Microwave excitation of Rydberg states of electrons on helium by rapid adiabatic passage

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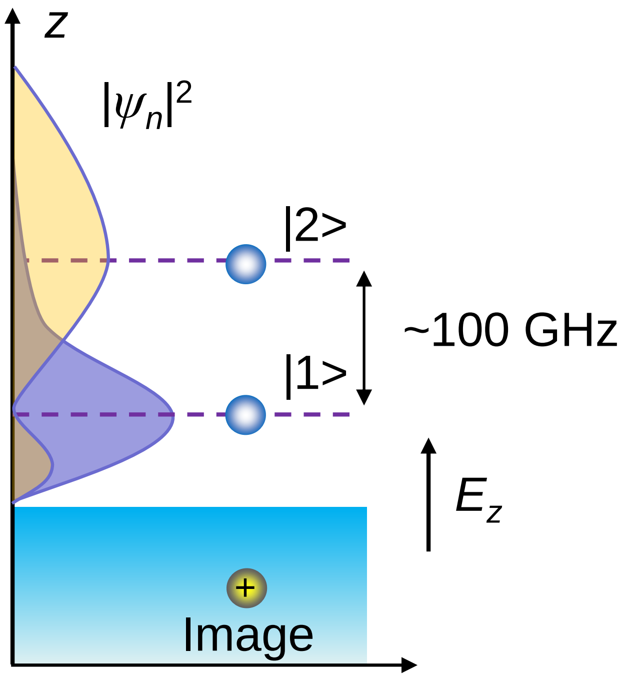
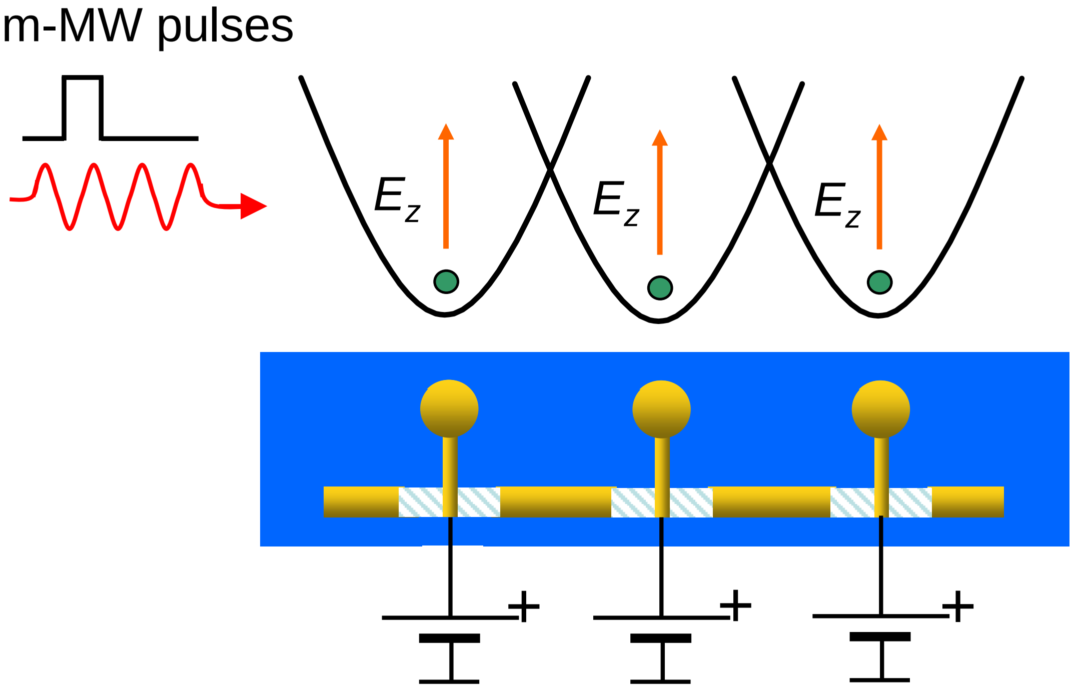
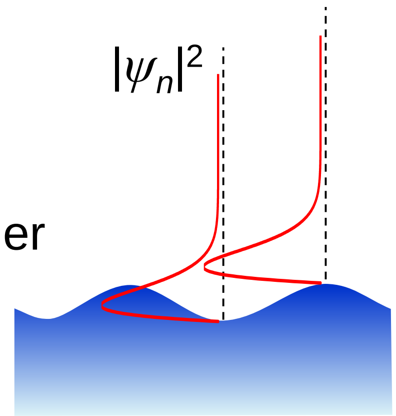
Rydberg states of electrons on helium



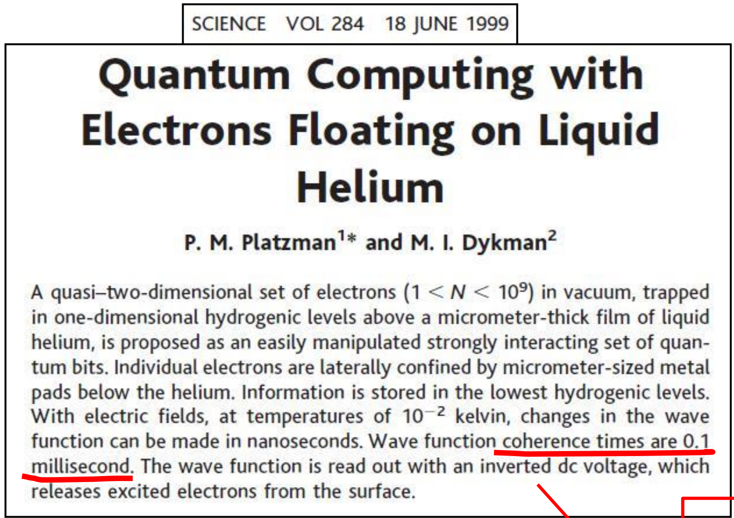




Dykman et al. PRB 2003

Infinite barrier

Rydberg states of electrons on helium



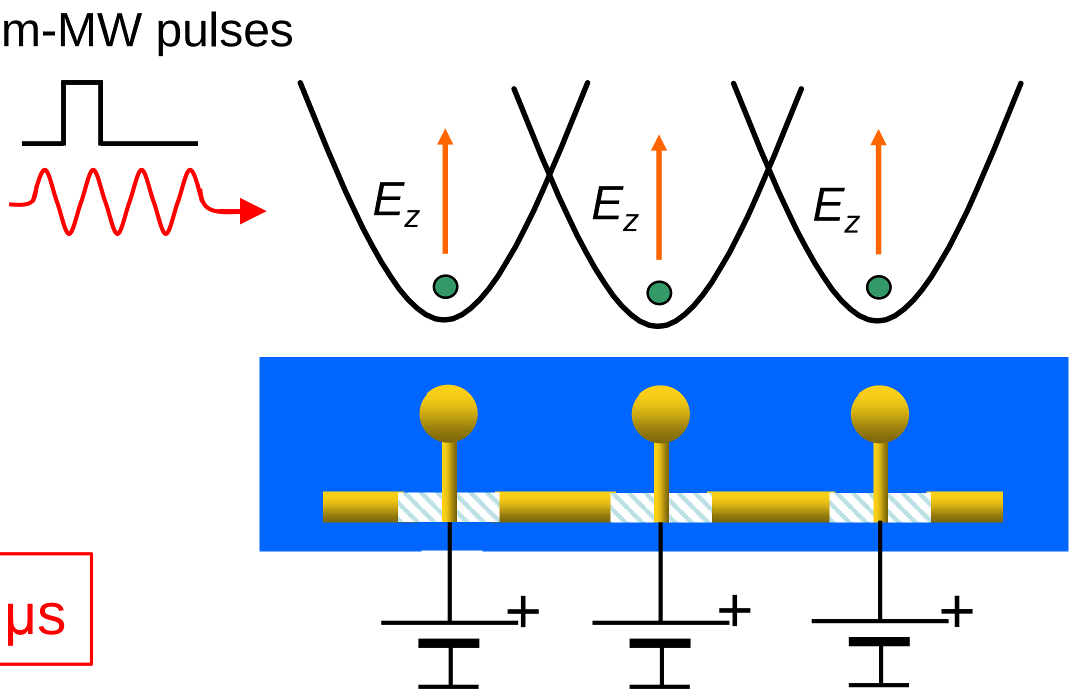
SCIENCE VOL 284 18 JUNE 1999

Quantum Computing with Electrons Floating on Liquid Helium

P. M. Platzman[1]* and M. I. Dykman[2]

A quasi–two-dimensional set of electrons ($1 < N < 10^9$) in vacuum, trapped in one-dimensional hydrogenic levels above a micrometer-thick film of liquid helium, is proposed as an easily manipulated strongly interacting set of quantum bits. Individual electrons are laterally confined by micrometer-sized metal pads below the helium. Information is stored in the lowest hydrogenic levels. With electric fields, at temperatures of 10^{-2} kelvin, changes in the wave function can be made in nanoseconds. Wave function coherence times are 0.1 millisecond. The wave function is read out with an inverted dc voltage, which releases excited electrons from the surface.

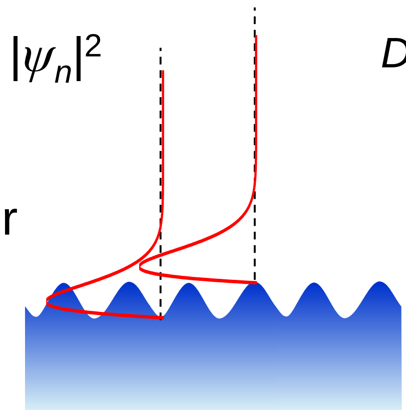
T_1~100 μs



Dykman et al. PRB 2003

$\mu_{ripplon} < \mu_{cut\text{-}off}$

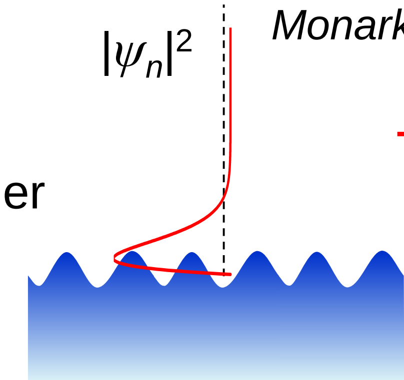
Infinite barrier



Monarkha JLTP 2007

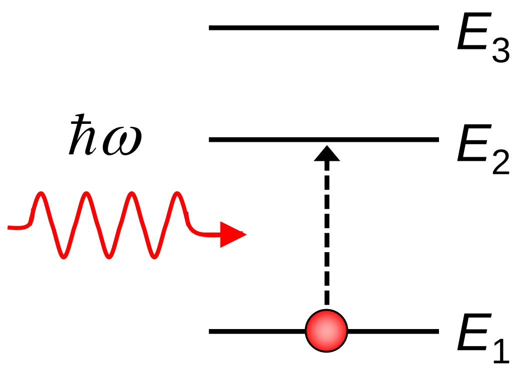
T_1~1 μs

Finite barrier

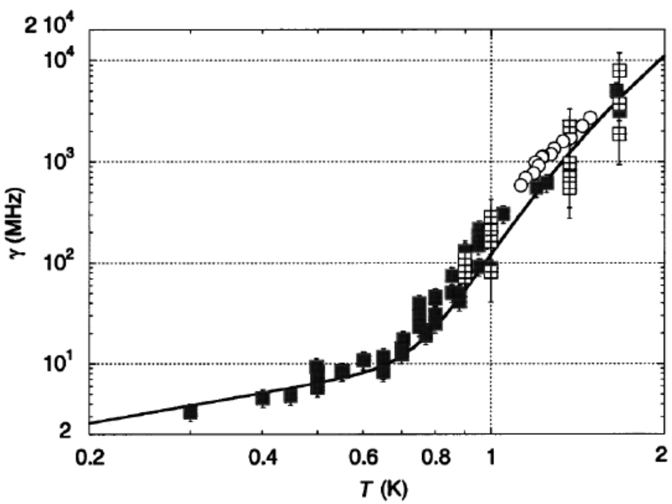


Absorption linewidth

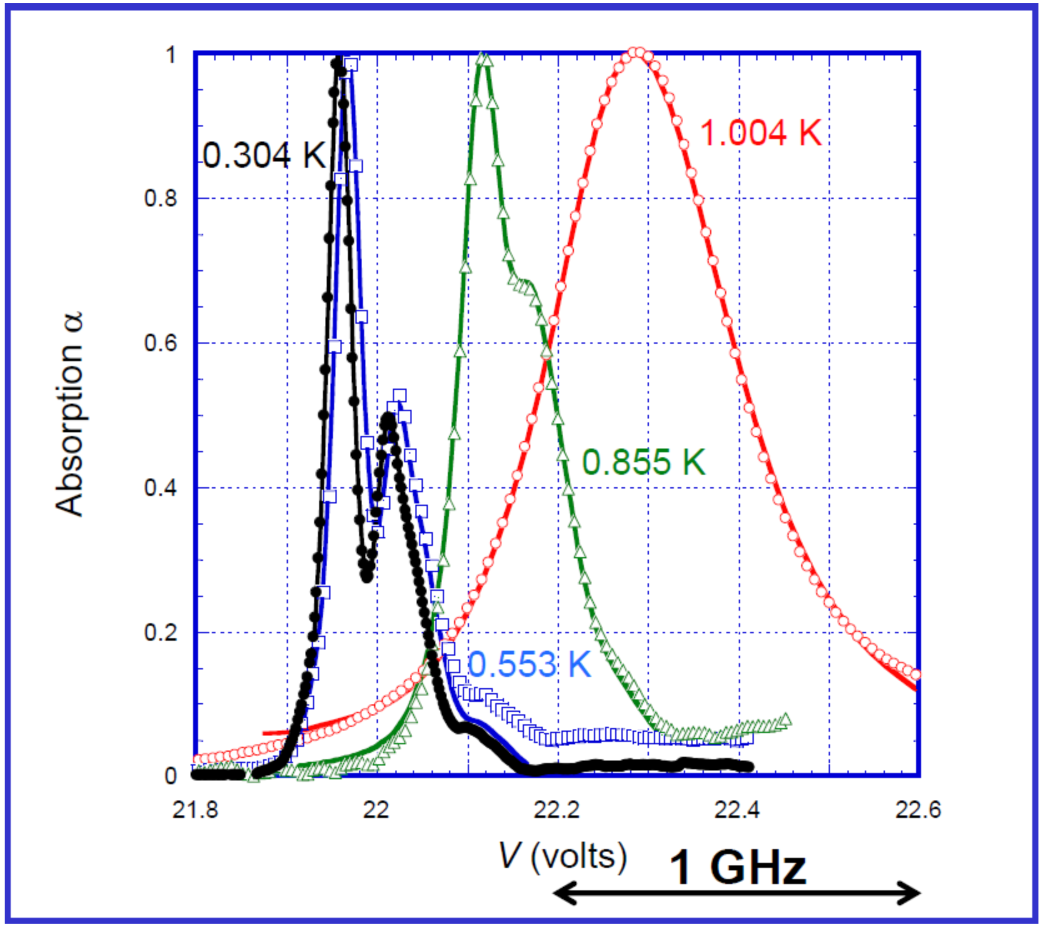
MW resonance: $\hbar\omega = E_2 - E_1$



2-level system



Collin et al. PRL 2002

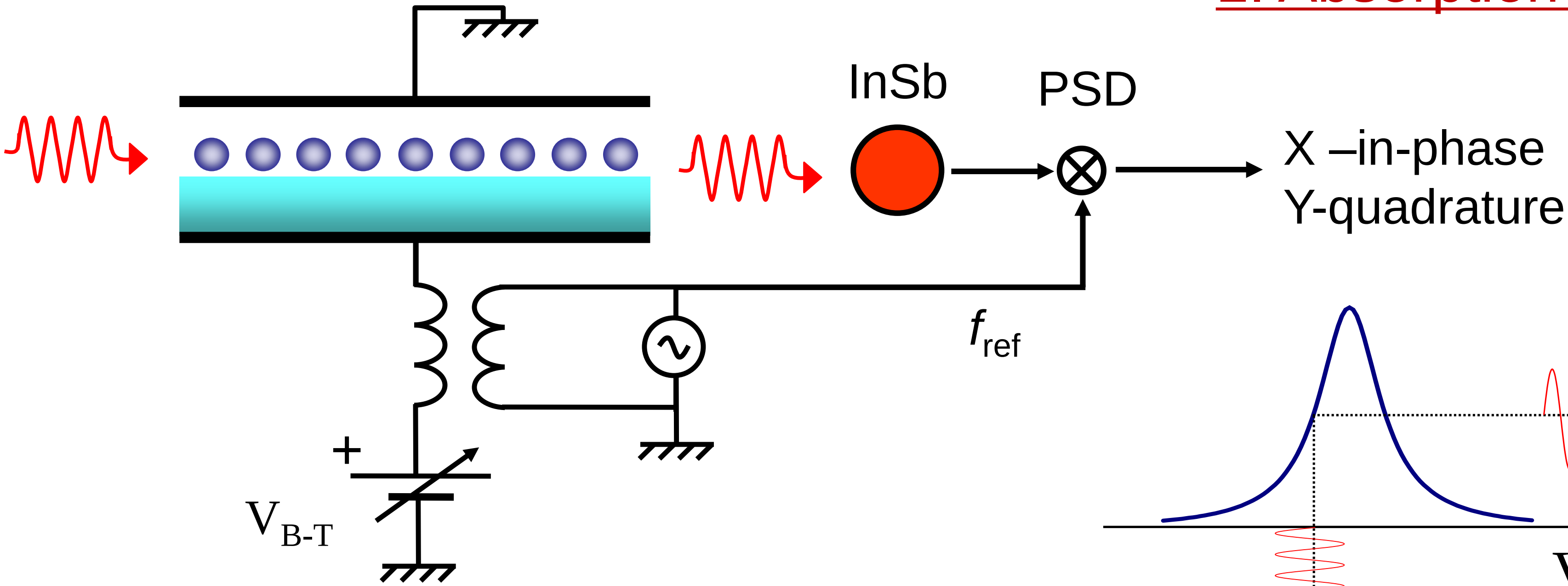


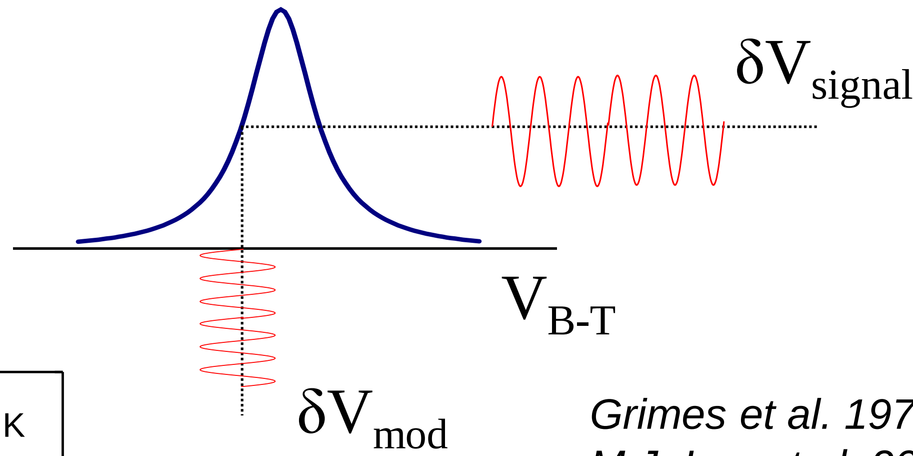
M.J. Lea et al. 2002

Inhomogeneous broadening ~1 GHz

Experimental methods

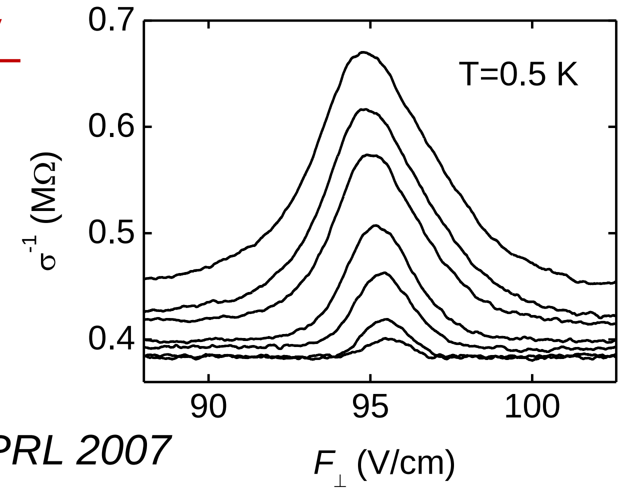
1. Absorption measurements





Grimes et al. 1974
M.J. Lea et al. 2002

2. Photo-conductivity



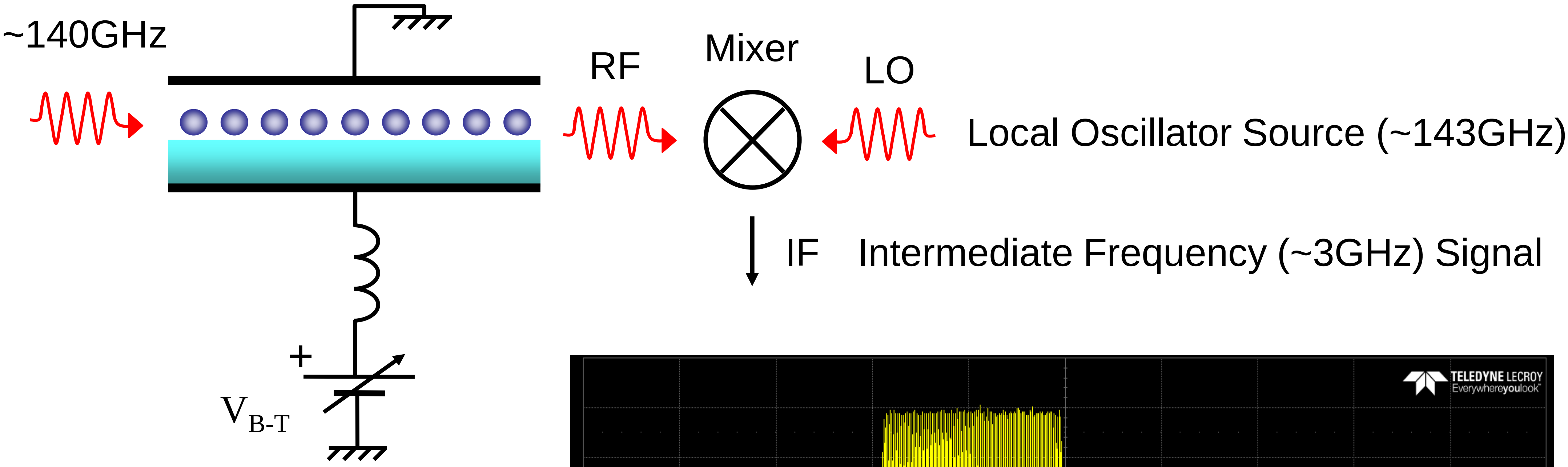
DK et al. PRL 2007

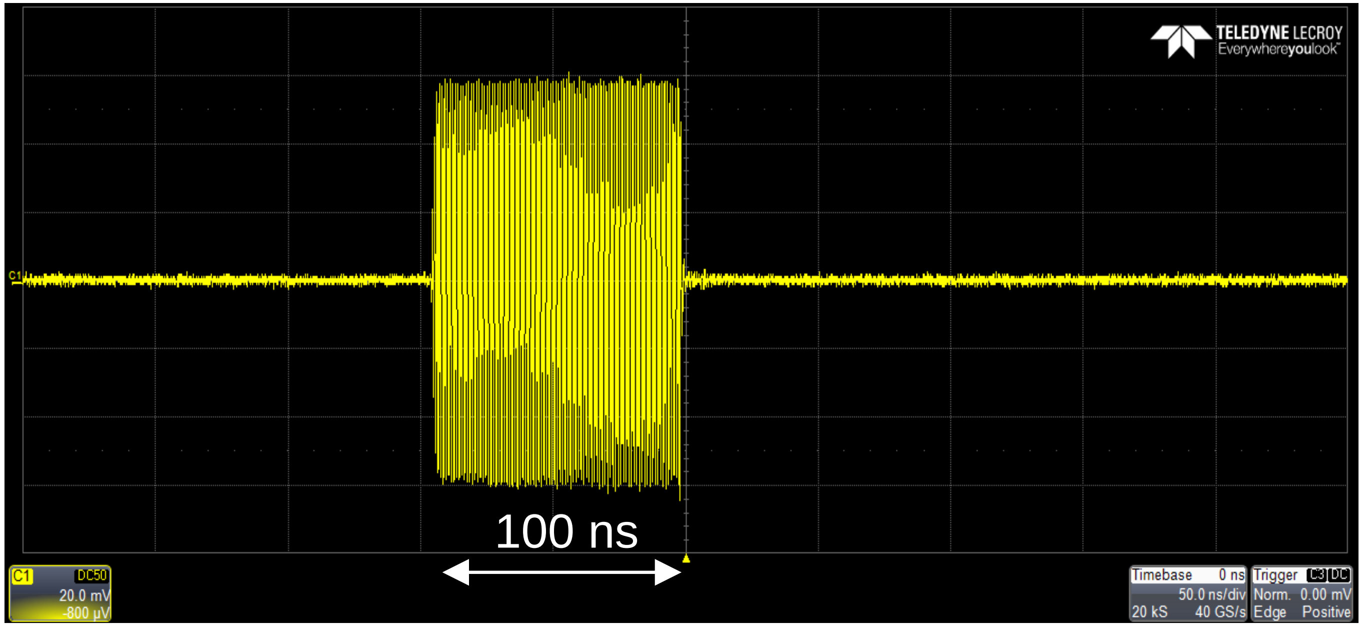
3. Image-charge detection

Kawakami et al. PRL 2019

Asem's talk

Heterodyne detection of absorption

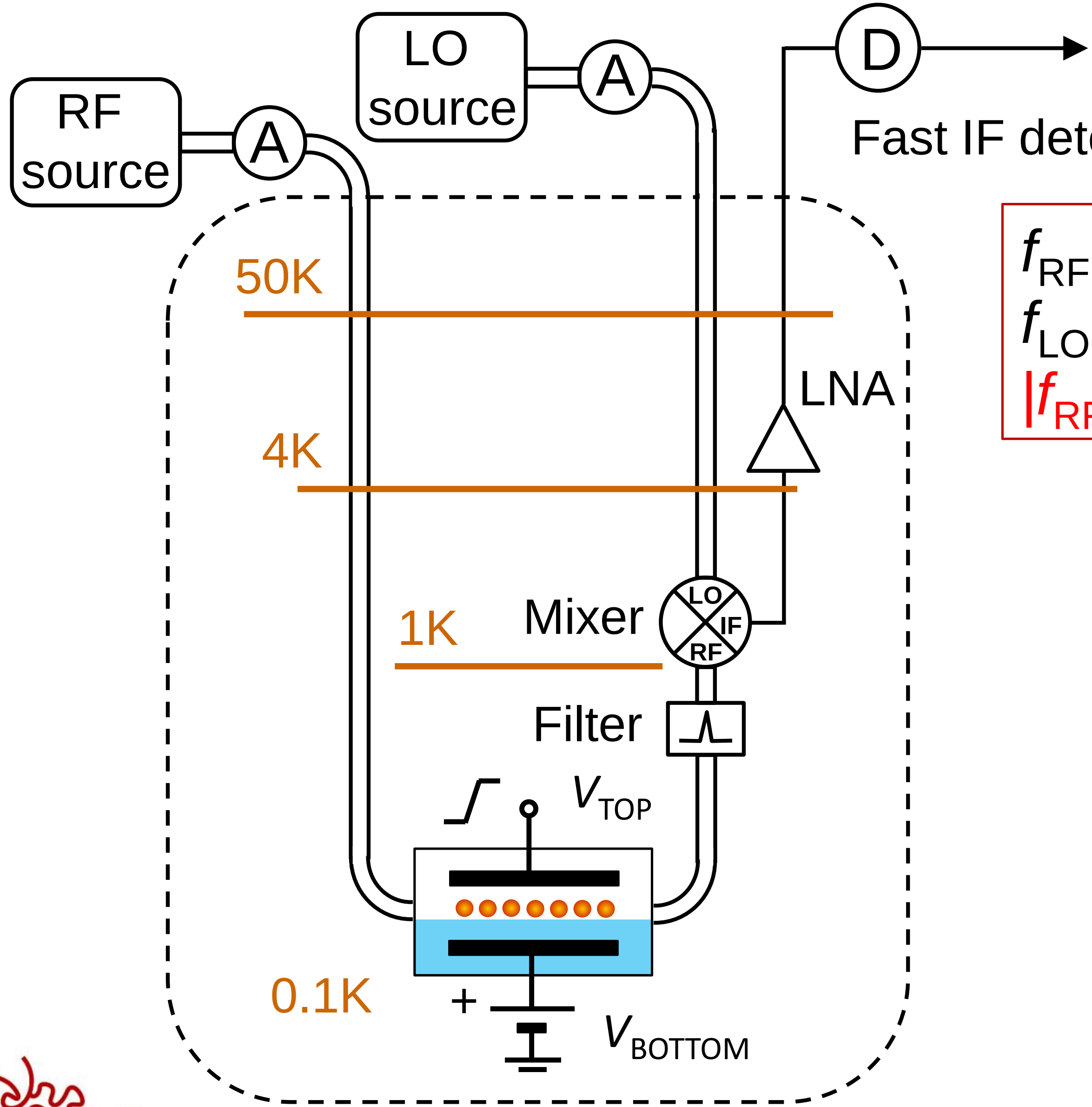




Homemade Cryogenic Mixer

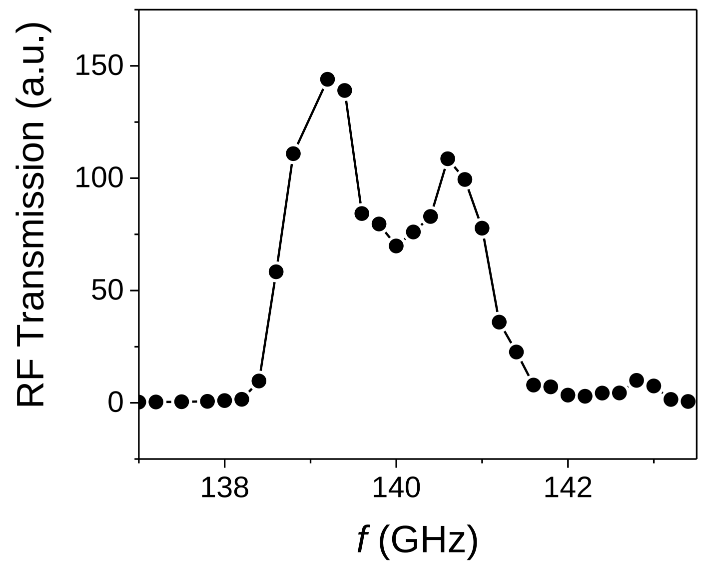
Slava Dvornichenko

Low-temperature experimental setup

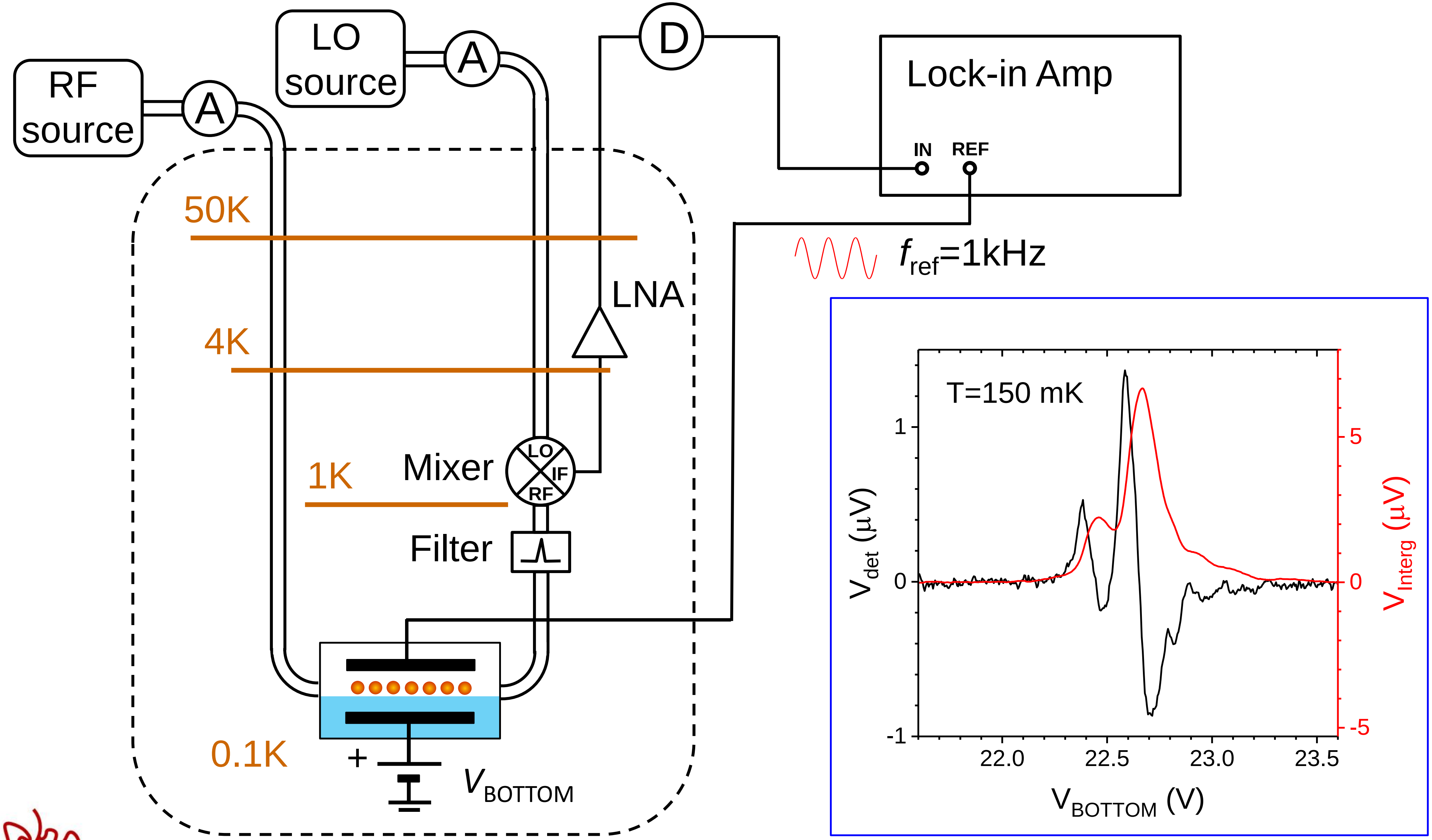


f_{RF}=140 GHz
f_{LO}=143 GHz
$|f_{RF}$-$f_{LO}|$=3 GHz

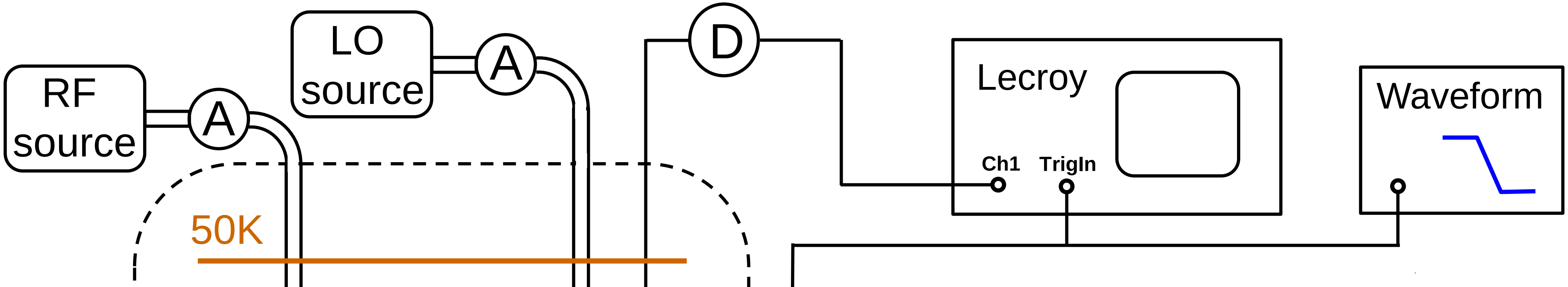
Band-pass RF Filter

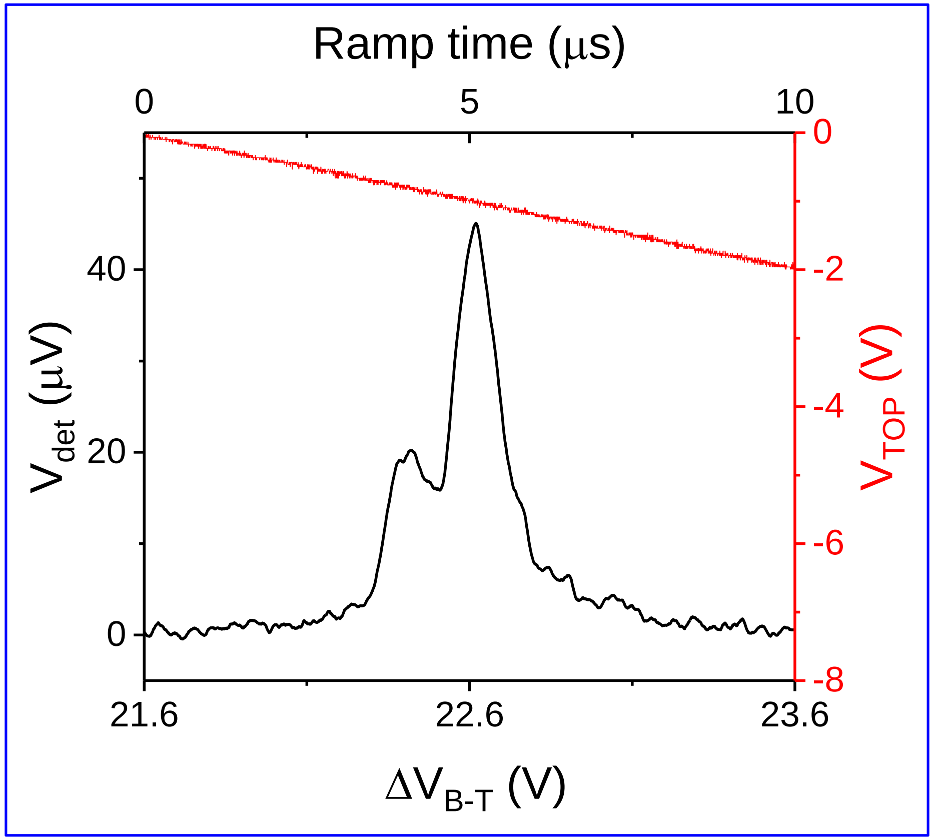


Absorption signal by slow modulation



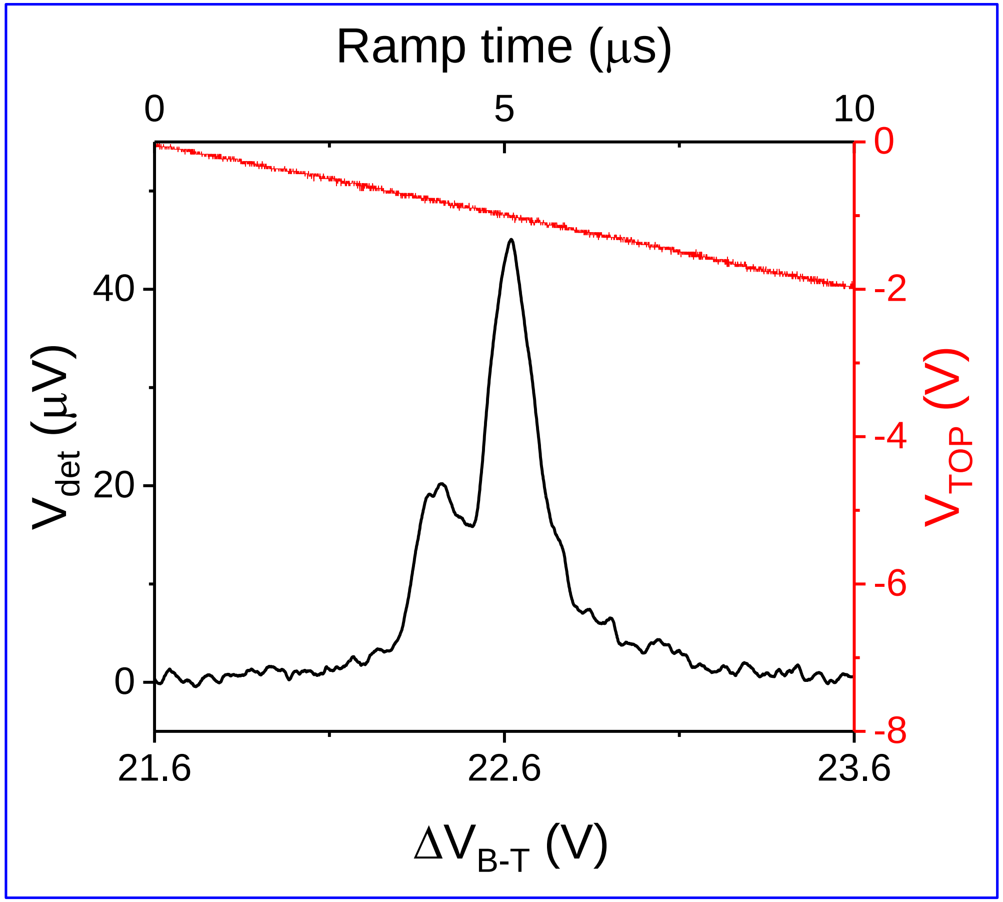
Absorption signal by fast sweep

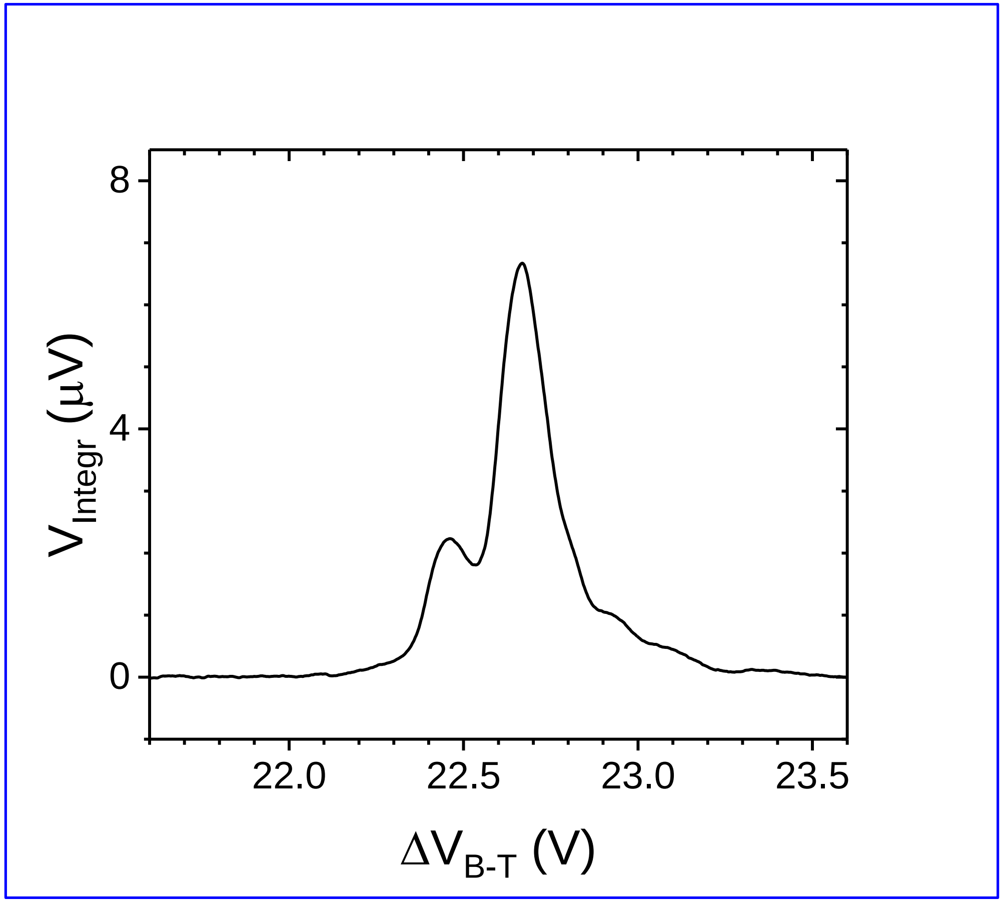




Demonstration of method

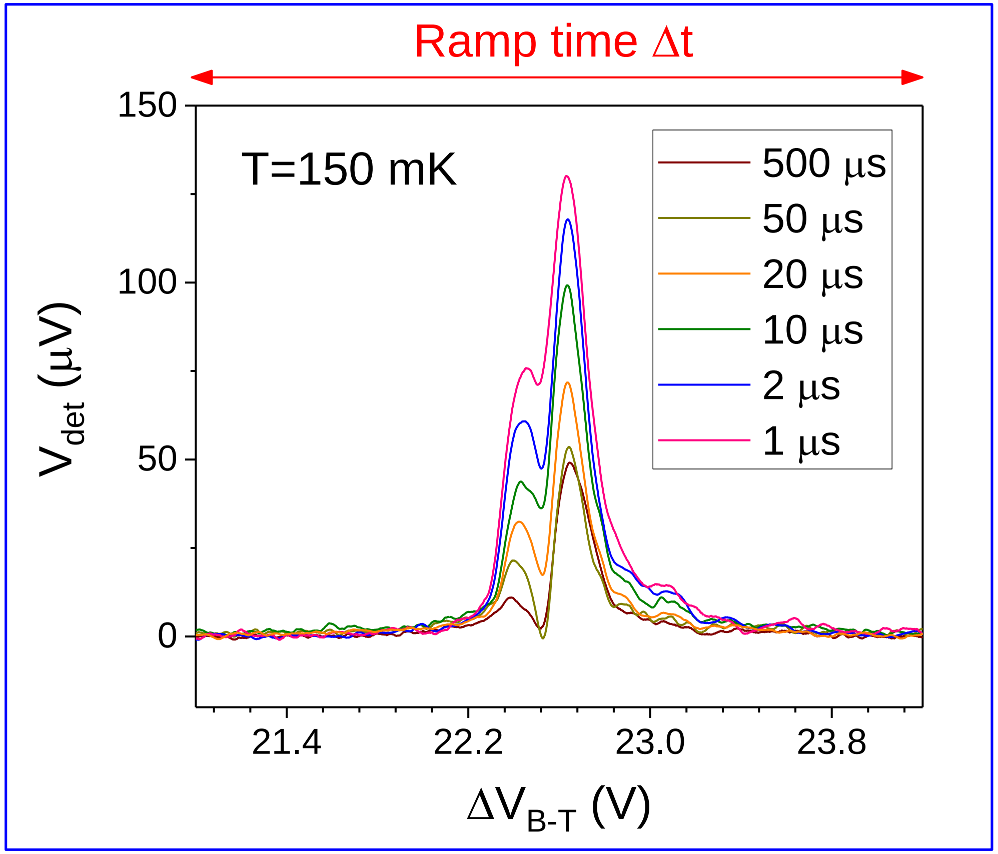
Now we can do it on a short time scale!

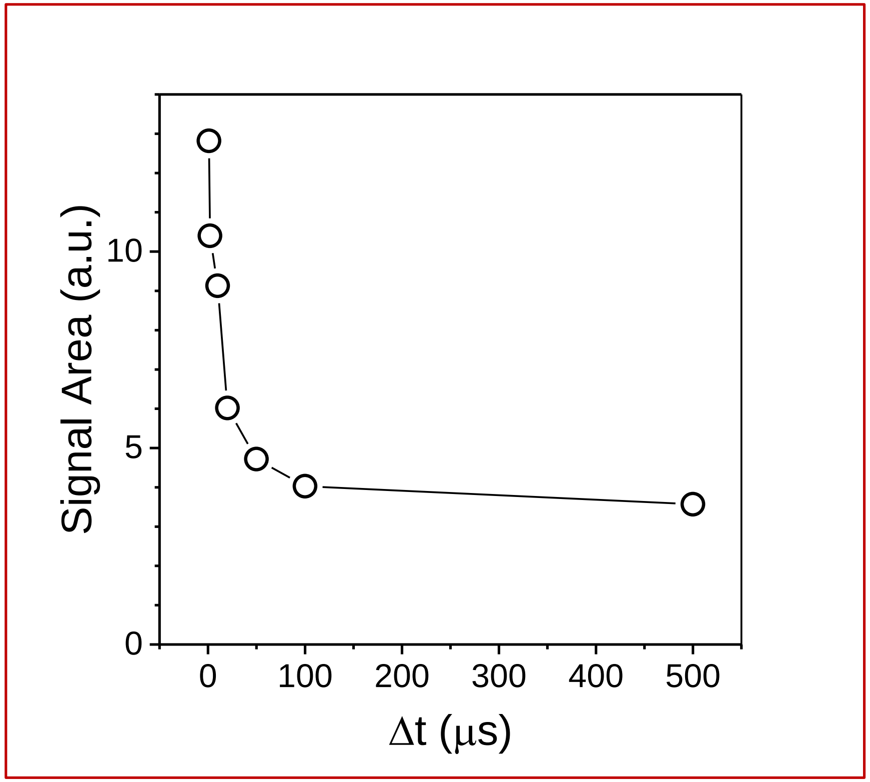




Dependence on Ramp rate

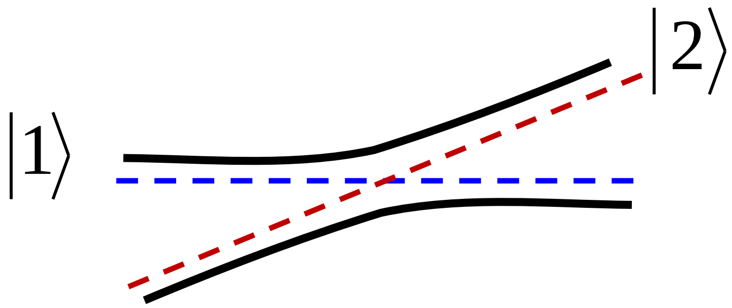
Strong dependence of absorption on ramp rate!



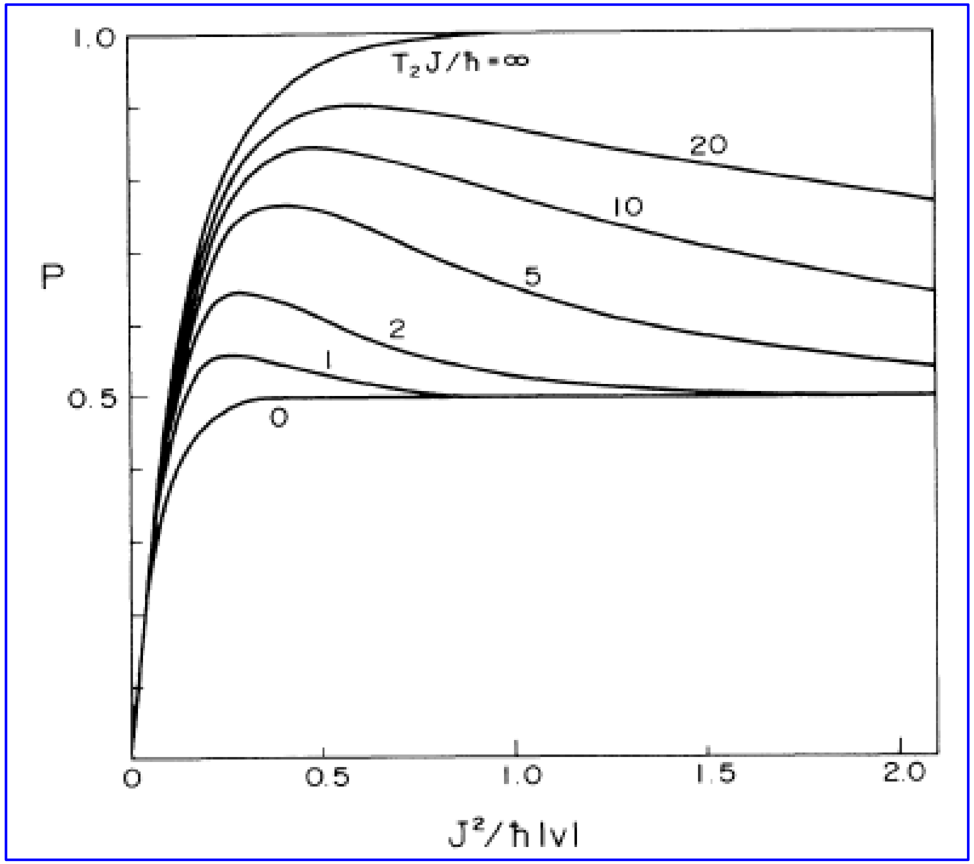


Rapid Adiabatic Passage

MW resonance: $\hbar\omega = E_2 - E_1$



Stark shift due to E_z

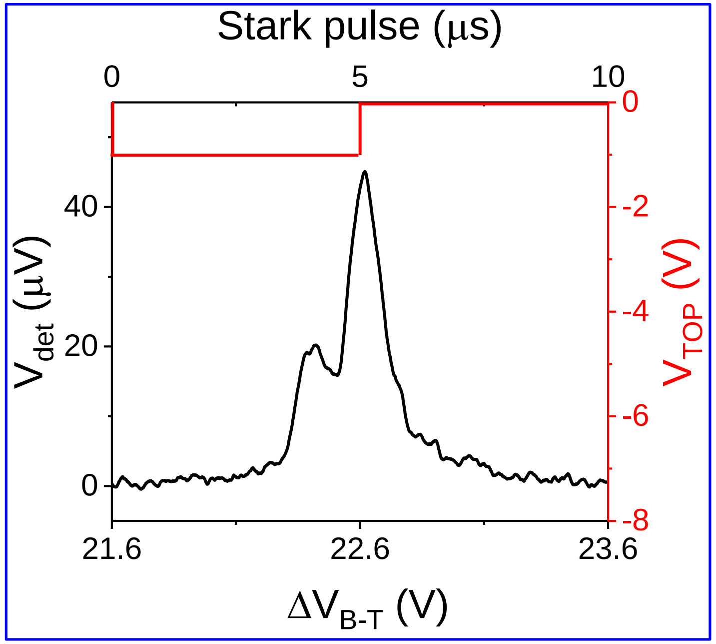


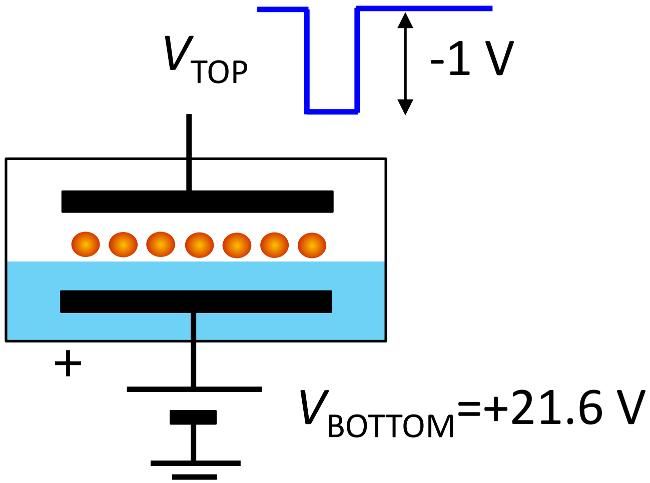
Kayanuma, PRL1987

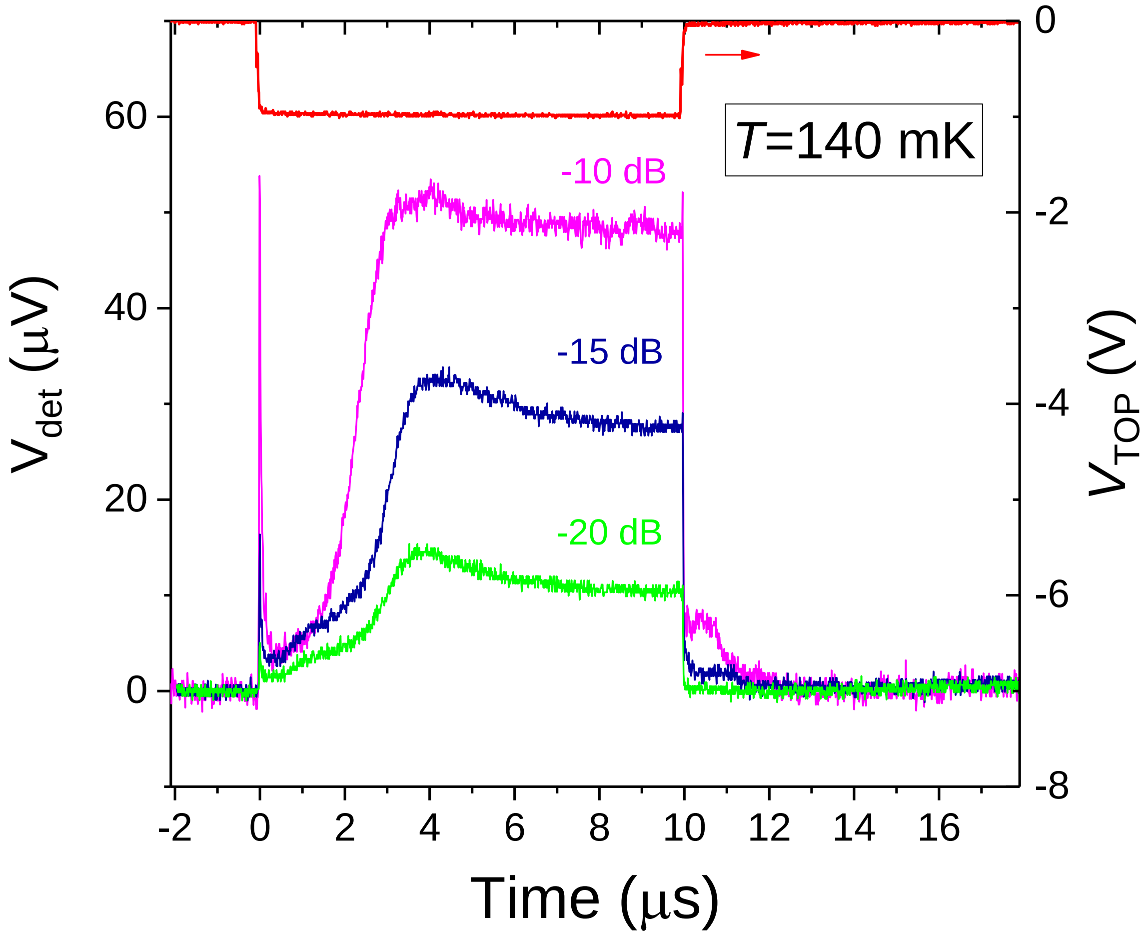
Landau-Zener formular

$$P_2(t=\infty) = 1 - \exp\left(-\frac{\pi\Omega^2}{2\dot{\omega}_{21}}\right)$$

Stark pulse

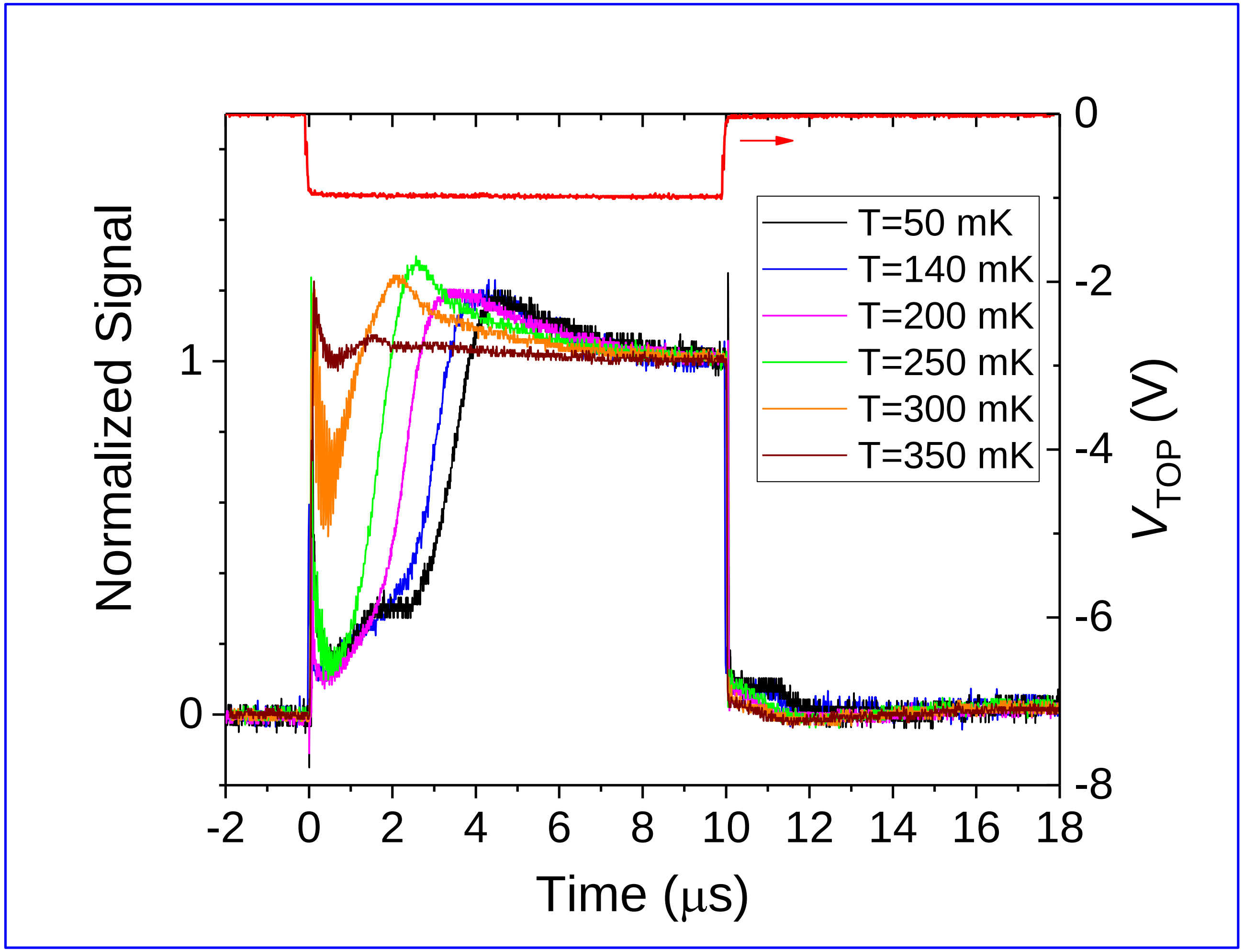




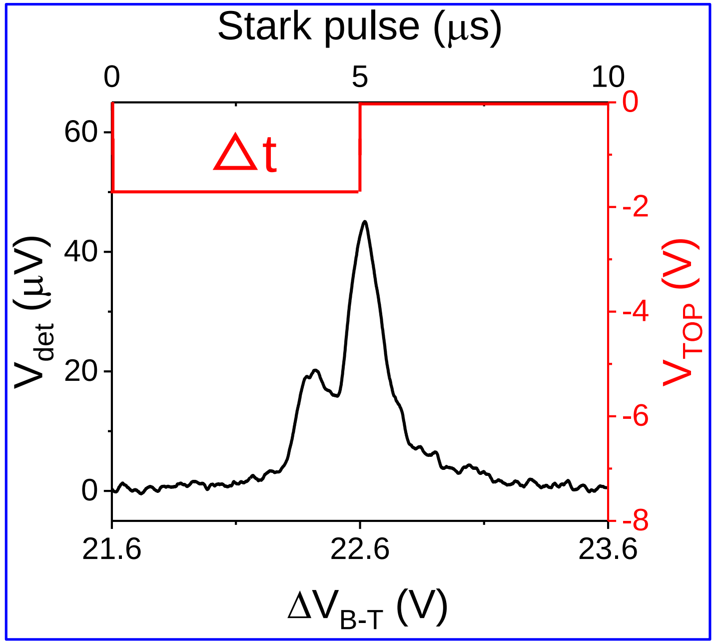


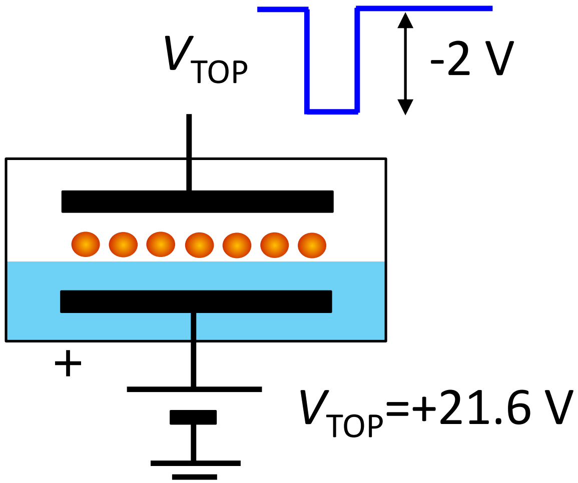
Brewer et al. 1971, Loy 1974

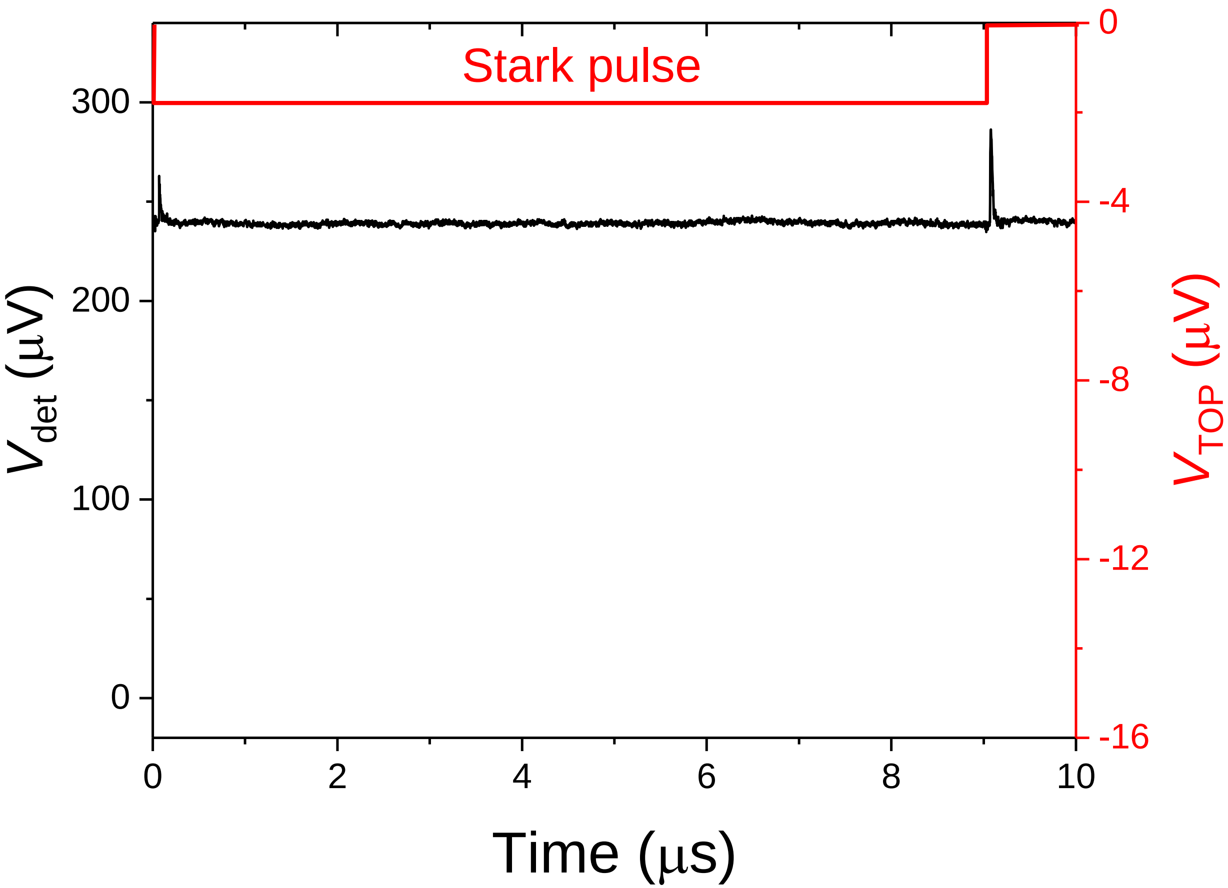
Temperature dependence



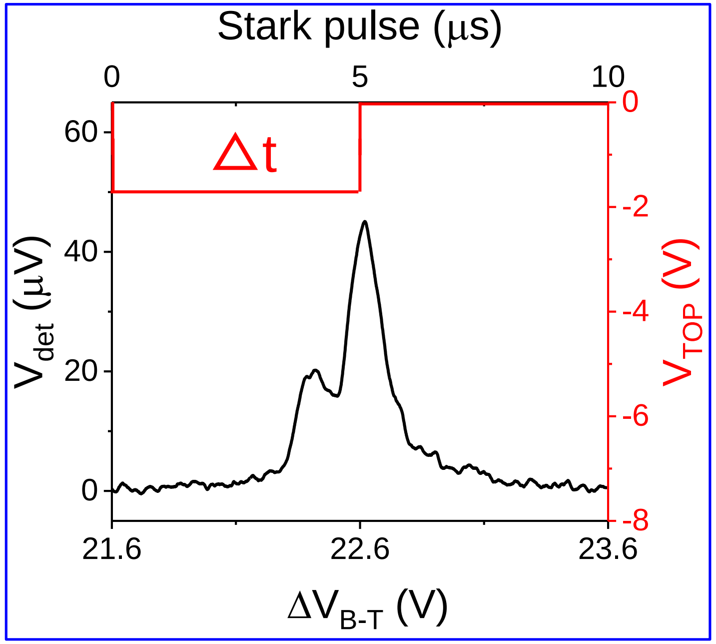
Stark pulse through resonace

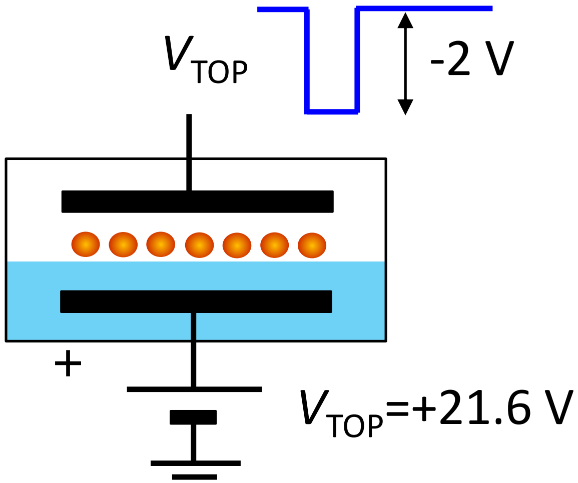


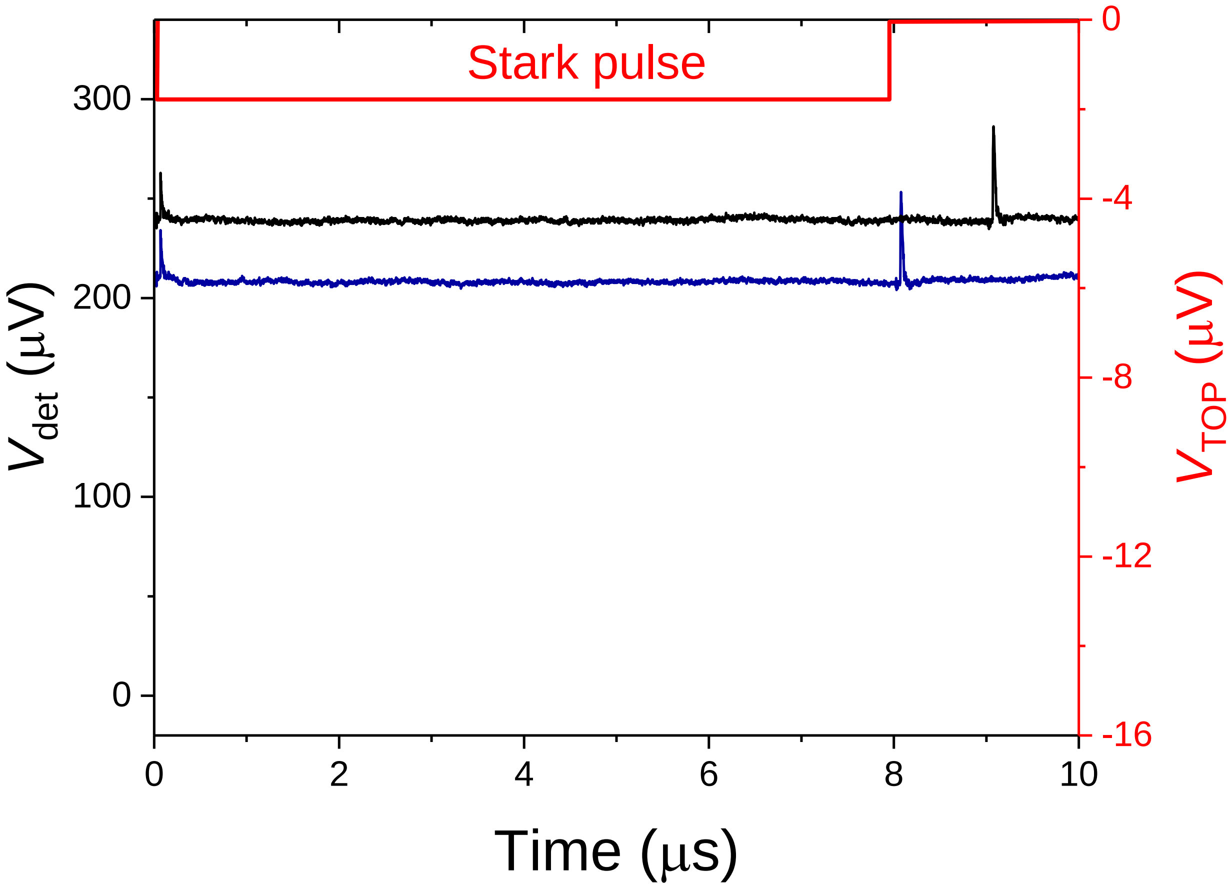




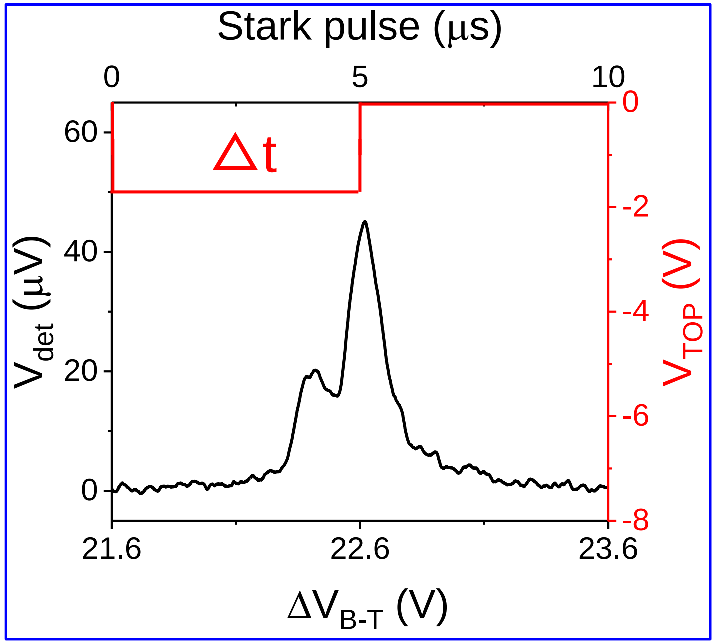
Stark pulse through resonace

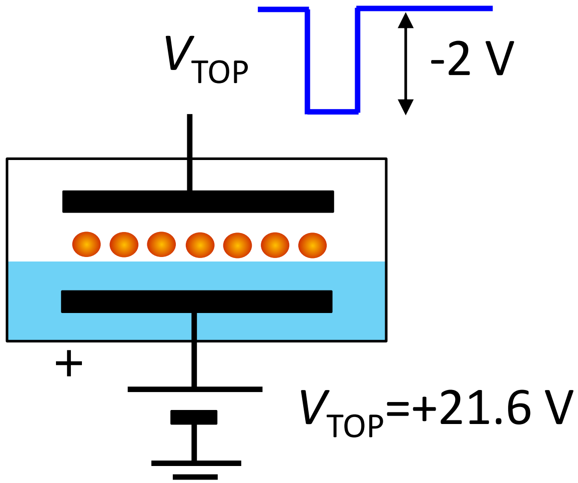


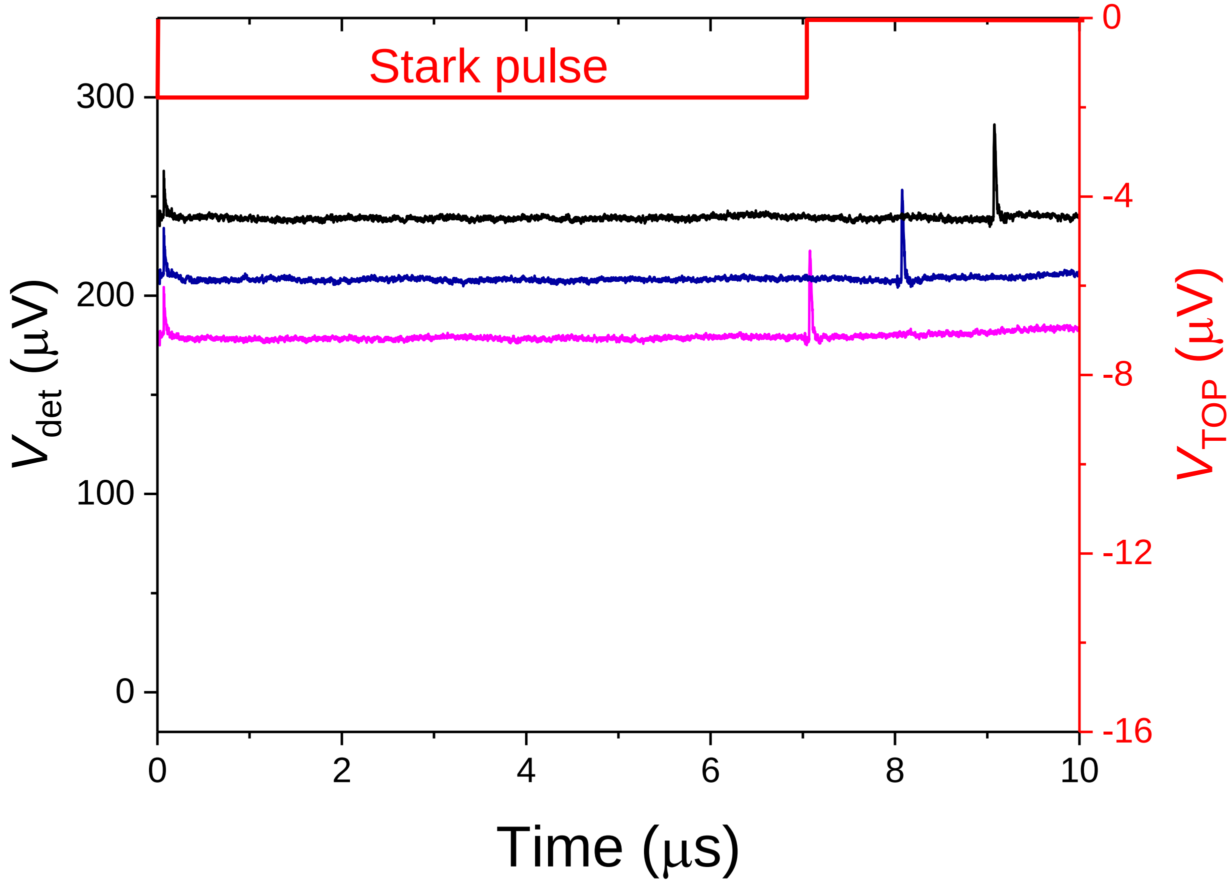




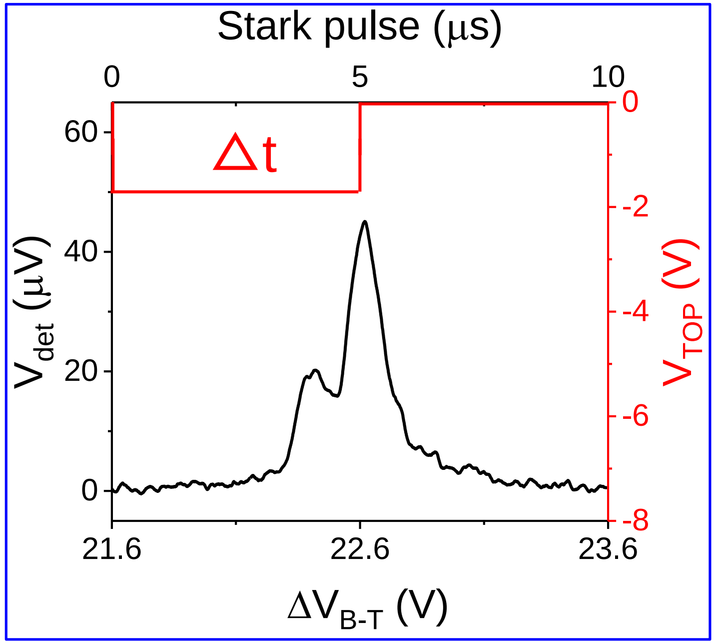
Stark pulse through resonace

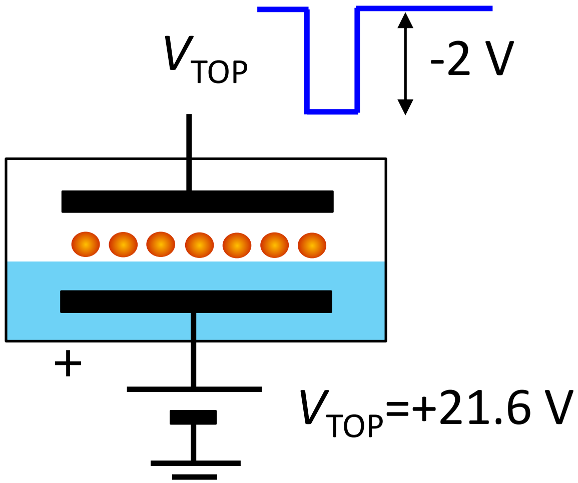


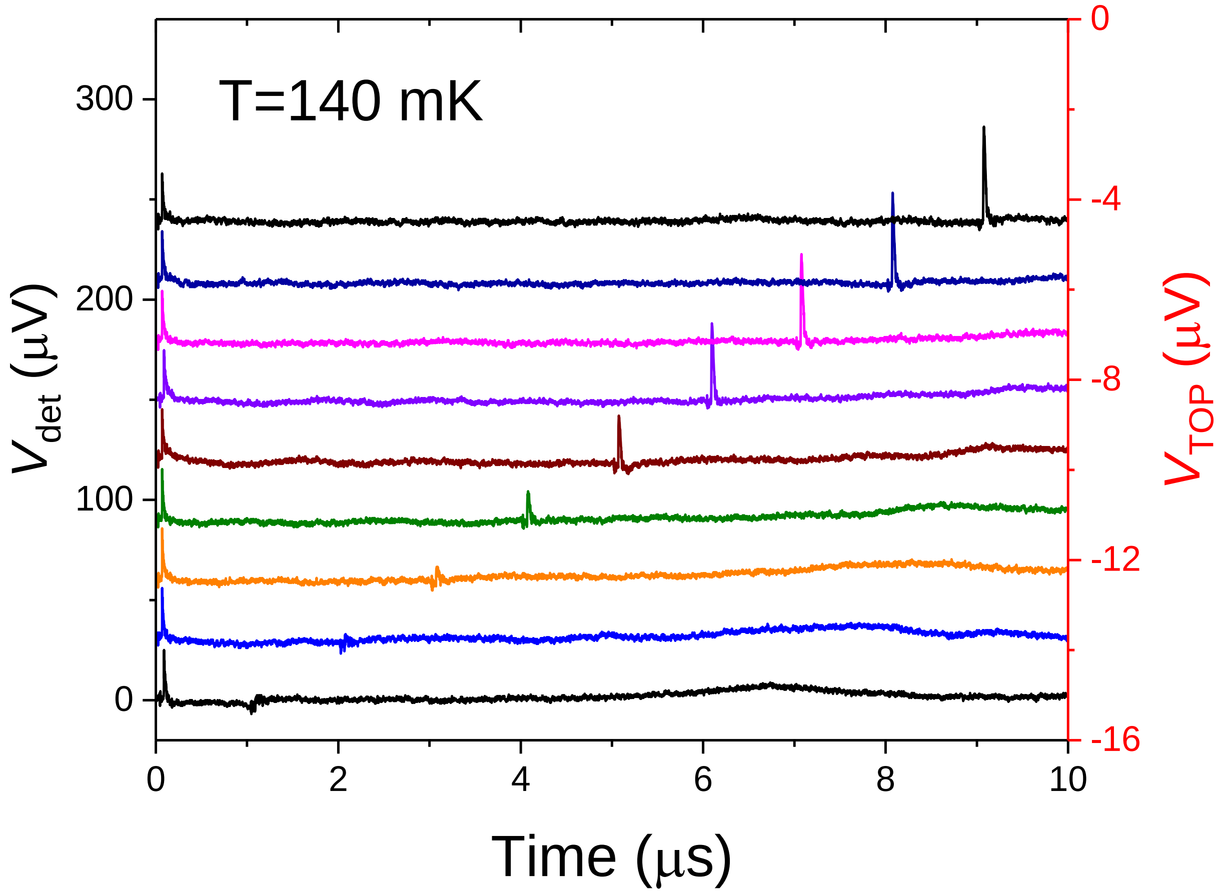




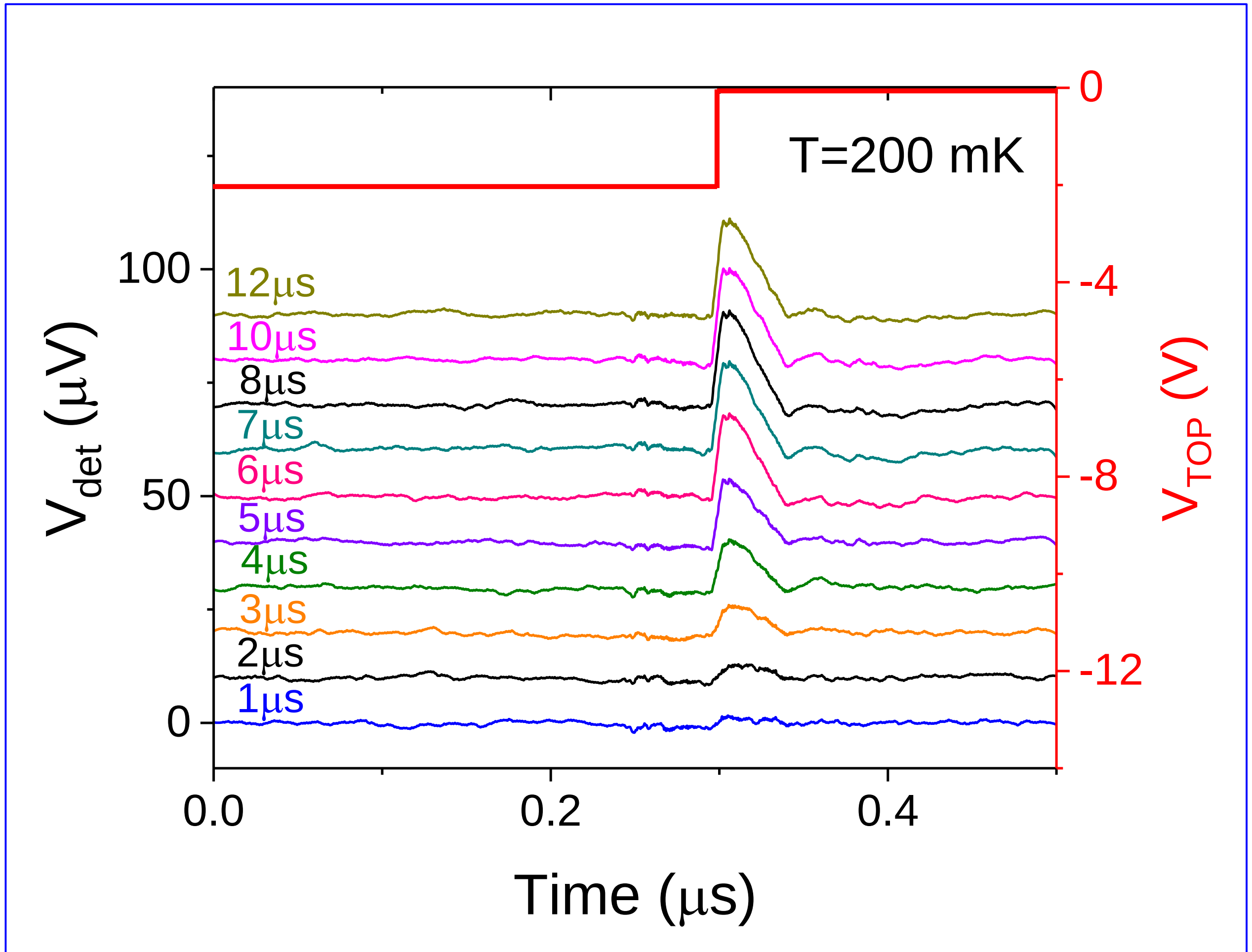
Stark pulse through resonace

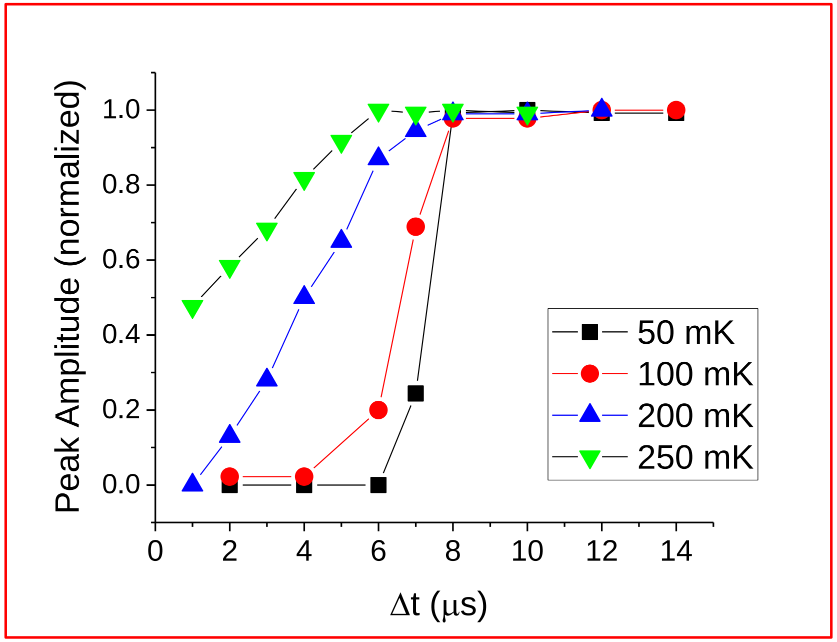






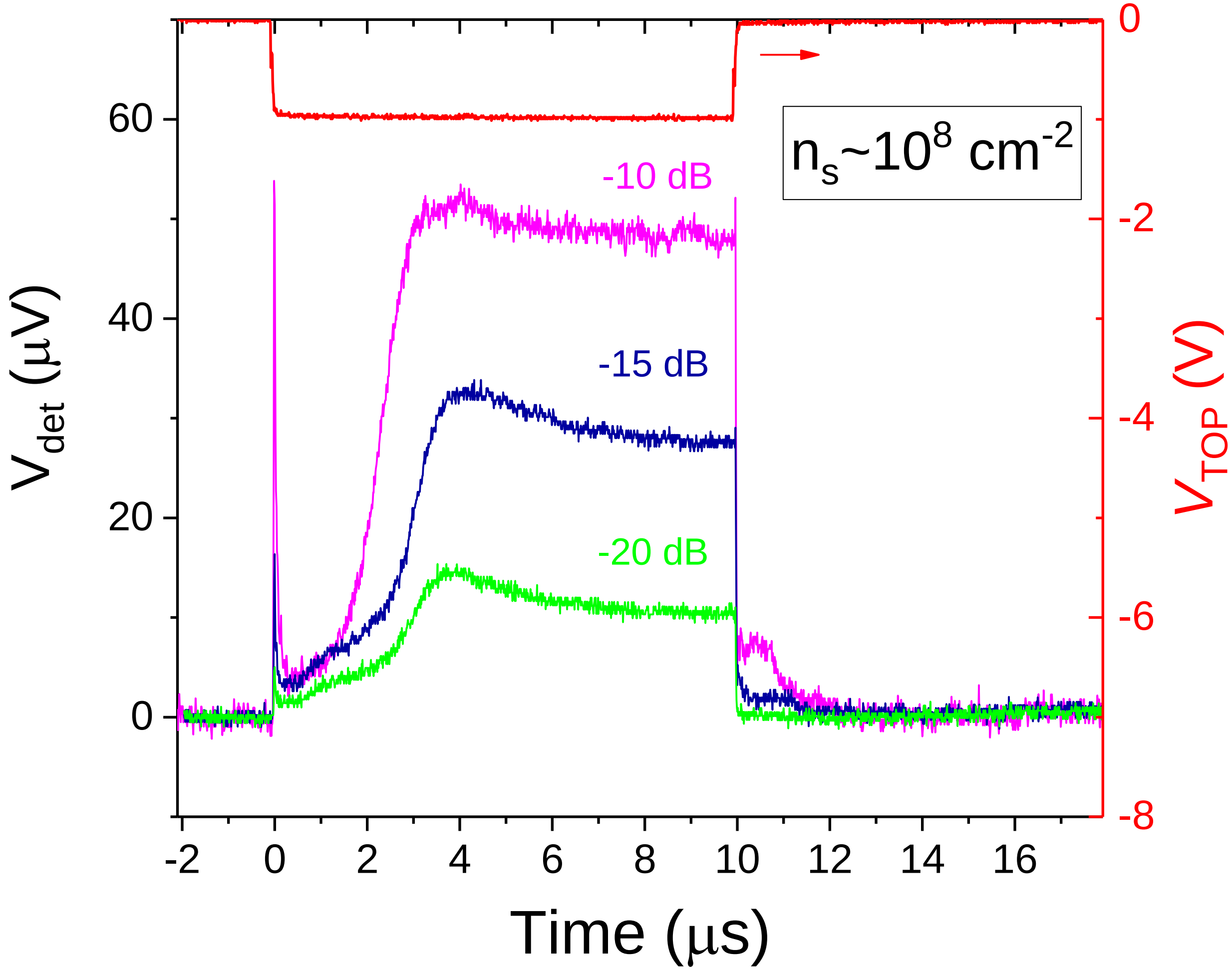
Temperature dependence



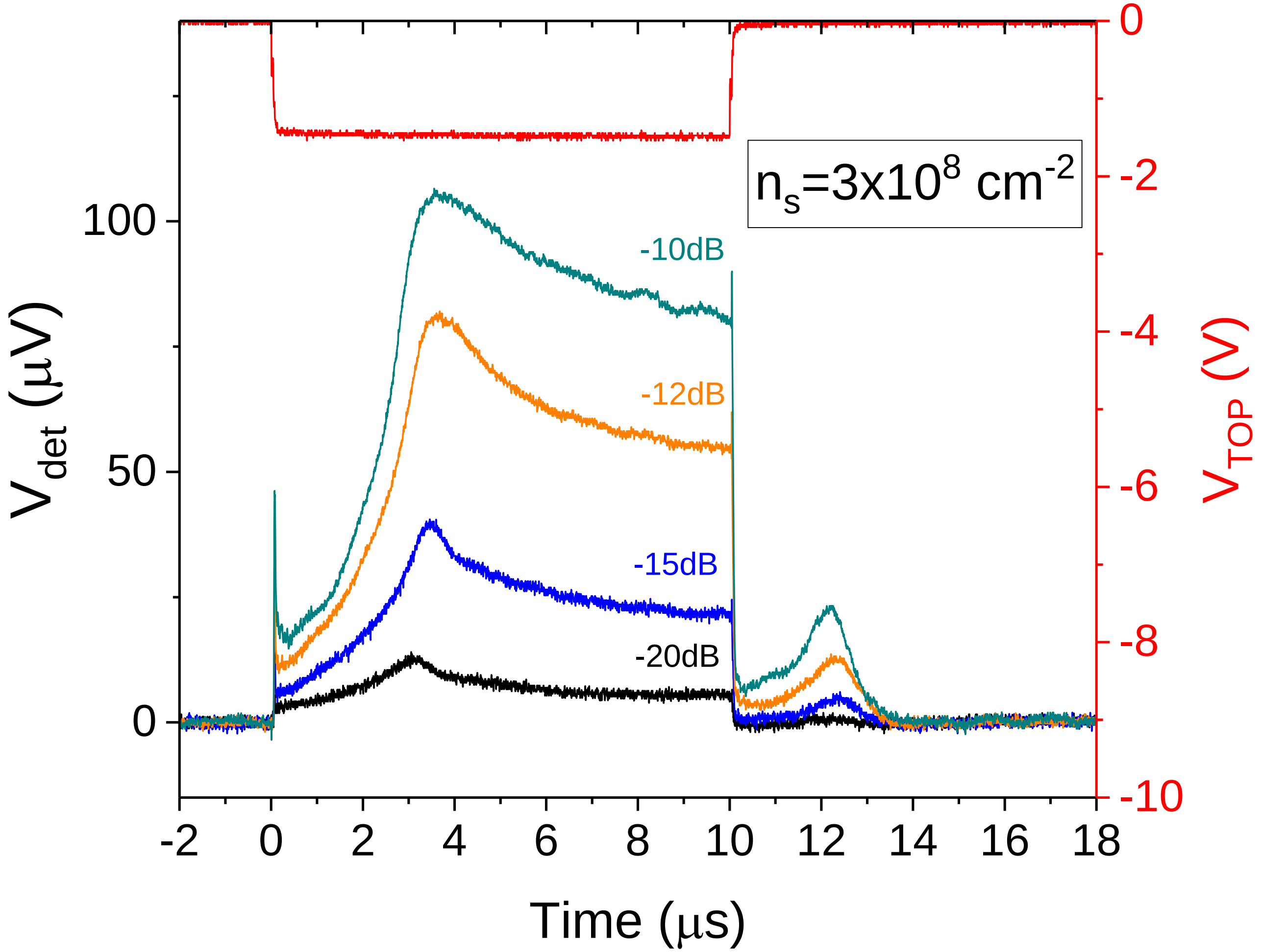


Relaxation time ~1 μs and decreases with increasing T!

“Free Induction Decay” signal

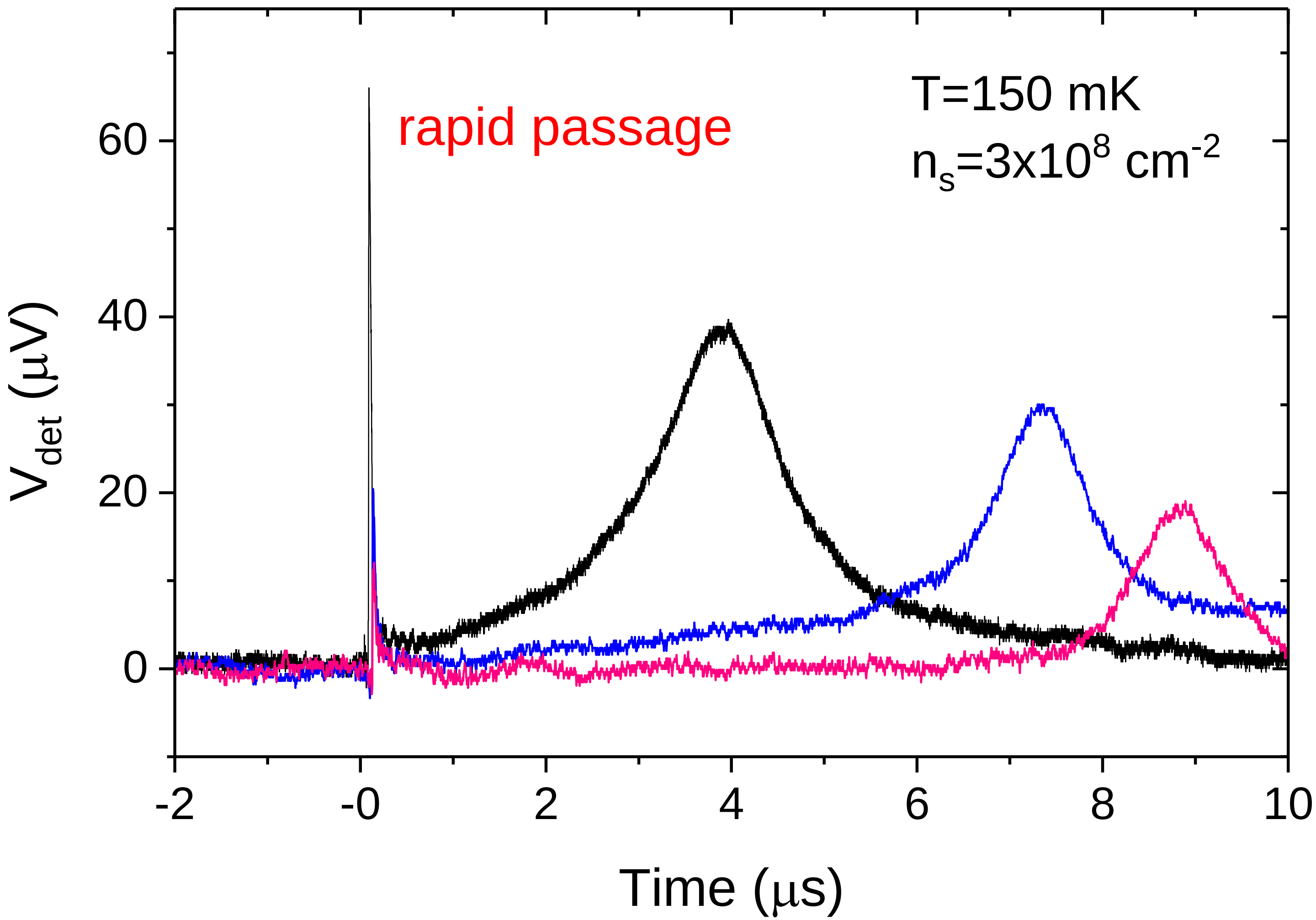


“Free Induction Decay” signal

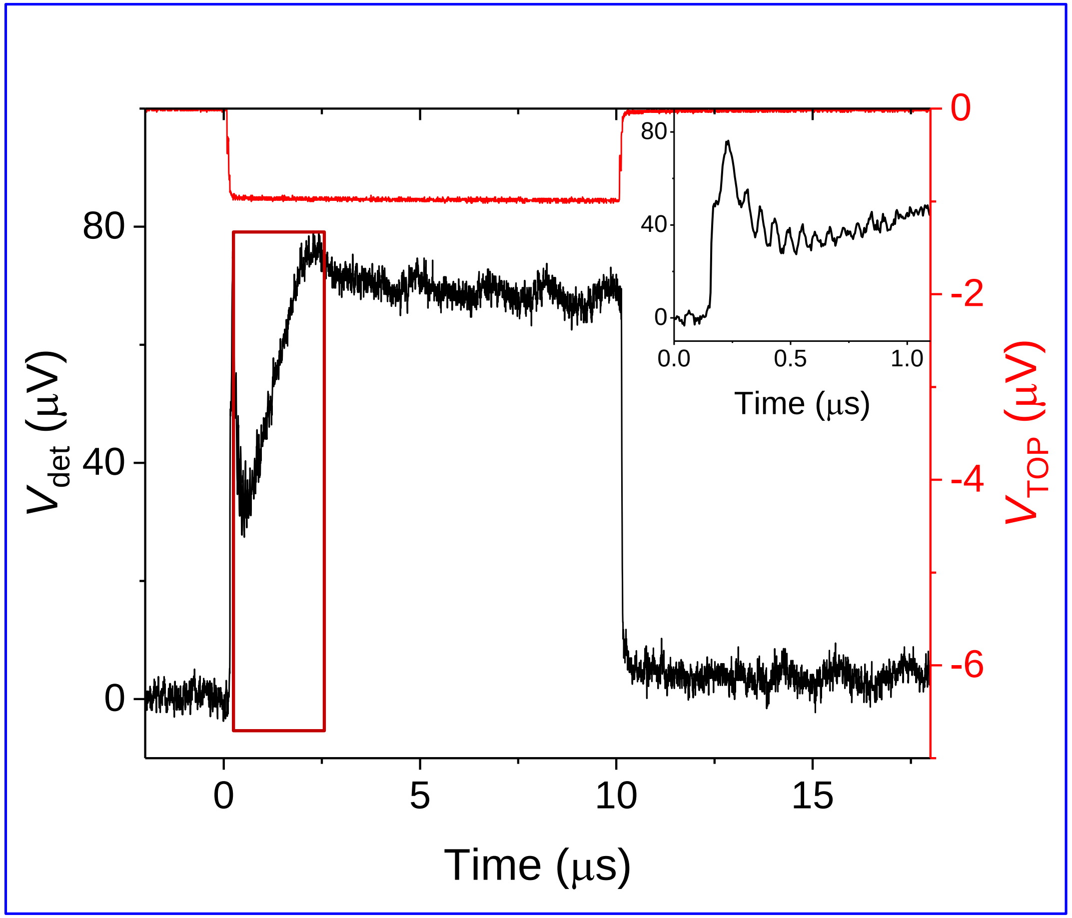


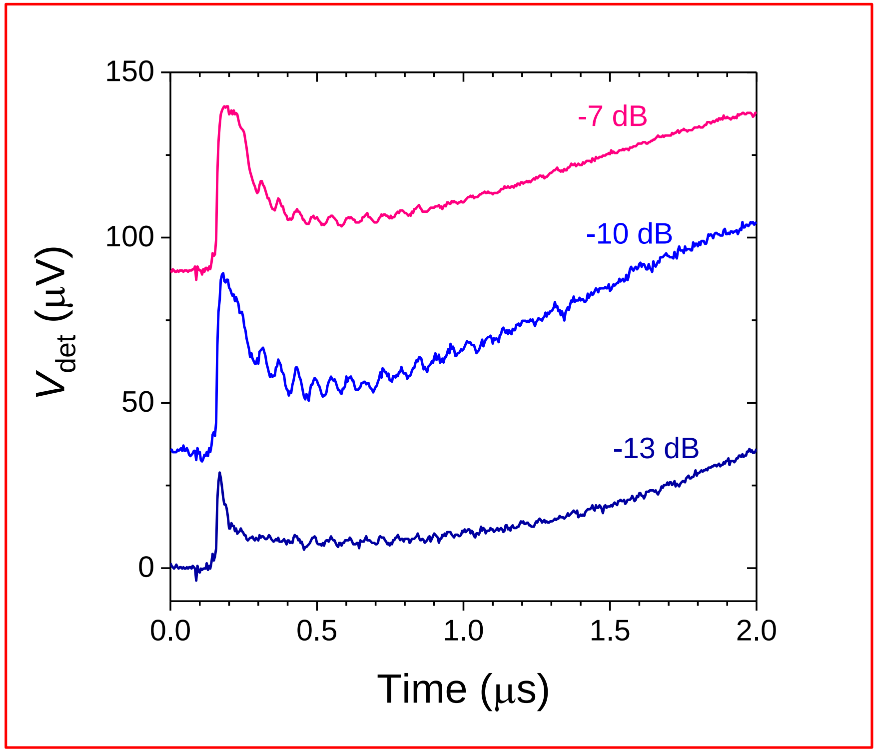
“Echo” signal

Time of “echo” appearance depends on the <u>rate of rapid passage</u>!



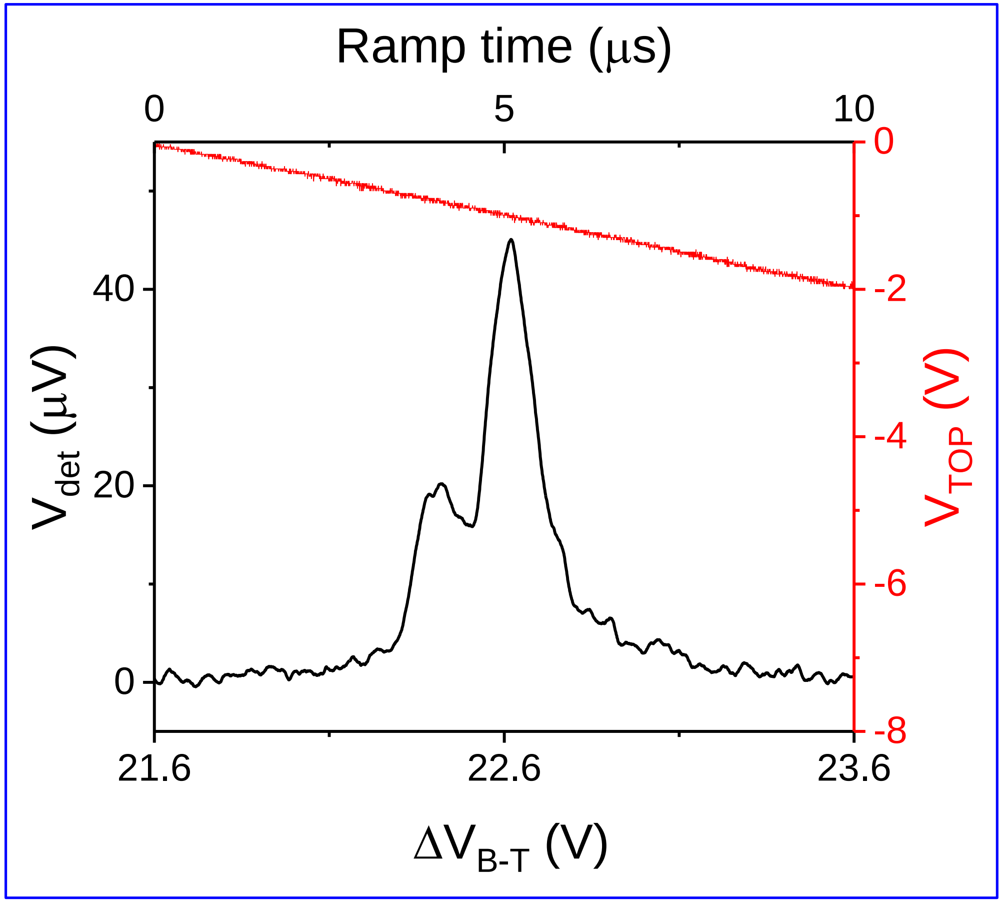
Oscillations





Period of oscillations does NOT depend on MW power, temperature, density of electrons! What is it?

Summary



We developed a new method to study MW excitation of the Rydberg states of EonHe on short time-scale

Might allow to study relaxation processes in excited EonHe system

Fast Adiabatic Passage (Landau-Zenner gate) might be valuable for qubit operation

Can we apply ideas from AMO?!