Comparative study of the electric field dependent variations of carrier recombination and drift parameters in MCZ Si detectors irradiated by different fluences of neutrons

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- Motivation of investigations - to clarify a role of applied electric filed on carrier trapping lifetime

- The main photoconductivity decay time constant in neutron and proton irradiated samples decrease nearly lineary on fluence in the all range of fluence (10^{12} – 10^{16} cm^{-2}), that allows to propose the clusters are responsible for its value, and we look for the peculiarities of photoconductivity that confirms the role of defect clusters.

Methods:

- This situation forced us to introduce more powerful control of photoconductivity signal dependence on excitation and bias of sample.

- Now it was implemented (We like to perform comparison of "our traditional" and "typical for RD50" methods) :

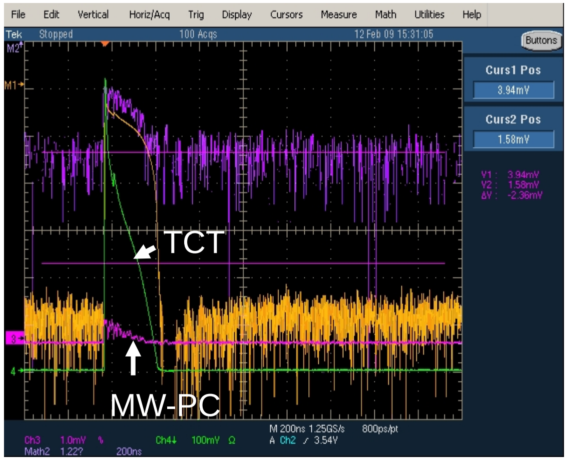
  – measurement of photoconductivity decay (PC) by microwaves using the surface and bulk excitation;

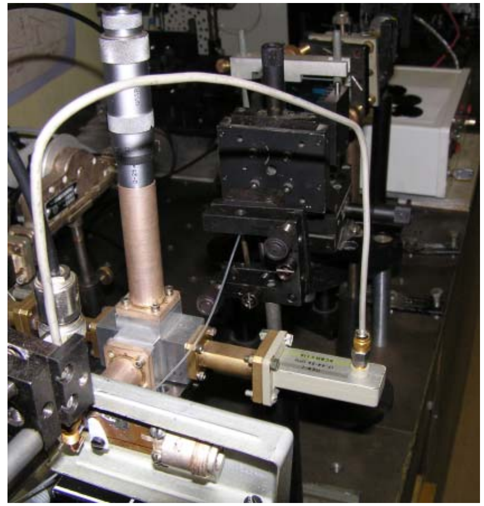
  – measurement of carrier drift by:
    - The time-of-flight (TOF) method (constant bias on the sample)
    - The TCT method (using the additional resistor (that changes the bias voltage on the sample) and taking the signal from the sample)

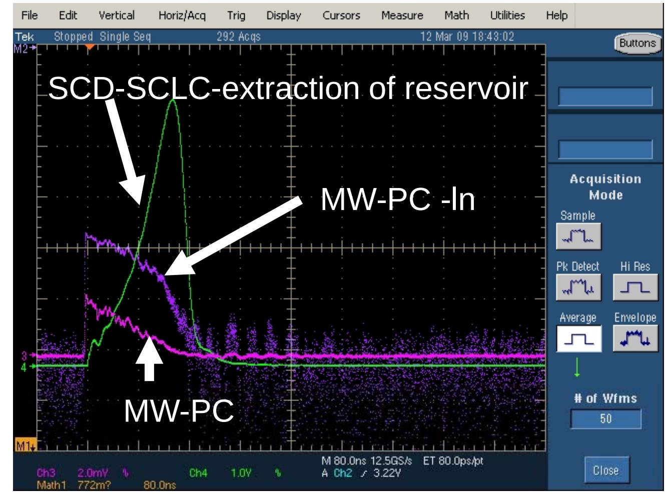
For comparison of current transient registration regimes the bulk & surface injection of carriers was used

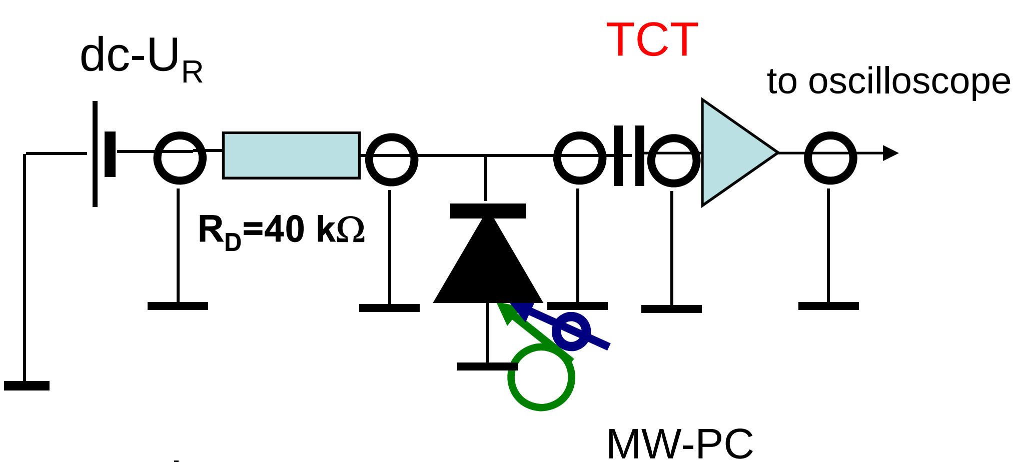
Techniques & samples

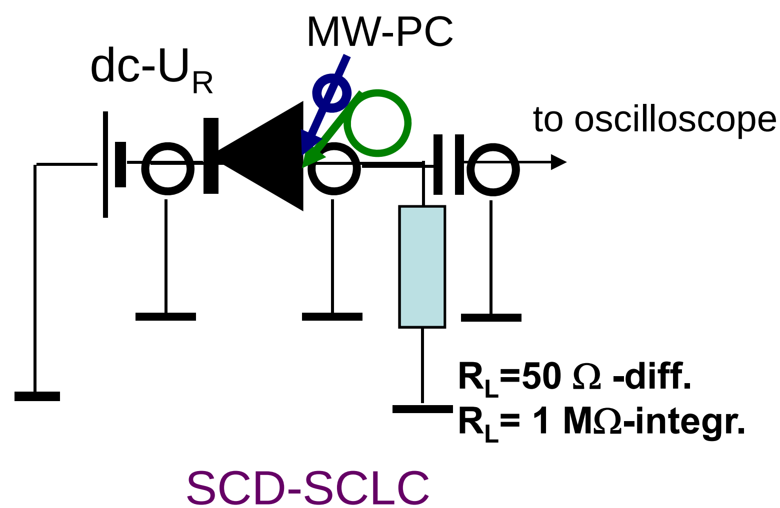
Experimental setup of simultaneous and combined measurements of carrier recombination and drift transients by MW-PC and SCD/TCT/SCLC









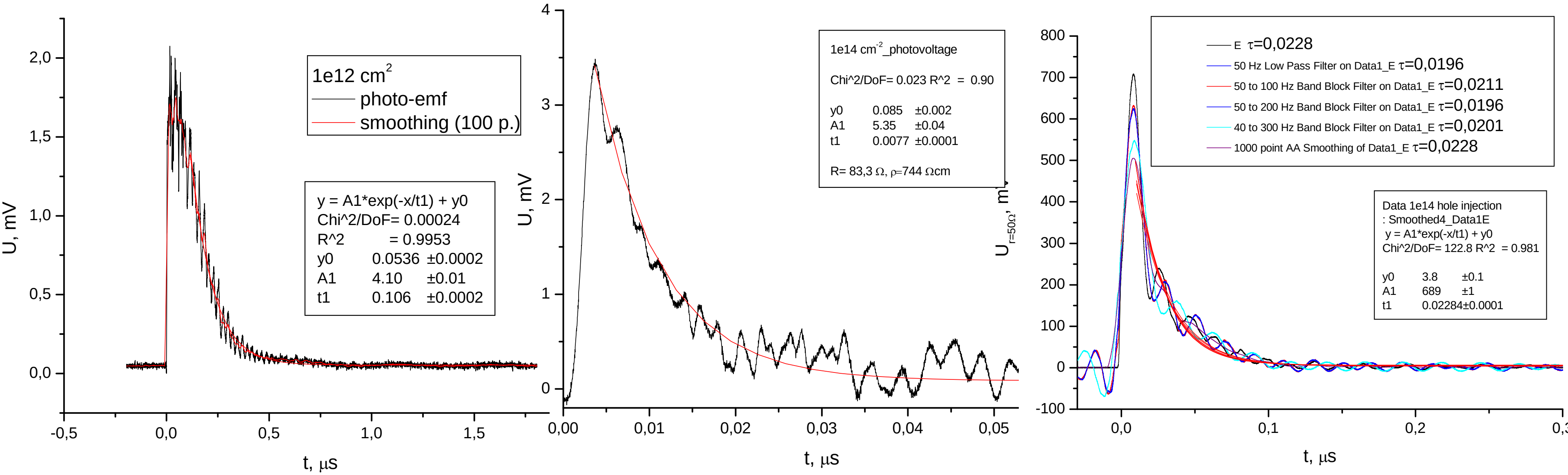


We analyze:

the p*-n-n* WODEAN series samples, neutron irradiated, fluence range 10^{12}-10^{16} cm^{-2}

A test of structure: Photo-emf response

Photovoltage time constant is equal to the structure bulk RC if recombination is neglected (280 mm   5 x 5 mm2 C=9,25 pF, in 10^{12} cm^{-2} = 102,4 kΩcm ??)



The photovoltage decay demonstrates that recombination (trapping) is significant

Changing the injection level (surface excitation):

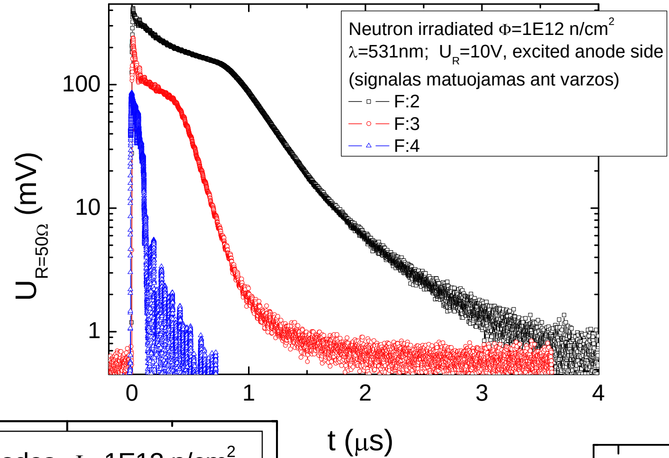
If the injection is low, only a drift of carriers in high voltage region is observed.

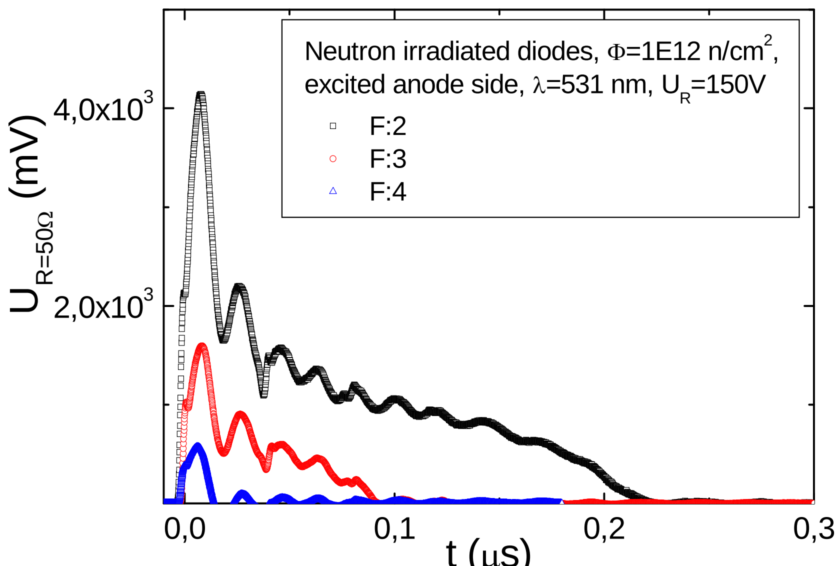
Increasing the level of excitation the space charge injection current transient character is revealed

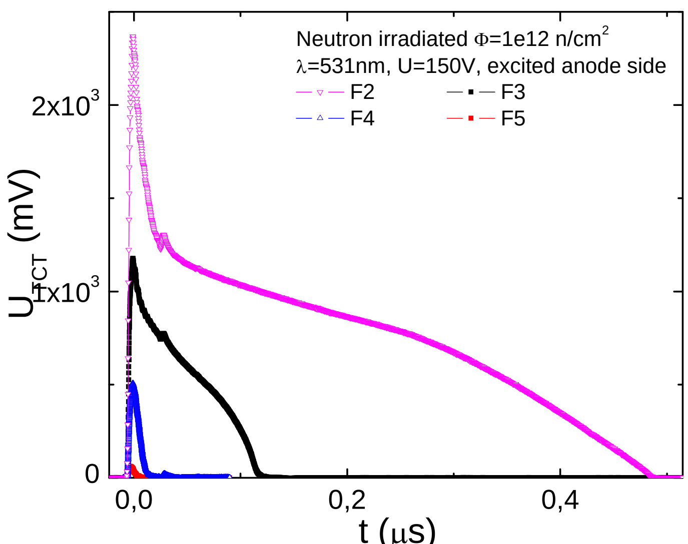
Follow-up increase of injection causes the extraction current observation.

10^{12} neutrons/cm^2 electrons

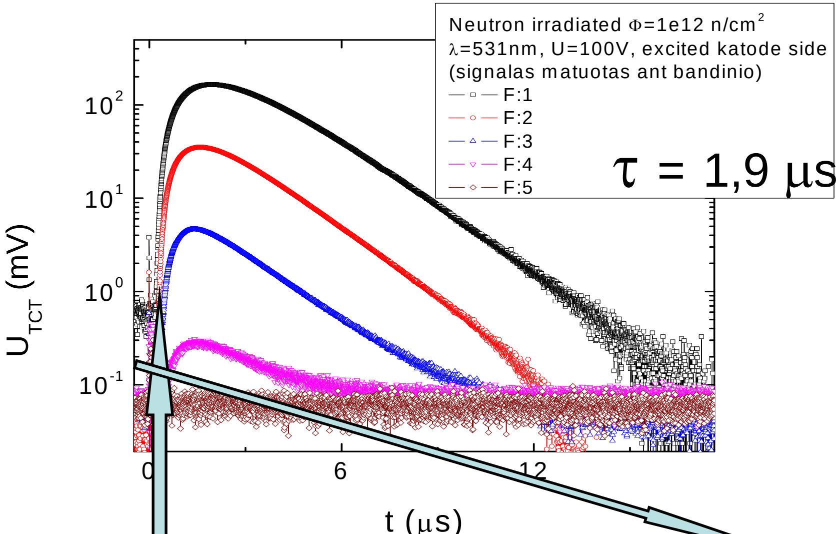
Drift of

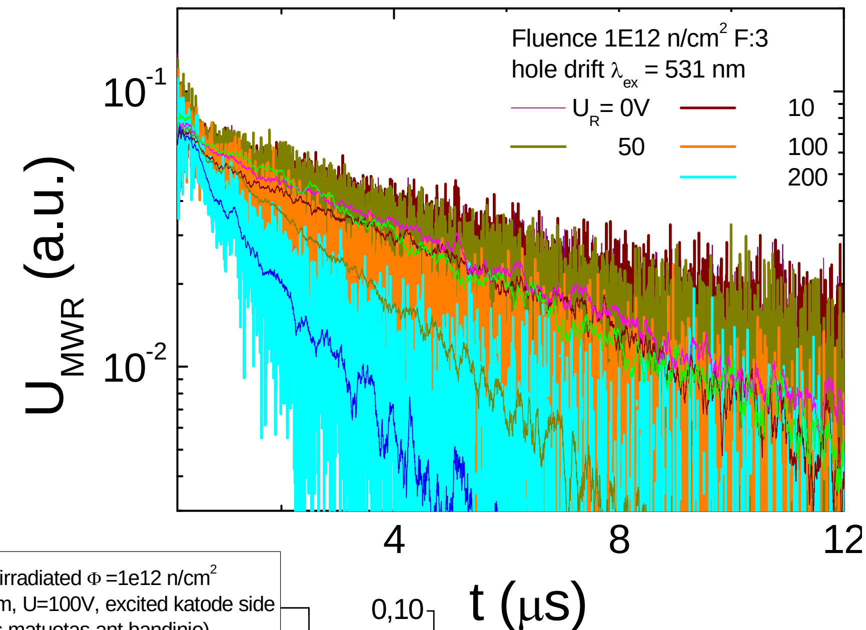


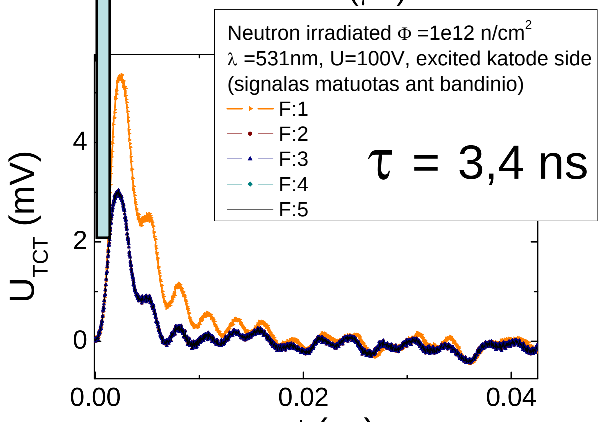


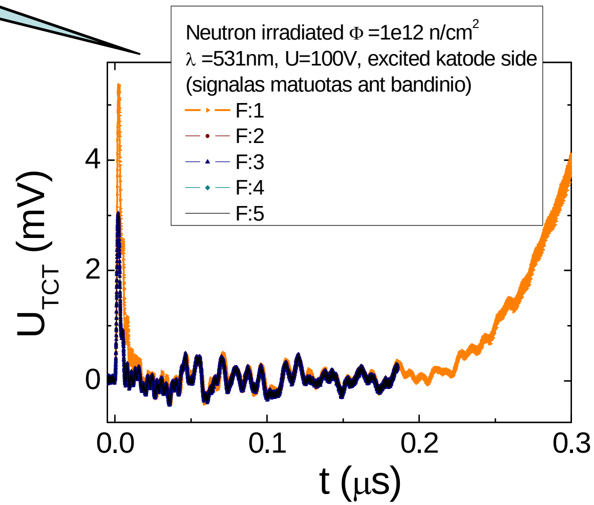


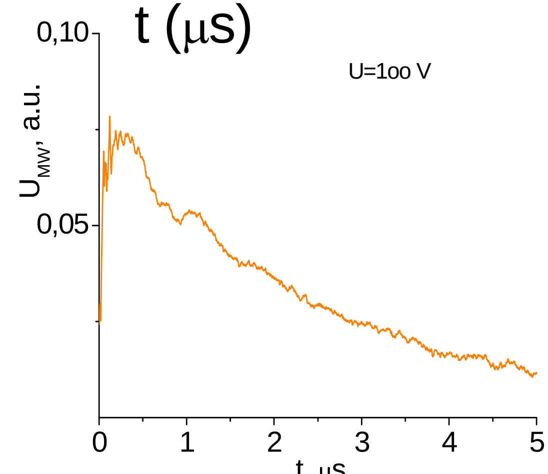
Surface excitation (10^{12} n/cm^2) Drift of holes











Two parts of transient: ???

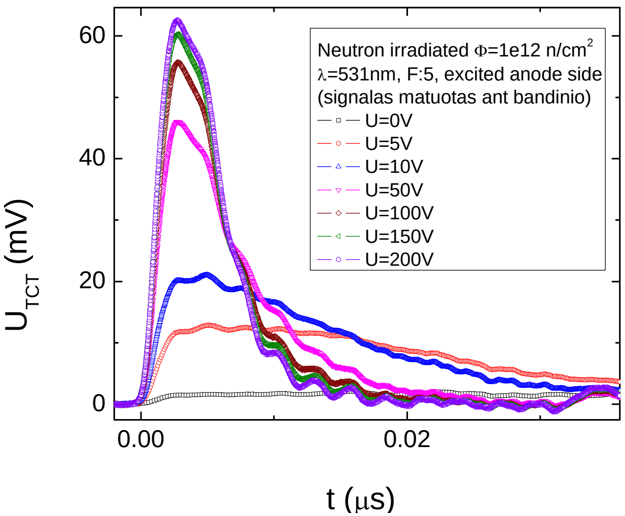
It can be explained by the influence of trapping: the first peak – a displacement current signal, the second appears after filling of fast traps. The similar effect was observed in CdS.

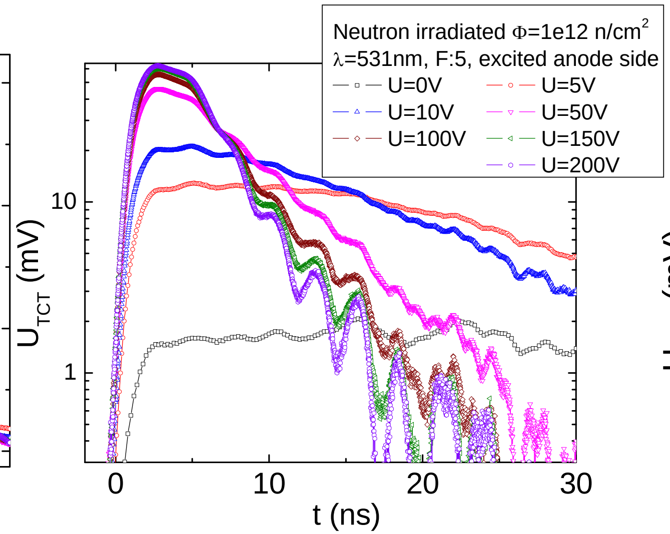
Experimental results: current / electrical – surface excitation 531 nm, drift of electrons and holes dependent on bias

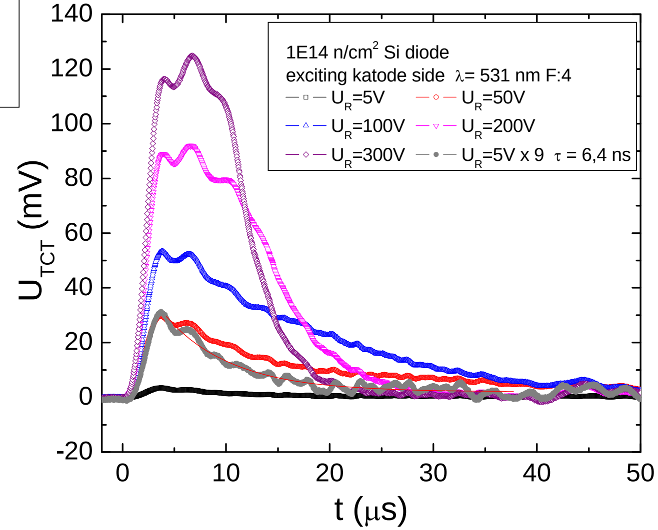
drift of electrons

10^{12} n/cm^2

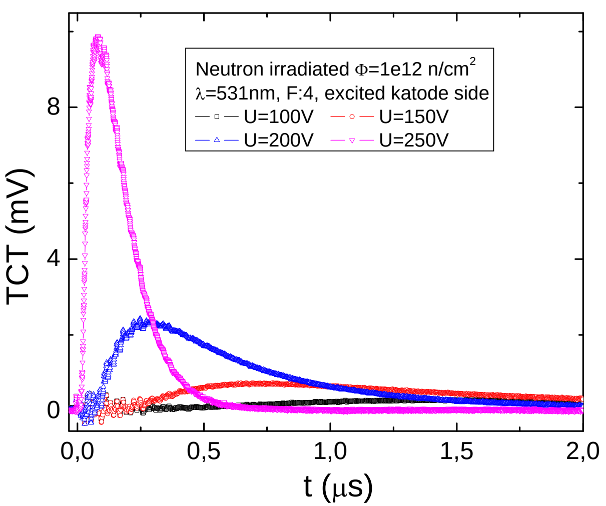
10^{14} n/cm^2

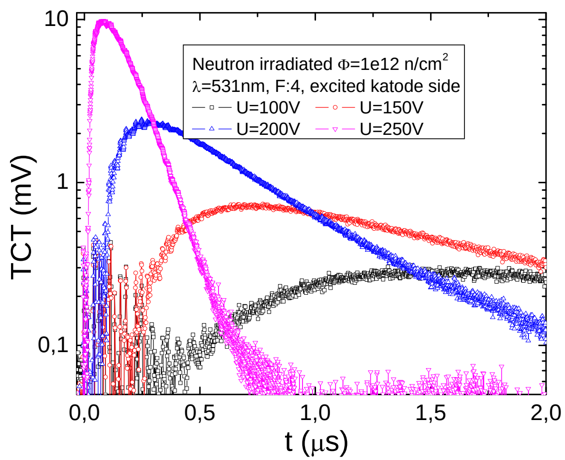


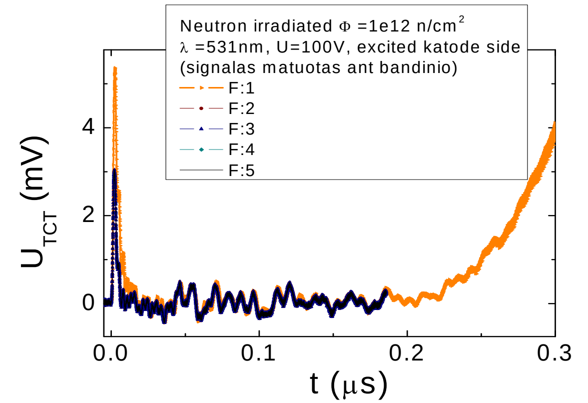




drift of holes

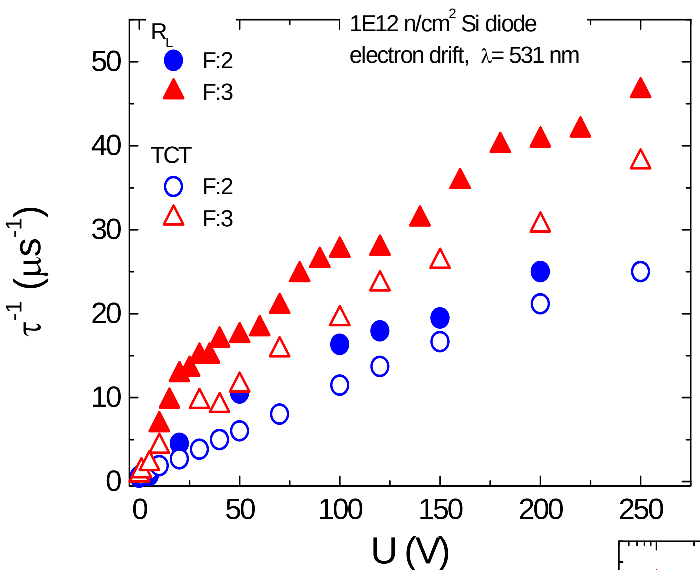


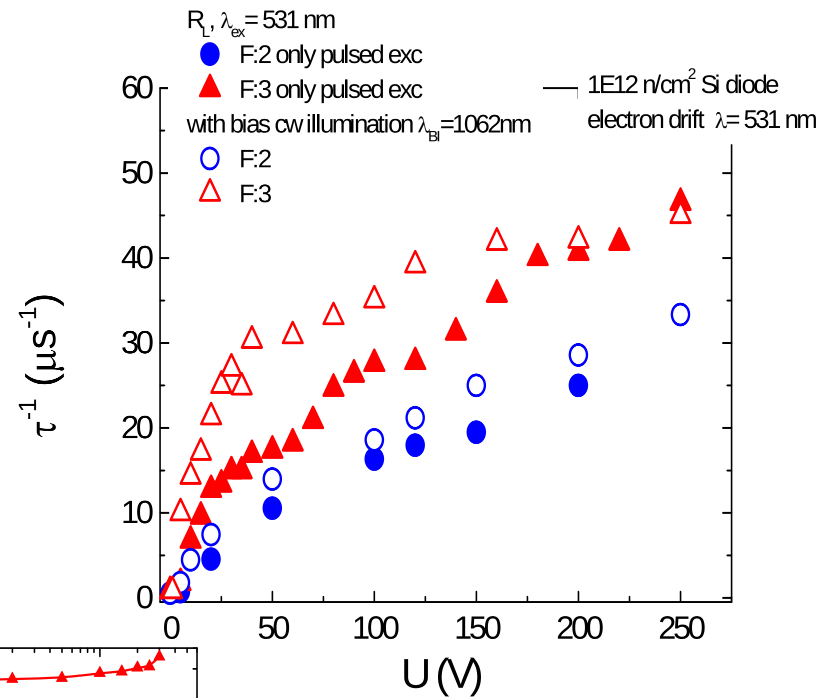




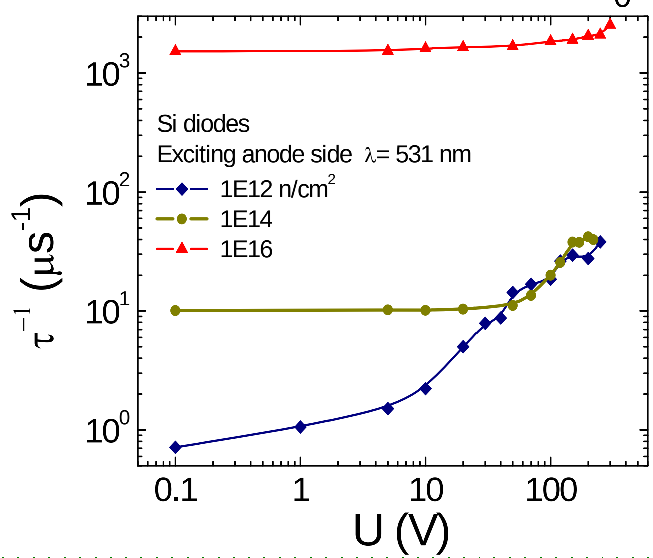
Experimental results: MW-PC/contactless - surface excitation 531 nm

Drift of electrons



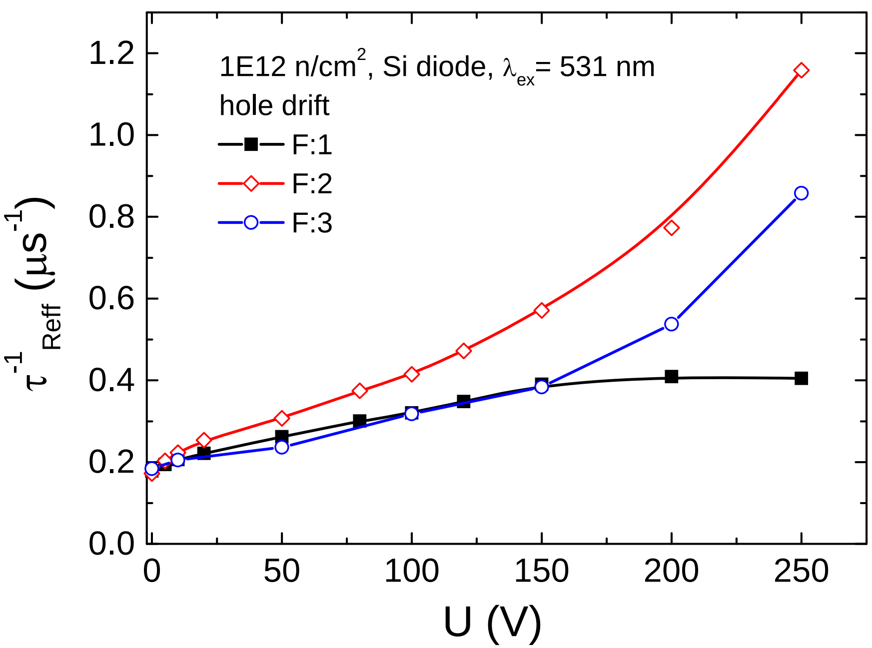


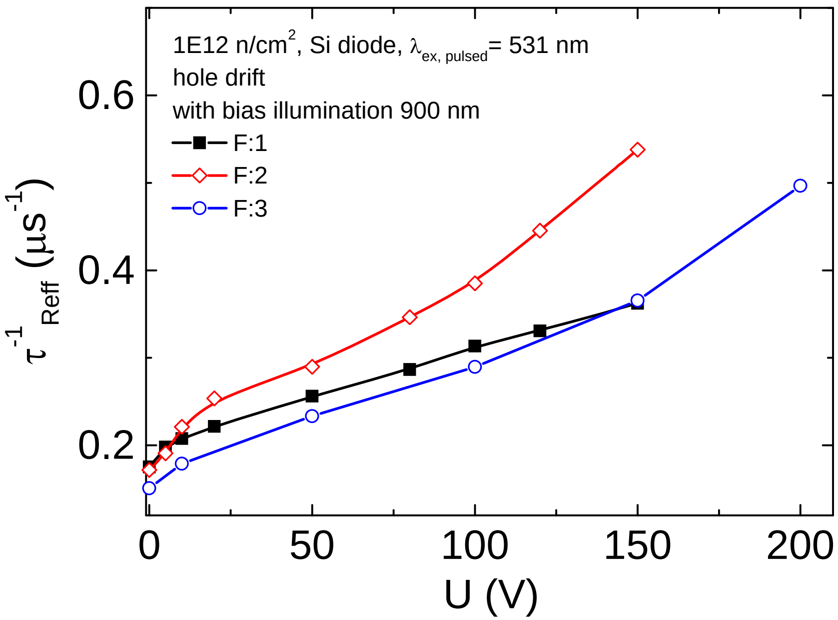
Bias illumination:
900 nm GaAs LED



Experimental results: MW-PC/contactless - surface excitation 531 nm, dependent on intensity of pulsed and bias cw excitation

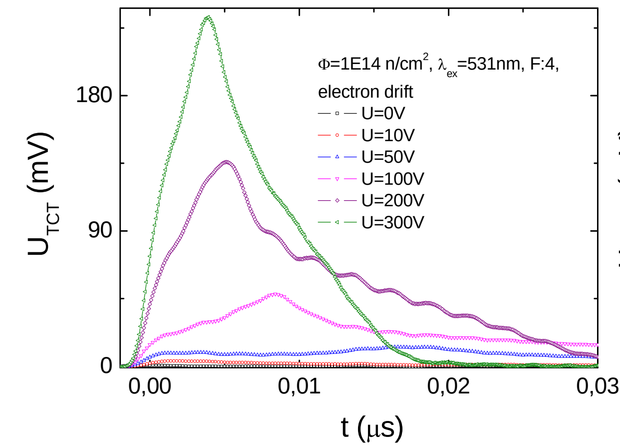
Drift of holes

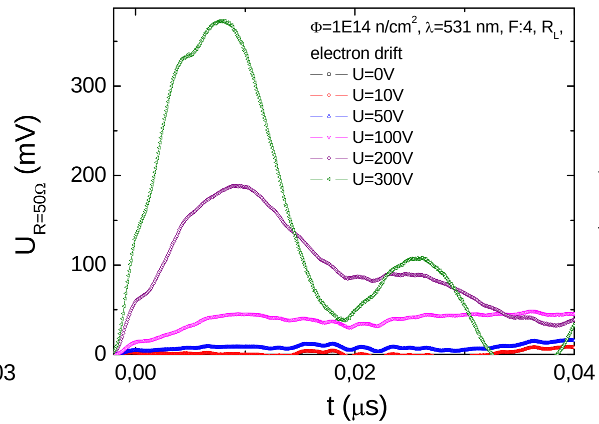


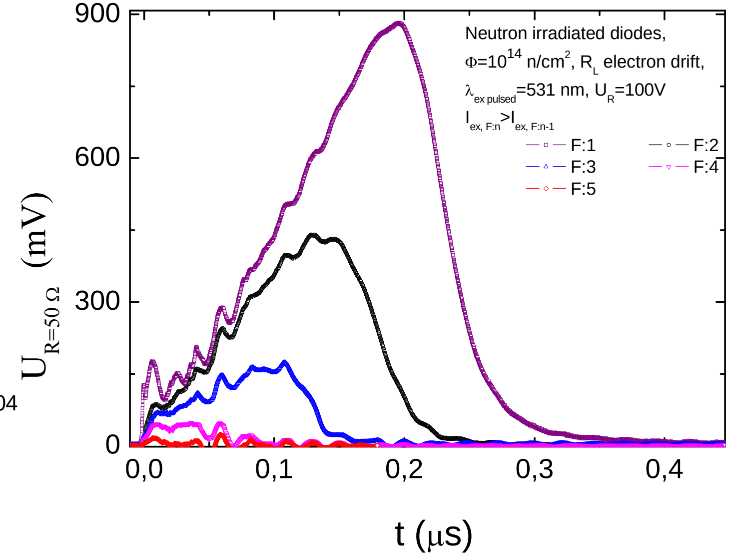


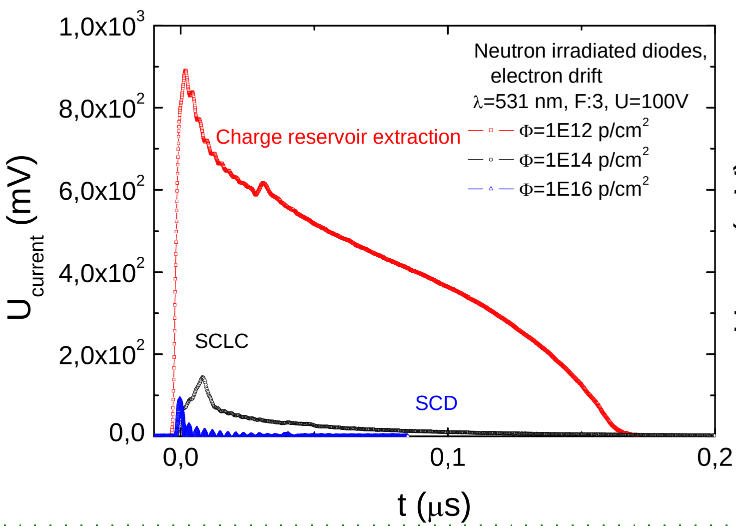
Experimental results: current / electrical – surface excitation 531 nm, dependent on voltage, registration mode, excitation and fluence

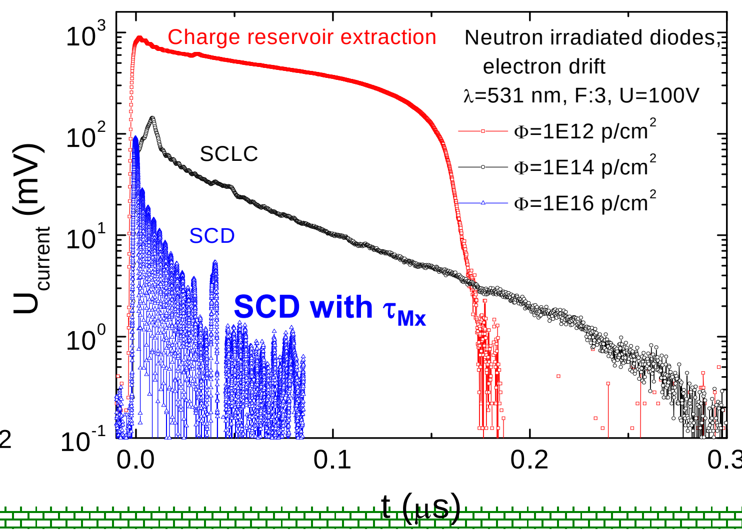
Drift of electrons 1E14 n/cm^2





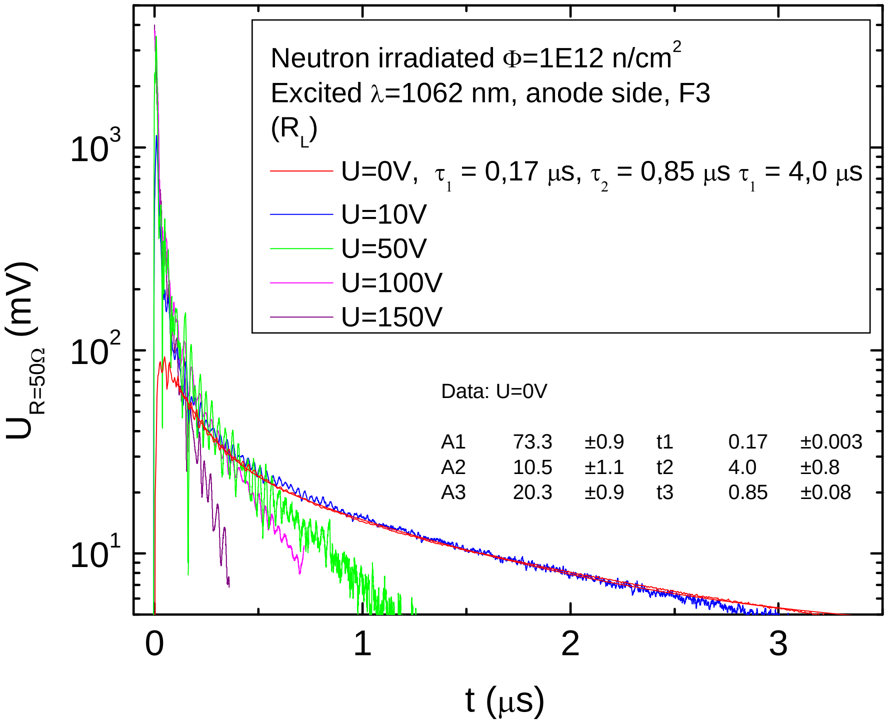


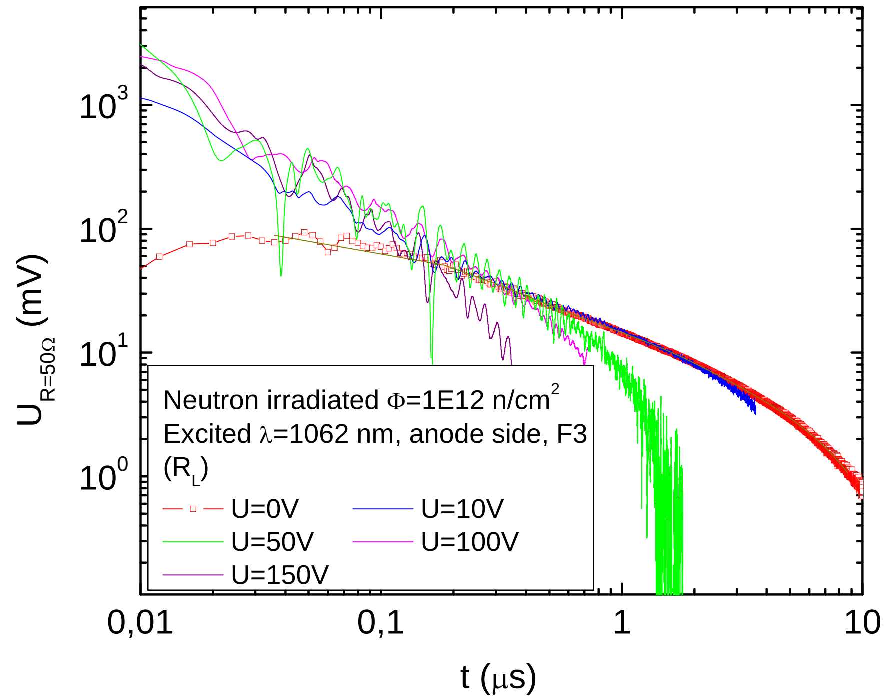




At fixed excitation, when fluence is varied, due to recombination/trapping of carriers, different drift current regimes are observed: CRE, SCLC, SCD

Bulk excitation: recombination and carrier extraction
(bias dependent)





Models of description

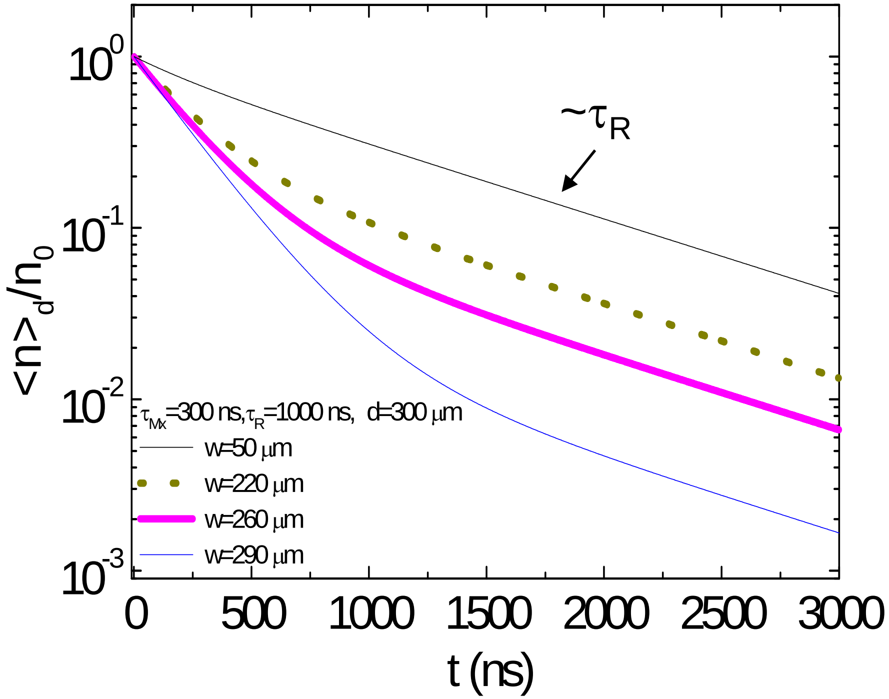
MWR at $U < U_{Full\ Depl} = U_C$

$\langle n_{ex}(t)\rangle|_d = n_0 \times \exp[-t/\tau_R] \times [1-(w/d) \times (1- \exp\{-t/\tau_{Mx}\})]$

becomes two exponential with U

$W=(2\varepsilon\varepsilon_0 U/eN_{ef})^{1/2}$

$\tau_{Mx}=\varepsilon\varepsilon_0\rho$



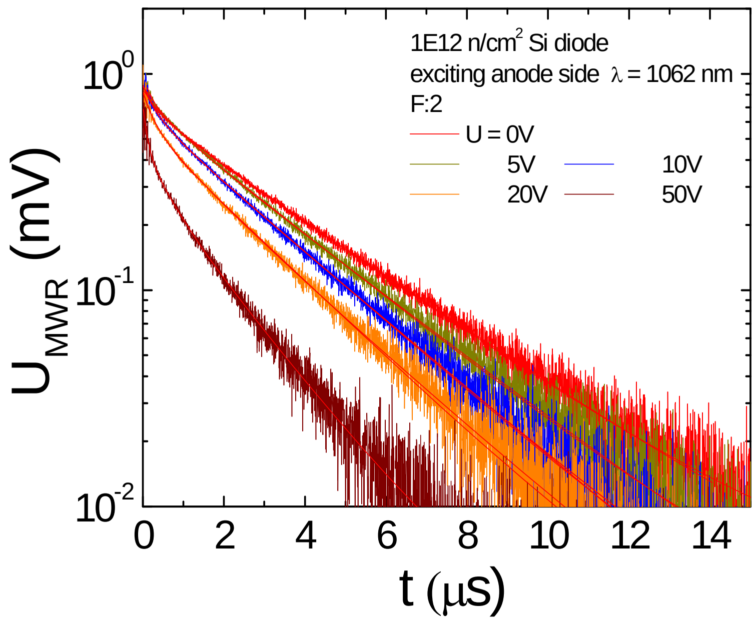
MWR for $U \geq U_{Full\ Depl} = U_C$

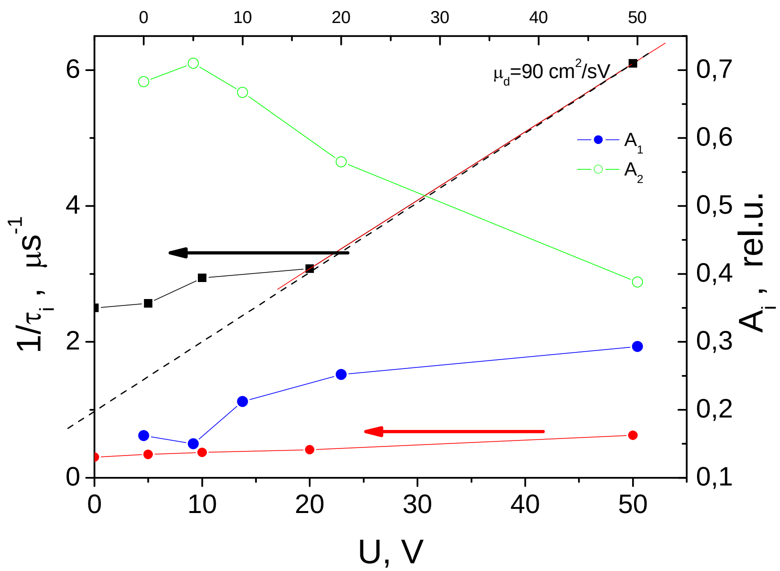
$\langle n_{ex}(t)\rangle|_d = n_0 \exp[-t(\tau_R^{-1} + t_{tr}^{-1})]$

$t_{tr} = d^2/\mu U$

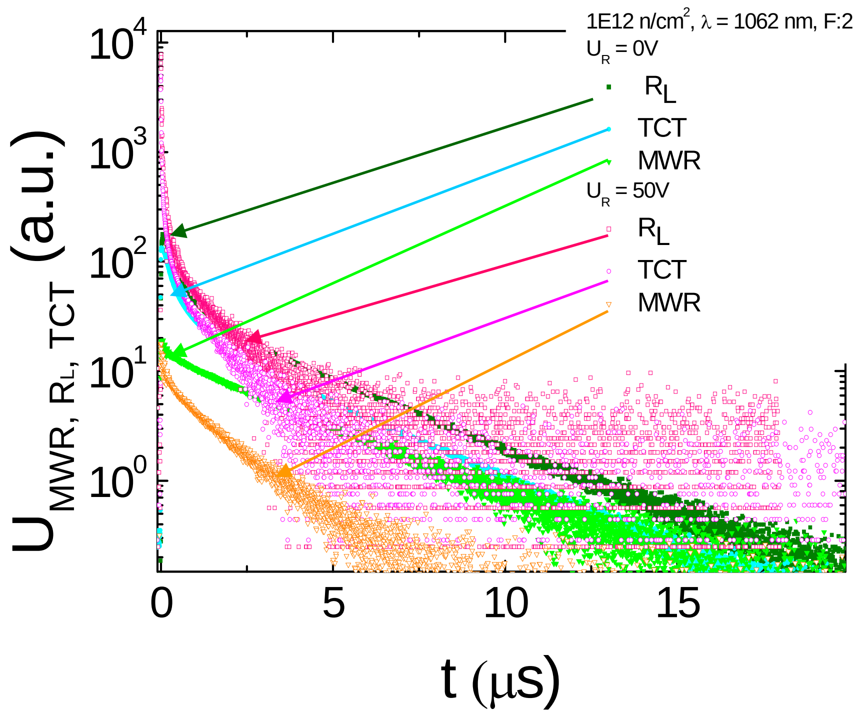
single exp which decreases faster with U

Experimental results MW-PC/contactless - bulk excitation at 1062 nm

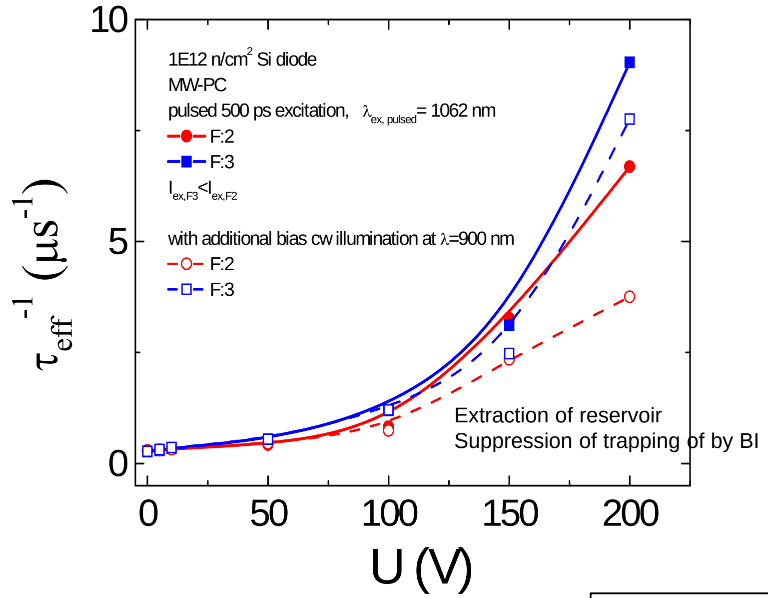


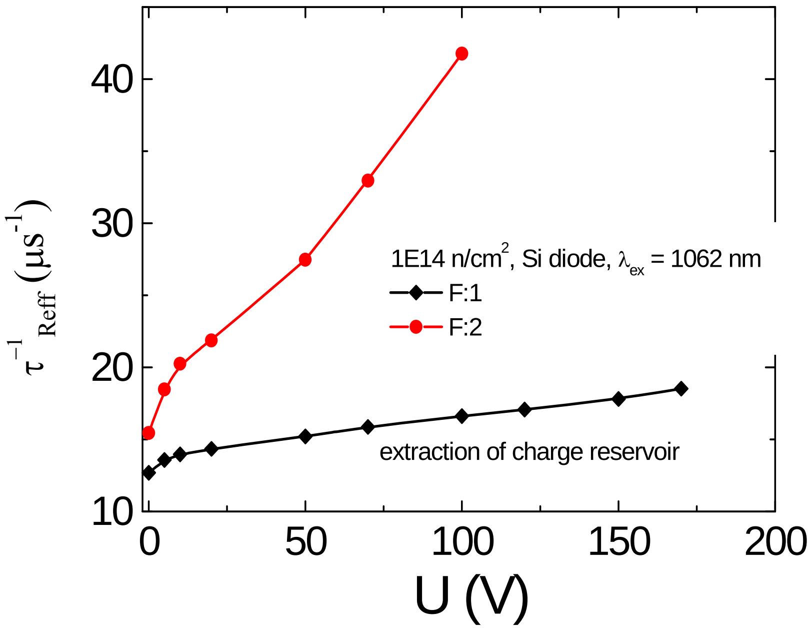


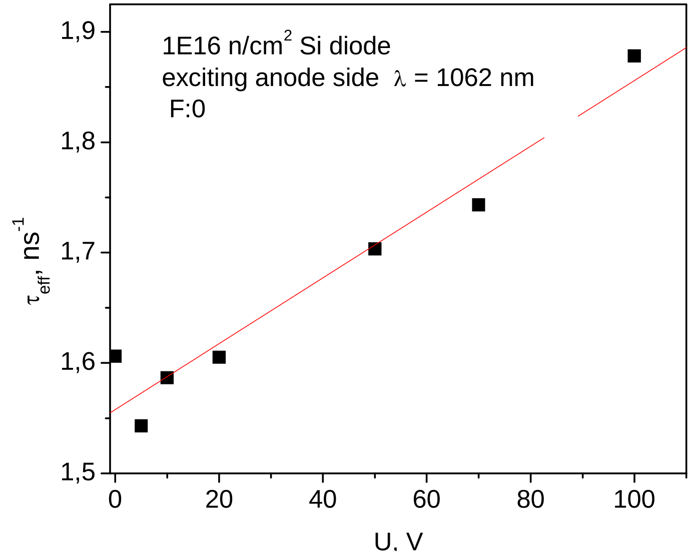
MW-PC comparison with TCT & R_L



Experimental results: MW-PC/contactless, bulk excitation

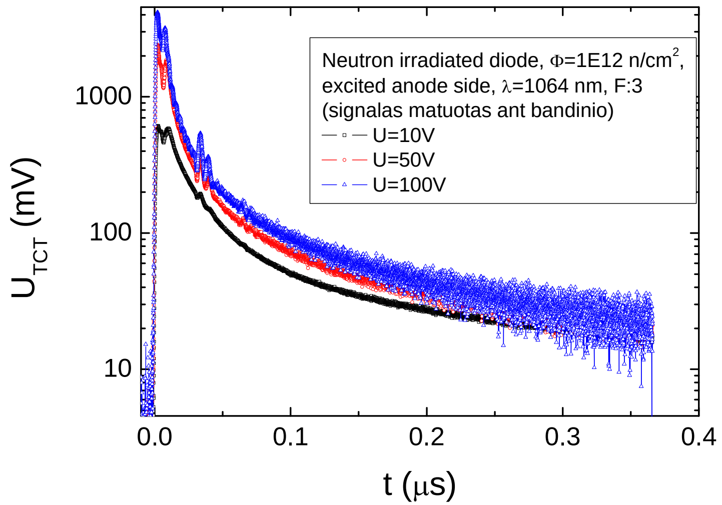


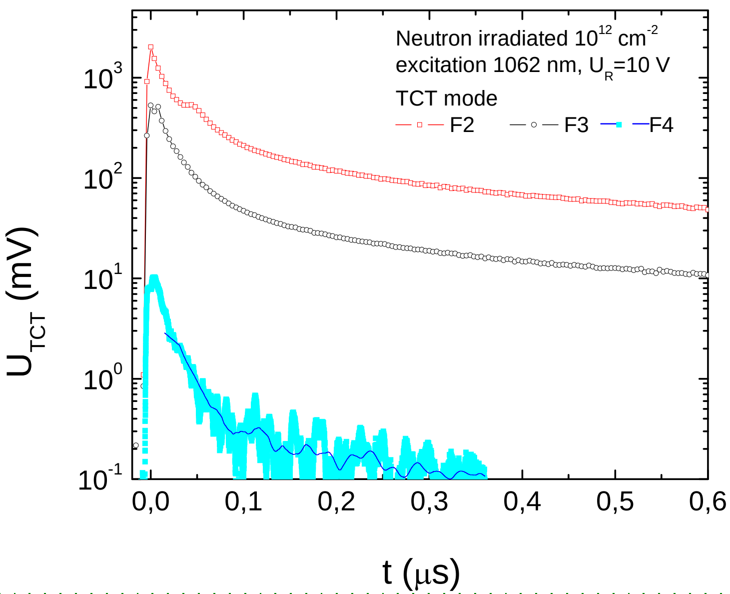


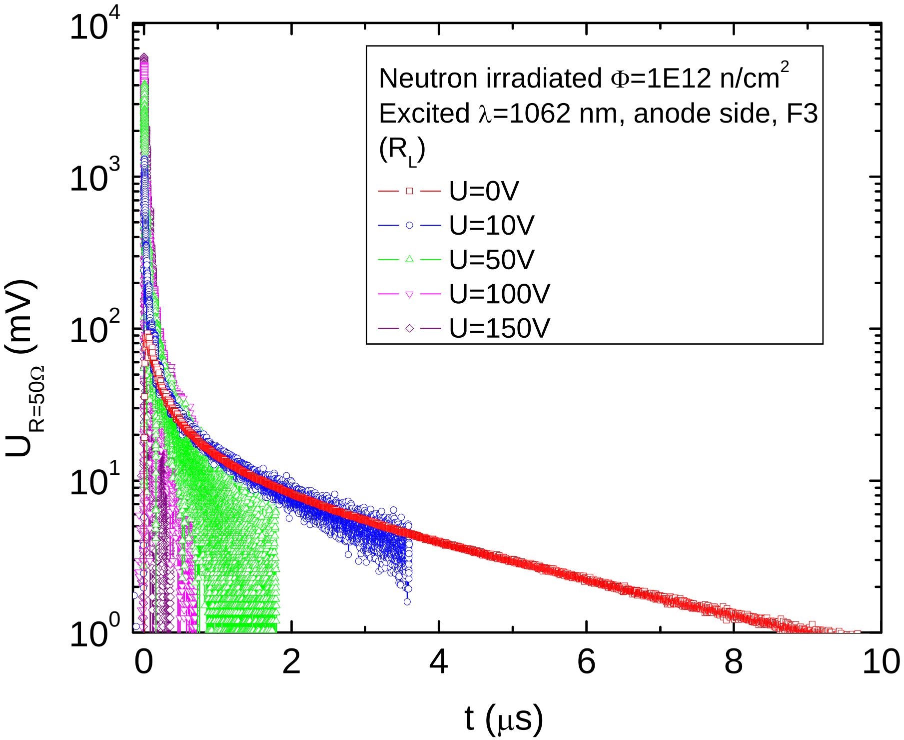


Experimental results: current / electrical, bulk excitation

10^{12} n/cm^2 TCT (sample)   and R_L (j(U))



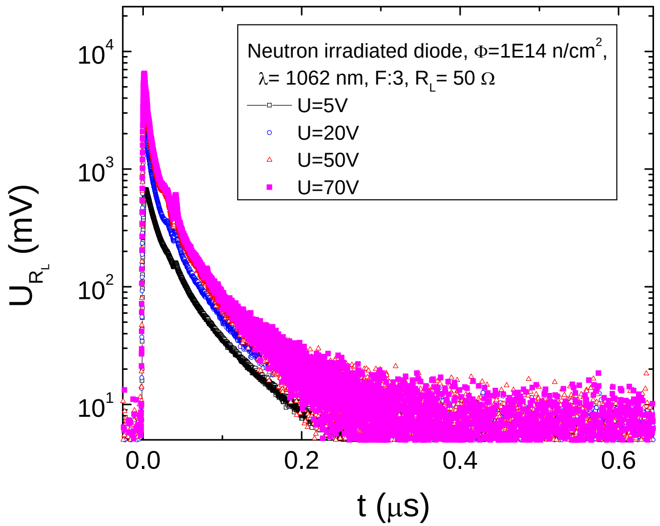


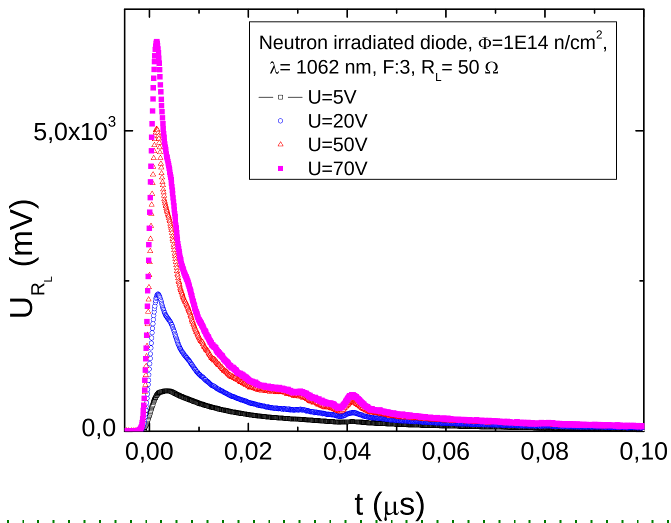


j (I_{ex}), $I_{F5}<I_{F4}<I_{F3}$ ...

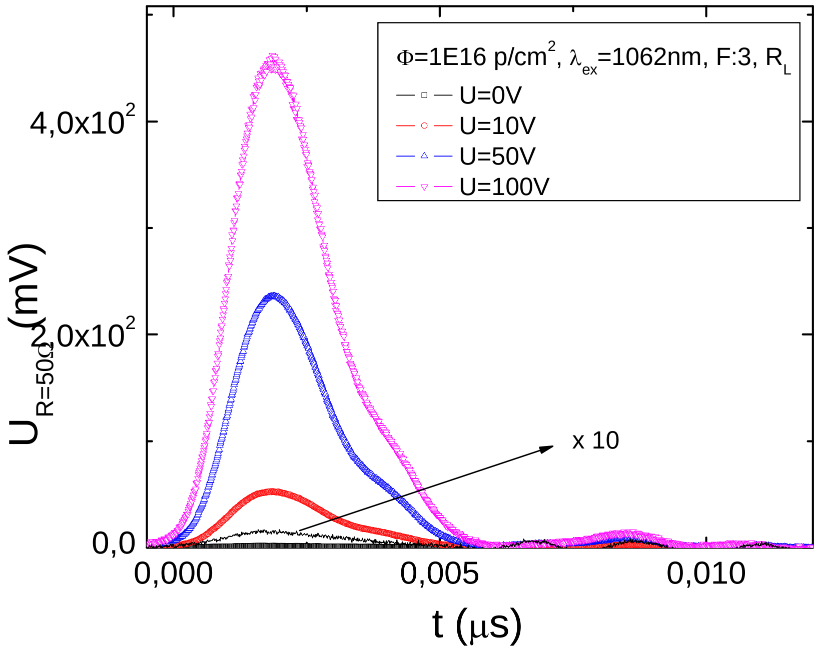
Experimental results: current / electrical, bulk excitation, dependent on fluence

1E14 n/cm^2





1E16 n/cm^2



Summary: (qualitative effects, quantative will follow)

- Photoconductivity decay does not show the direct dependence of recombination lifetime on the applied electric field, but allows to control the redistribution of carriers. The different behavior was observed in case of constant bias and TCT regimes, and it shows better reliability of TOF method.

- MW-PC transients, when depth averaged carrier density changes in time are registered, have an additional components dependent on U due to simultaneous carrier recombination and extraction;

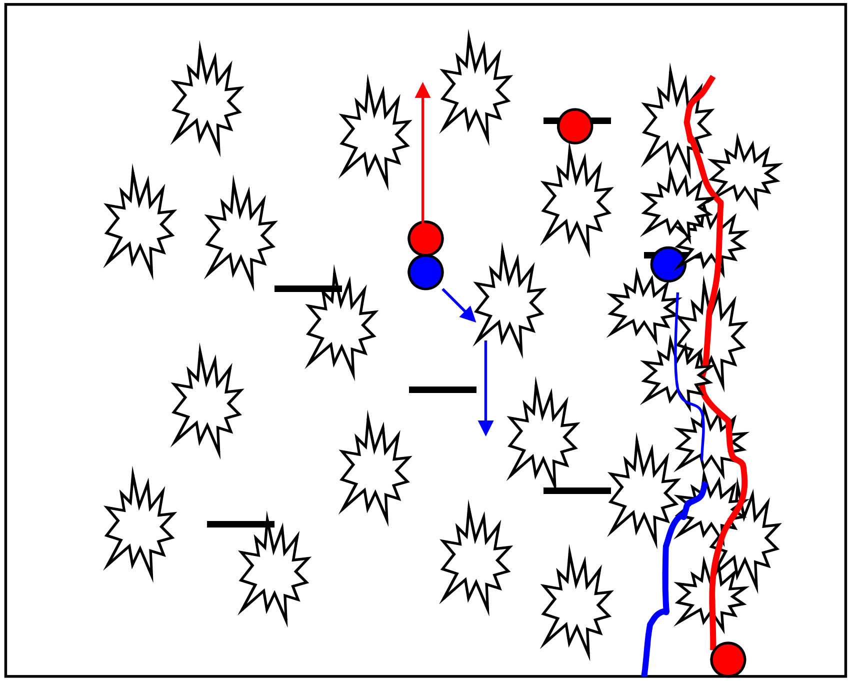
- At fixed the same excitation intensity, for samples of varied irradiation fluence, due to recombination/trapping of carriers and necessary enhanced excitation density, different drift current regimes were observed.

- The considerably reduced carrier drift mobility and the dispersion of the instantaneous decay time were observed and it fits to the model of clusters surrounded by disordered distribution of other defects. I.e., reduction of carrier capture lifetime might be due to formation of clusters.

Thank You for attention!

and

Acknowledgements to Lithuanian Science and Studies Foundation, Ministry of Education and Science for support of this work
and to Prof. G.Juška for the discussion of TOF and TCT results



At high fluences

Pool-Frenkel and avalanche process in the overlap of cluster non-crystalline regions.

Journal of Non-Crystalline Solids
Volume 354, Issues 19-25, 1 May 2008,
A new concept of an indirect conversion flat panel detector utilizing avalanche multiplication phenomena in amorphous selenium (a-Se) is described (25 years ago proposed by G.Juska). It is shown that high avalanche multiplication gain of 1,000 can be achieved for 35 μm thick a-Se layer. ed for 35 μm thick a-Se layer).
In a-Si(H) the CCE was <1.05 (G.Juska), but … in overlap of a-Si in cluster environment …