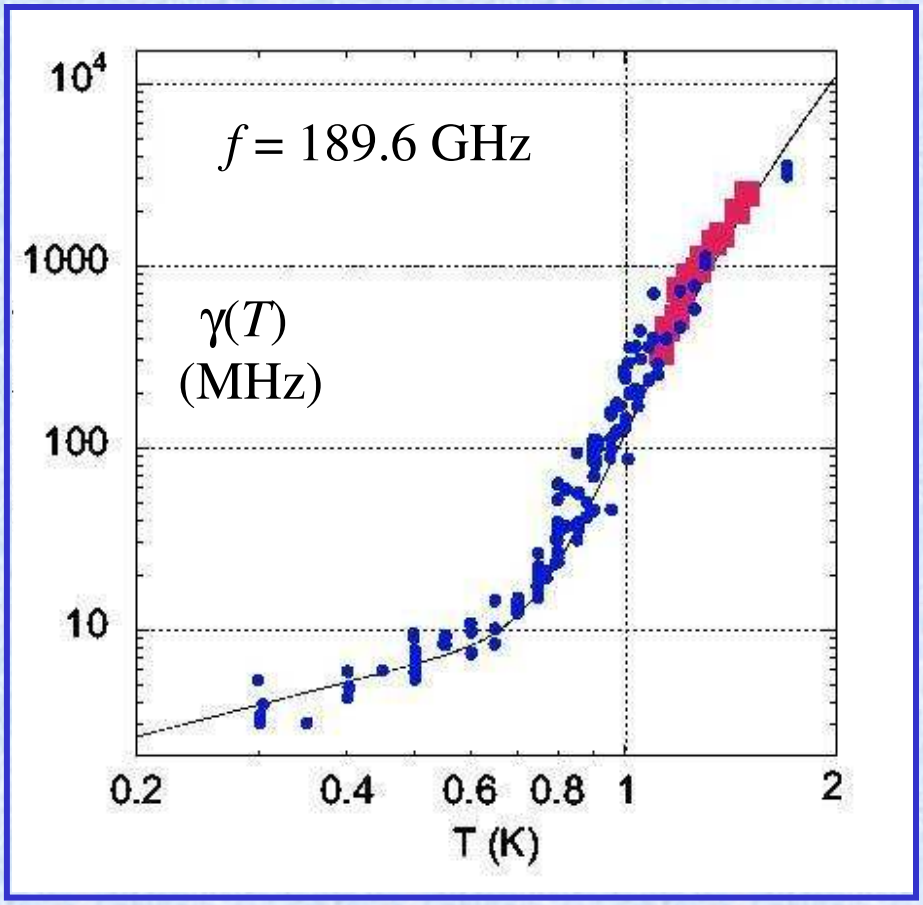
Medium temperatures
Inhomogenous broadening convoluted with a Lorentzian

High temperatures
Lorentzian broadening

Resonance frequency *decreases* as the temperature *increases*



Temperature dependent linewidth



E.Collin *et al.* PRL **89**, 245301 (2002)

- Grimes *et al.* (1976)

Theory: Ando (1976)

$$\gamma = AT + BN_{gas}$$

Ripplon Scattering — Gas atom

NB not the absolute linewidth
Inhomogeneous broadening
plus a contribution $\gamma(T)$

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Temperature dependent resonance

$\Delta f_{12}(T) = f_{12}(0) - f_{12}(T)$

$\approx$ 800 MHz at 1 K

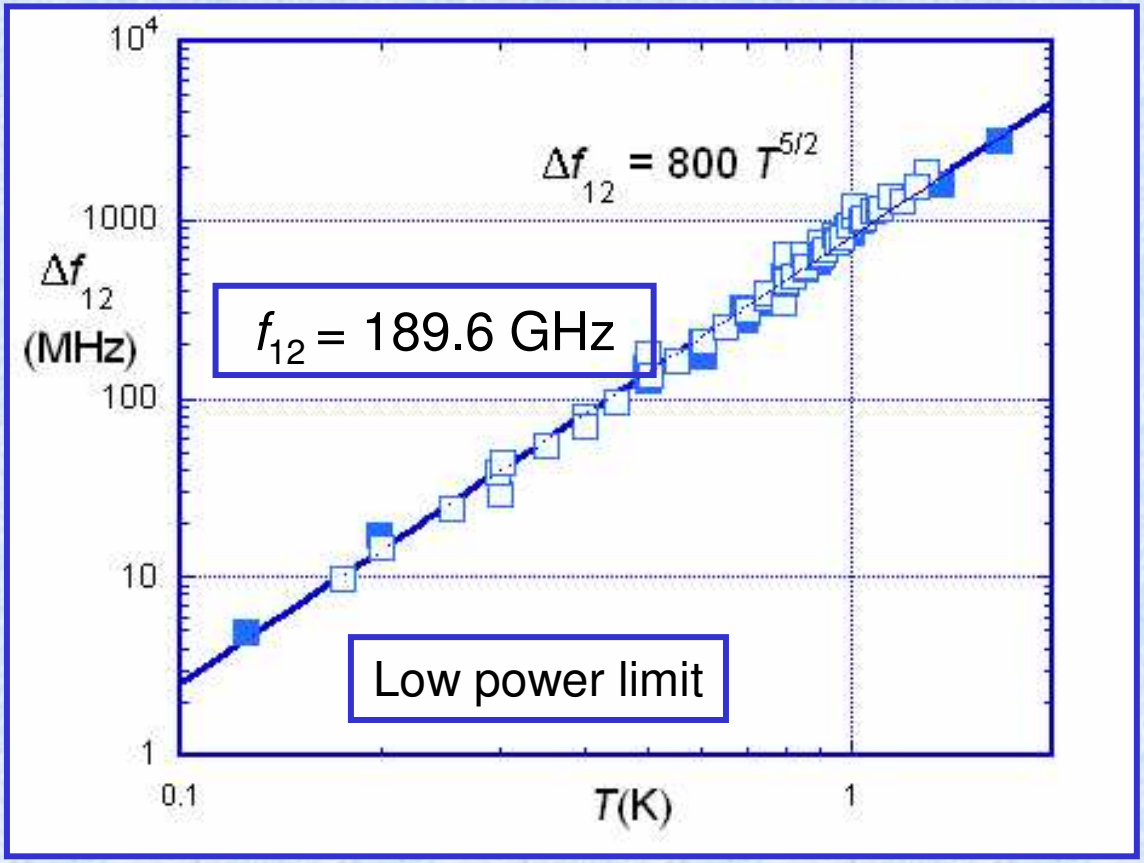
$\Delta f_{12}(T) \propto T^{5/2}$ or

$\propto T^{7/3}$

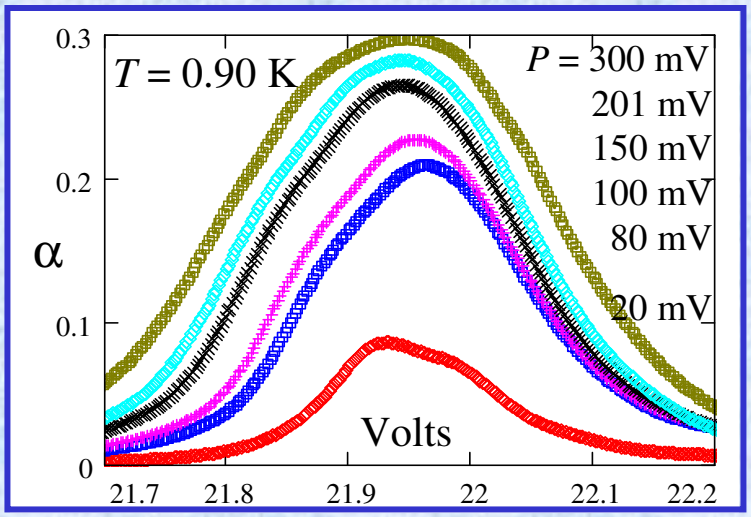
b

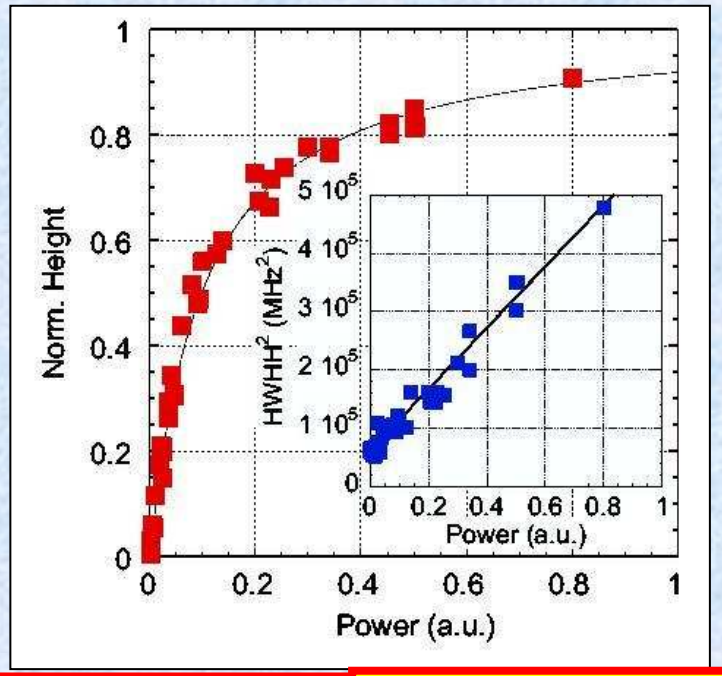
T-dependent surface profile and potential well

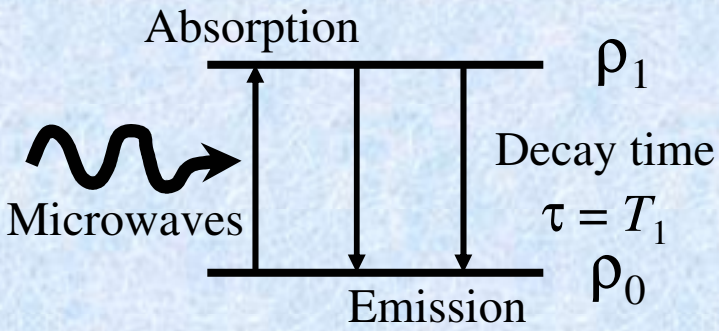
2-ripplon effects?



Absorption Saturation + Power Broadening







2-level system?

Rabi frequency Ω
$\Omega^2 \propto$ Power

$$\alpha = \frac{0.5N\gamma_1\Omega^2}{\delta^2 + \gamma^2 + \gamma\gamma_1\Omega^2}$$

$$\gamma_P^2 = \gamma^2 + \gamma\gamma_1\Omega^2$$

BUT:
Heating?
Higher sub-bands?
Bleaching?

Vertical transitions

Microwave absorption/emission

$1 \leftrightarrow 2$

Energy relaxation

τ_E: $N \rightarrow 2 \rightarrow 1$; $1 \rightarrow 1$

(1-ripplon and 2-ripplon)

Horizontal transitions

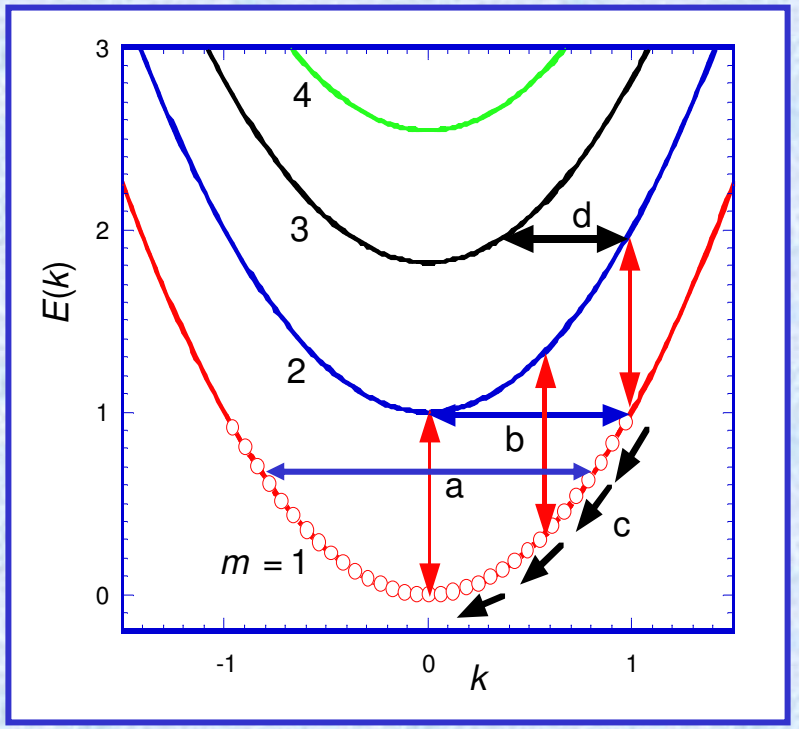
Momentum scattering

τ_k: $N \leftrightarrow 2 \leftrightarrow 1$; $1 \leftrightarrow 1$

(1-ripplon + gas atom)

Thermal equilibrium

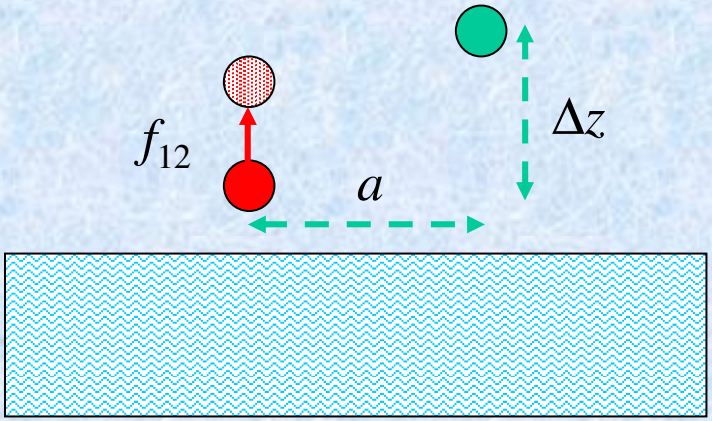
Electron-electron scattering τ_{ee}



$\tau_{ee} << \tau_k << \tau_E$

Microwave energy → Very hot electrons → Excited sub-bands
→ Bleaching + Population saturation
→ Power broadening + Absorption saturation

Coulomb Non-linearity



$$\Delta f_{12} = \frac{e^2 \Delta z^2}{4\pi\varepsilon_0 h a^3}$$

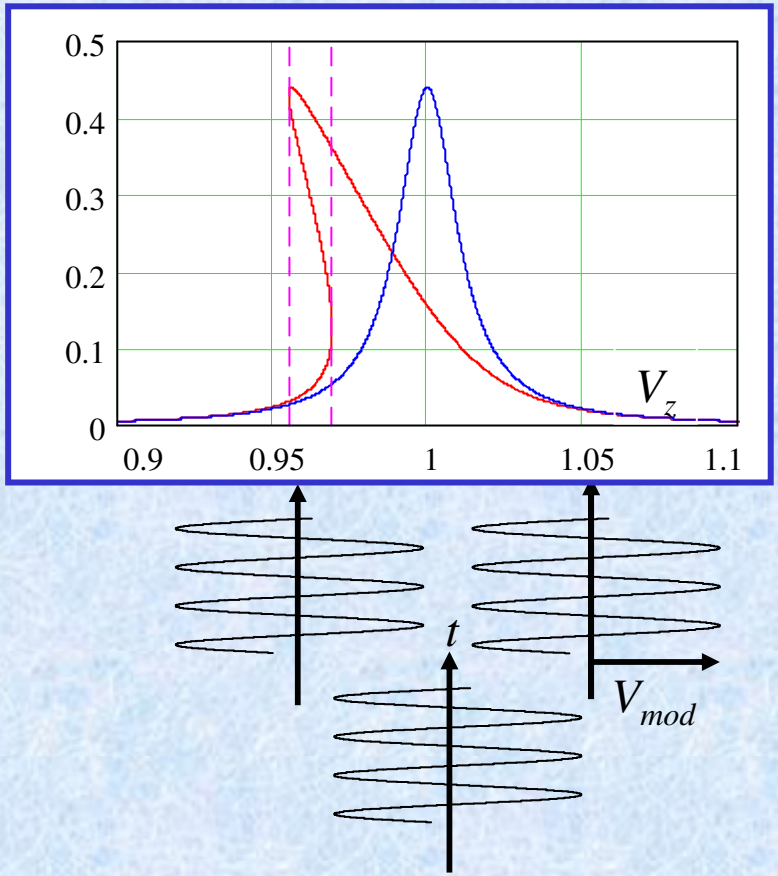
Resonance frequency shifts with

- Electron density
- Power absorbed
  (excited state population)

$\Delta f_{12} \approx 34$ MHz

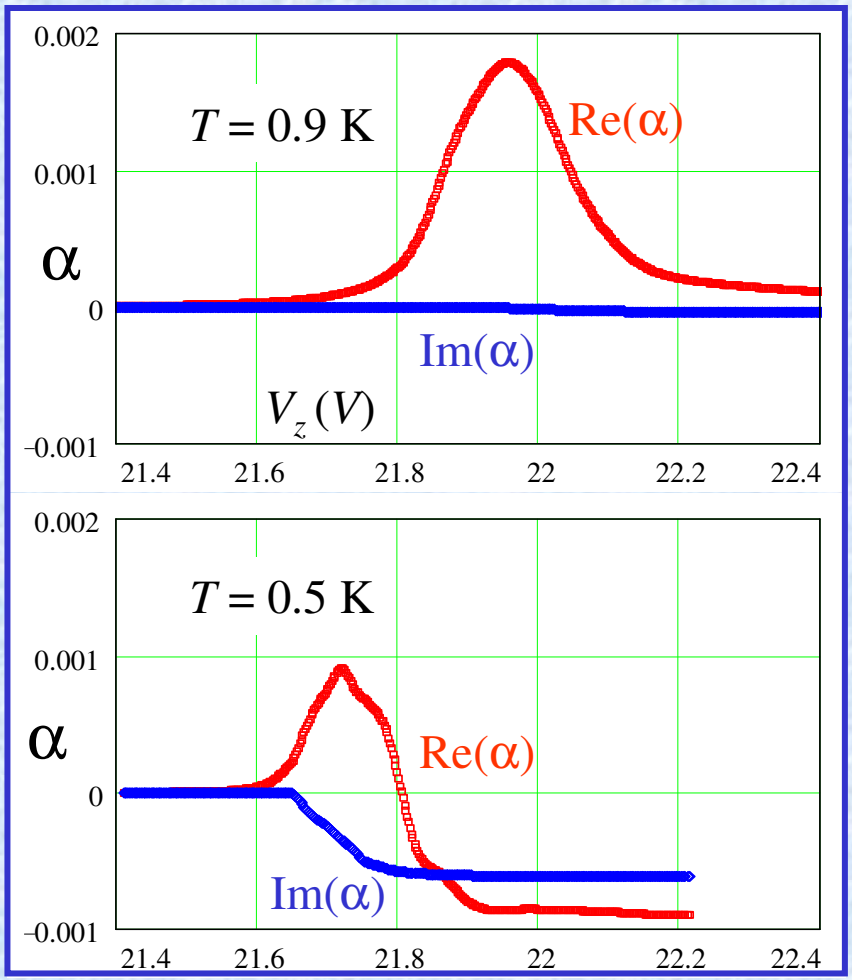
$n = 10^{11}$ m^{-2}

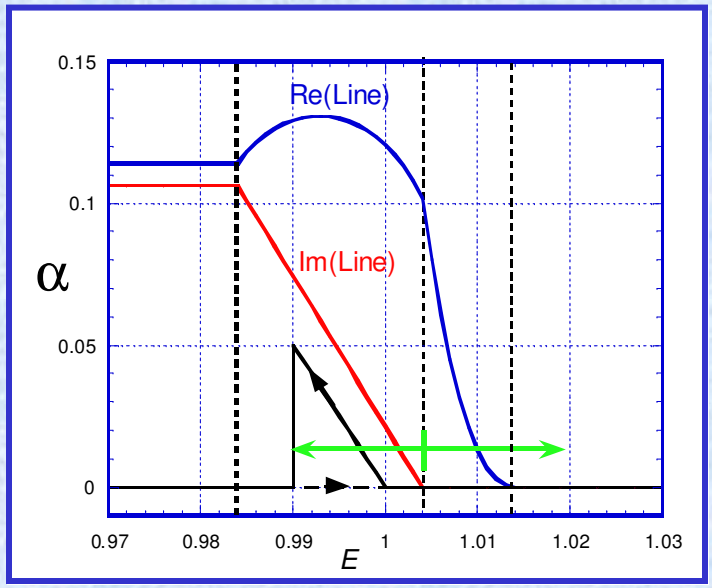
2-level saturation



Finite a.c. voltage modulation

Hysteresis ≡ Complex Lineshape





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