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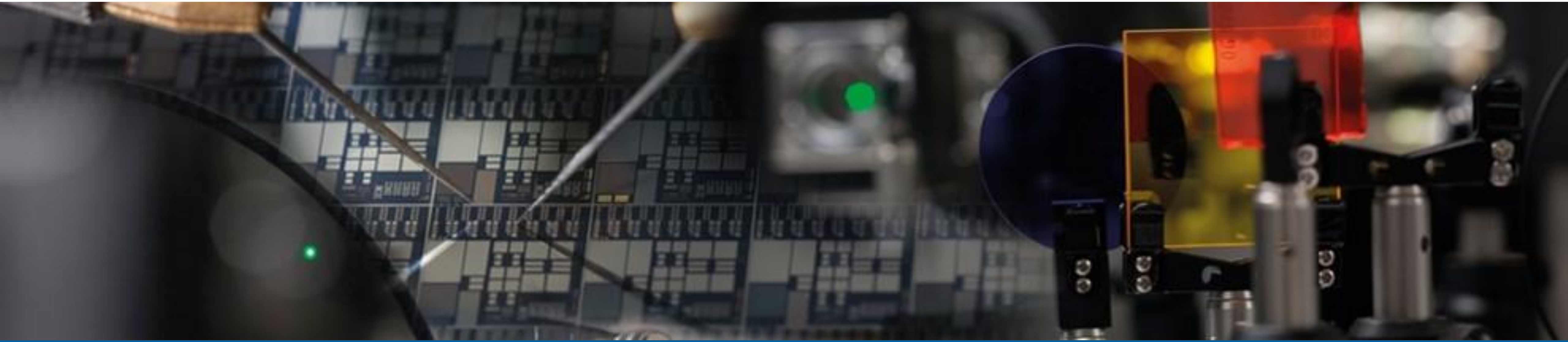
IAP

Pros for using MFIA in deep level transient spectroscopy studies



Teimuraz Mtchedlidze www.teimuraz.net Freiberg

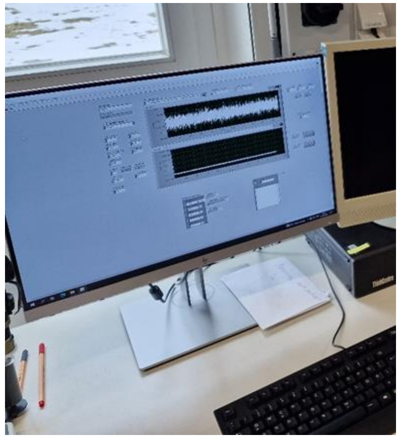
Contents:

- Implementation of the DLTS setup
- Standard measurements, comparison to HERA results
- Transient measurements under various settings
- Importance of the initial part of a transient
- Summary

MFIA and HERA DLTS systems

MFIA based system

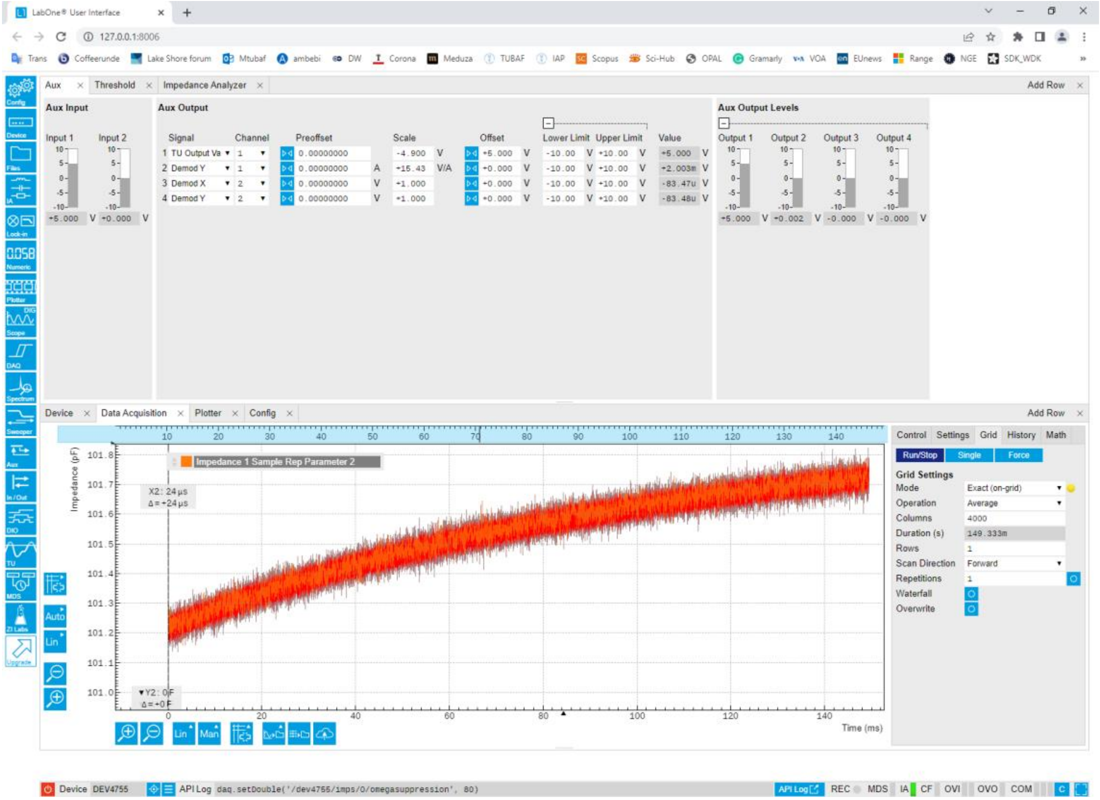
Zurich Instruments



PhysTech “HERA” DLTS system

Phys Tech

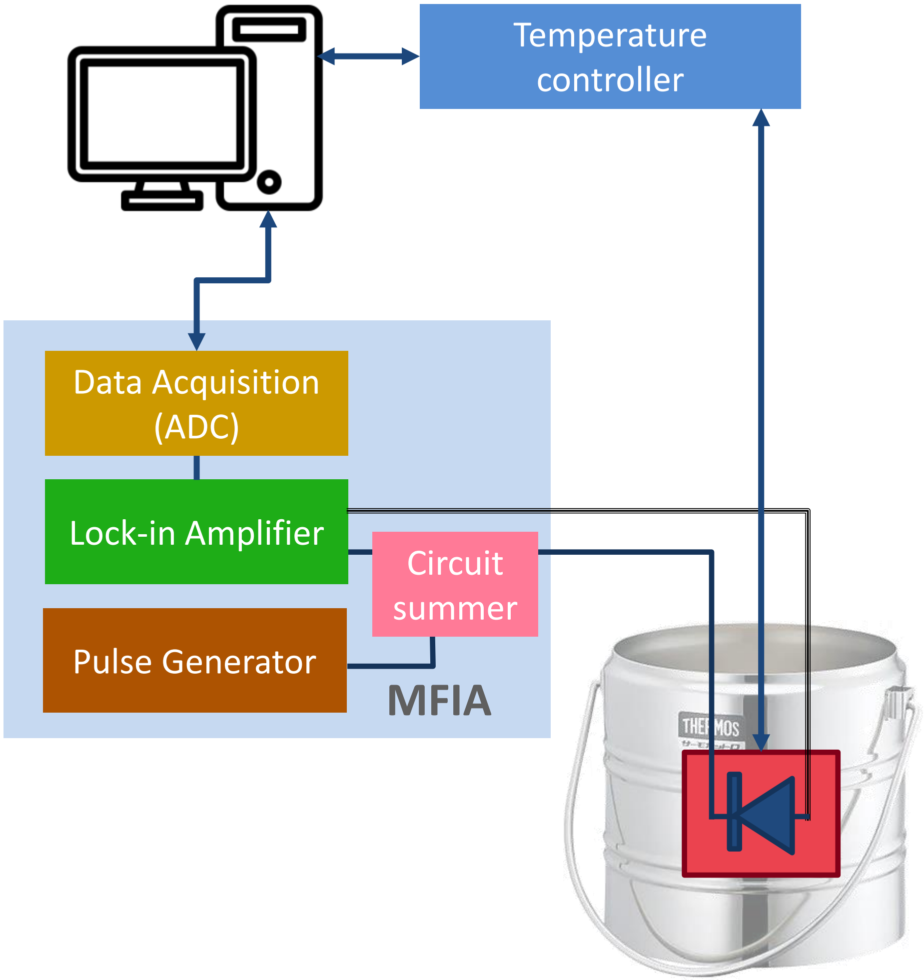
Detection of transients using UI of MFIA

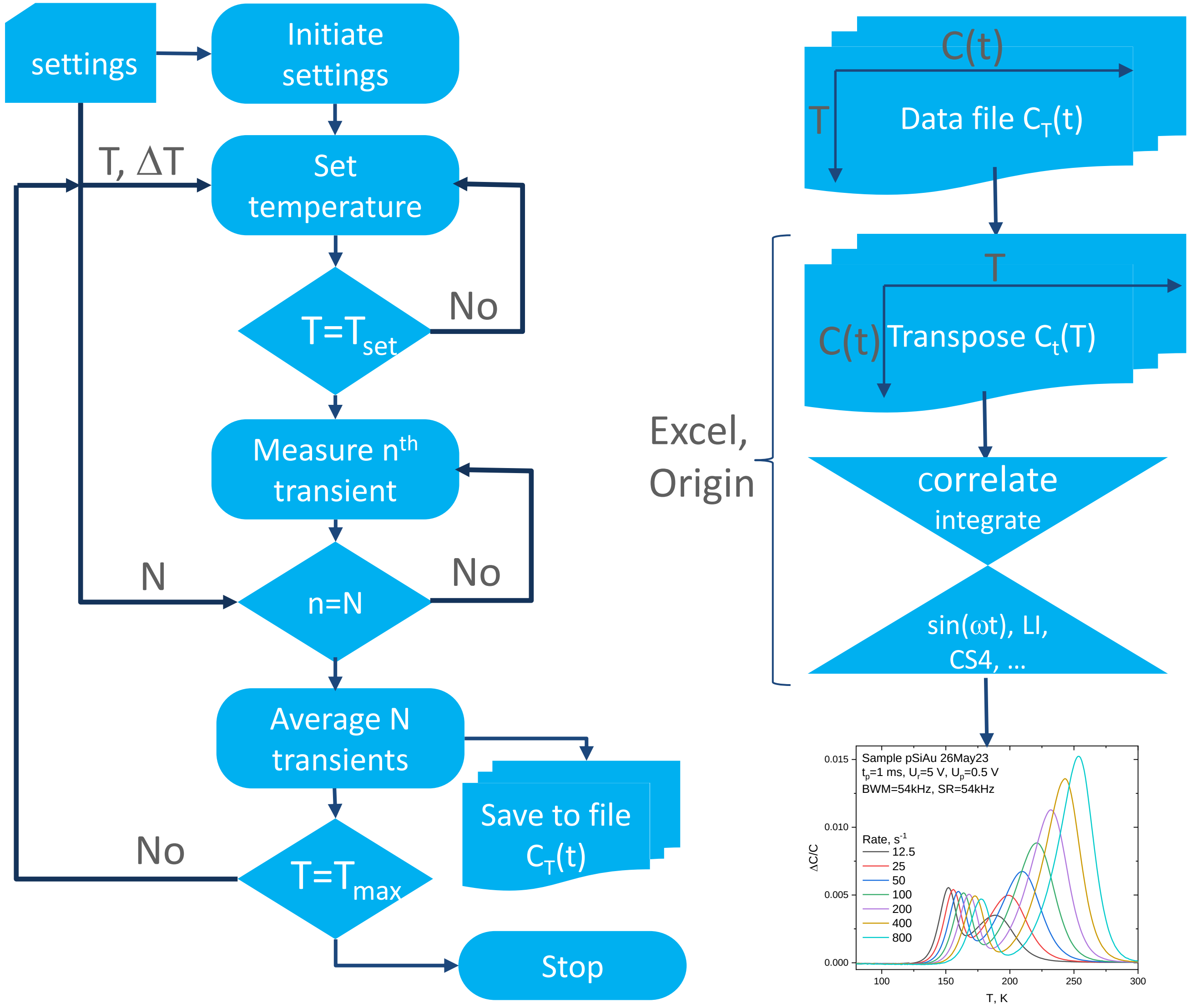


T=95K

T=150K

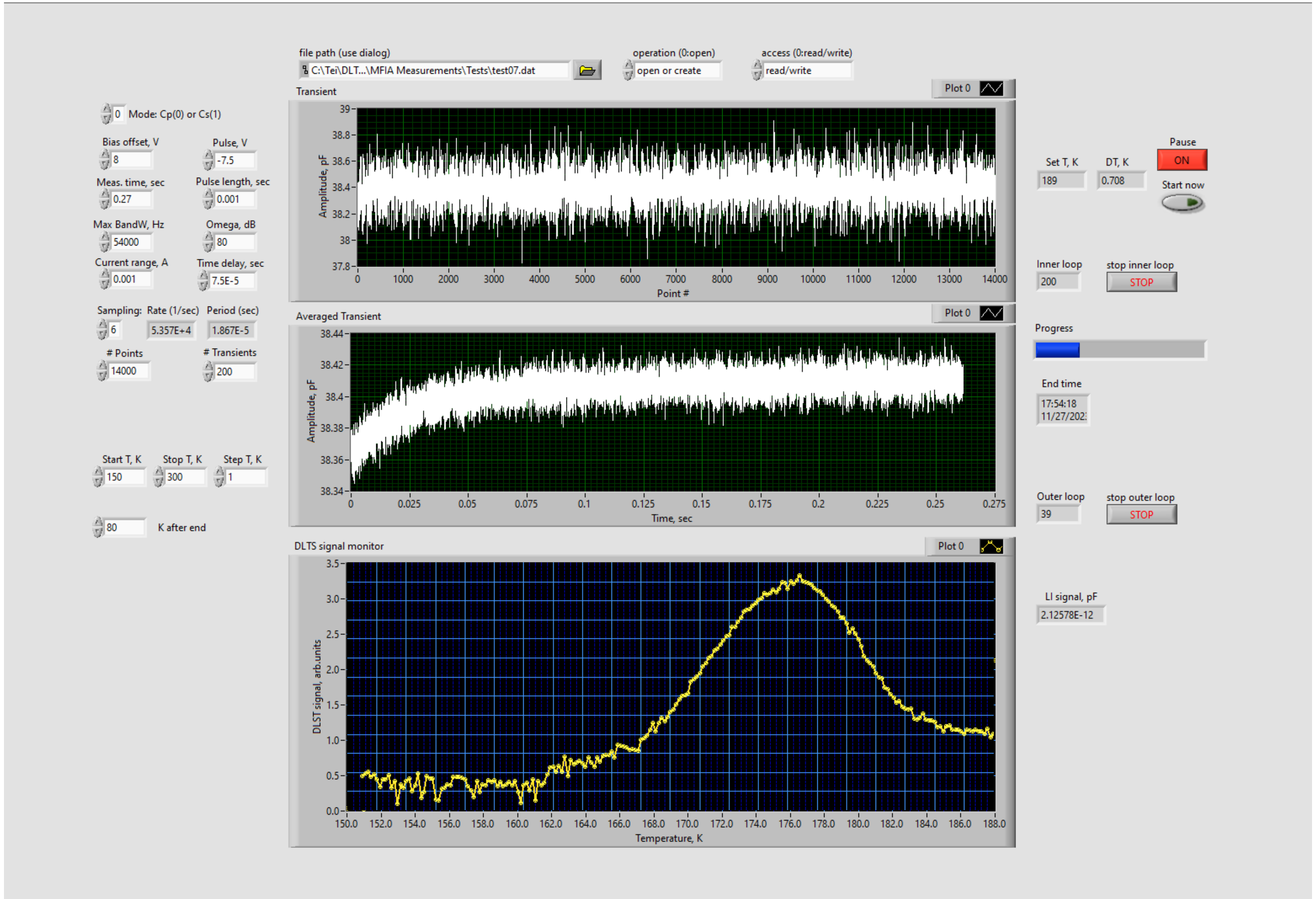
Block diagram, measurement routine, data treatment





[1] G.T. Nelson, et al., IEEE Trans on Nuclear Phys., 67 (2020) 2051
[2] C. Matre, MSc thesis, Uni Oslo (2019)

Interface of the LabVIEW program



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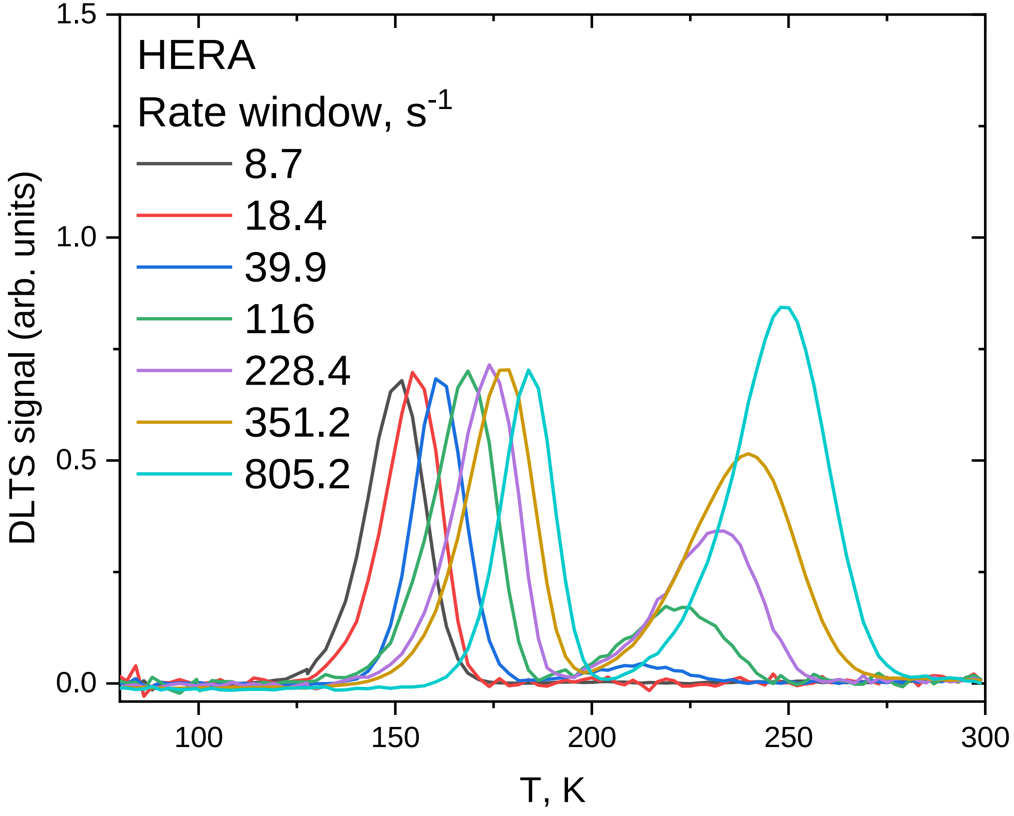
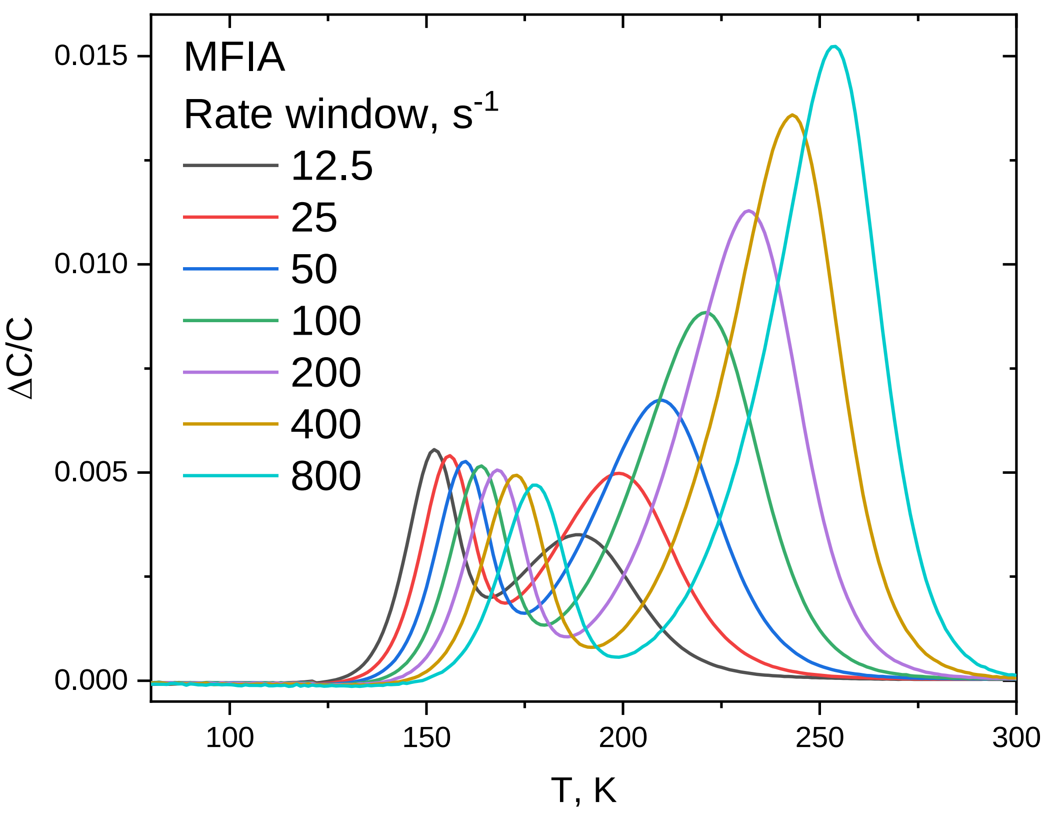
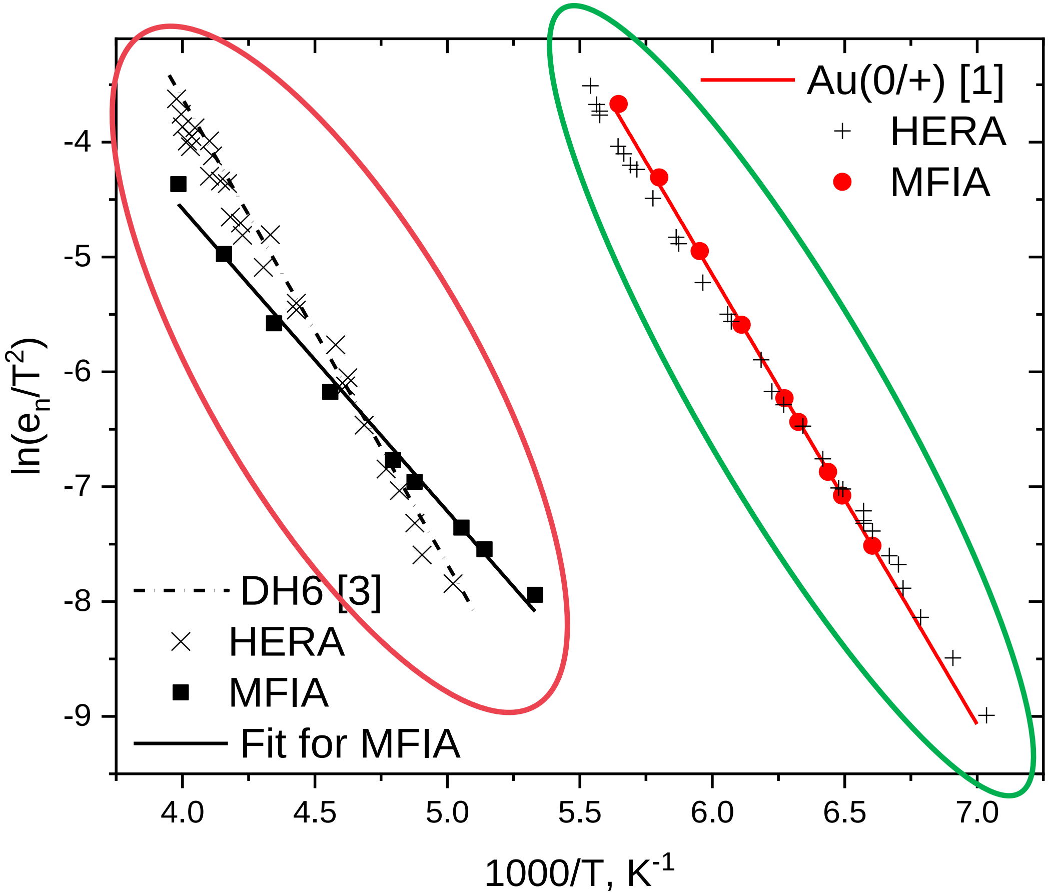
MFIA vs. HERA

Sample: B-doped ($N_a=1\times10^{15}$ cm^{-3}) FZ-Si sample contaminated by gold. Gold was introduced from the pre-deposited Au layer during 60 min annealing at 750˚C in the Ar atmosphere.





Extracted trap parameters



TRAP	E_{na}, eV	σ_{na}, cm^{-2}	C_t, cm^{-3}
Au(0/+) MFIA	0.34	6.2×10^{-14}	9.8×10^{12}
Au(0/+) HERA	0.334	7.5×10^{-14}	8×10^{12}
Au(0/+) [1]	0.34	6.2×10^{-14}	(1×10^{13}) [2]
DH6 MFIA	0.23	2×10^{-19}	2.9×10^{13}
DH6 HERA	0.33	3×10^{-16}	1×10^{13}
DH6 [3]	0.35	1.7×10^{-16}	Unknown

[1] K. Gwozdz, et al., JAP, **2018**, *124*, 015701.

[2] N. Stolwijk, et al., Physica B, **1983**, *116*, 335.

[3] V. Kveder, Et al., PSS(a), **1982**, 72, 701.

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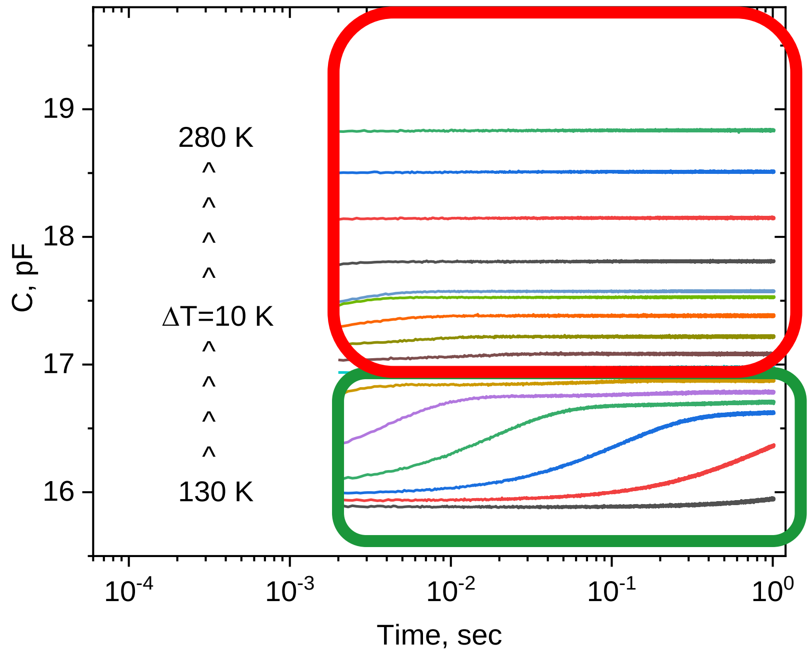
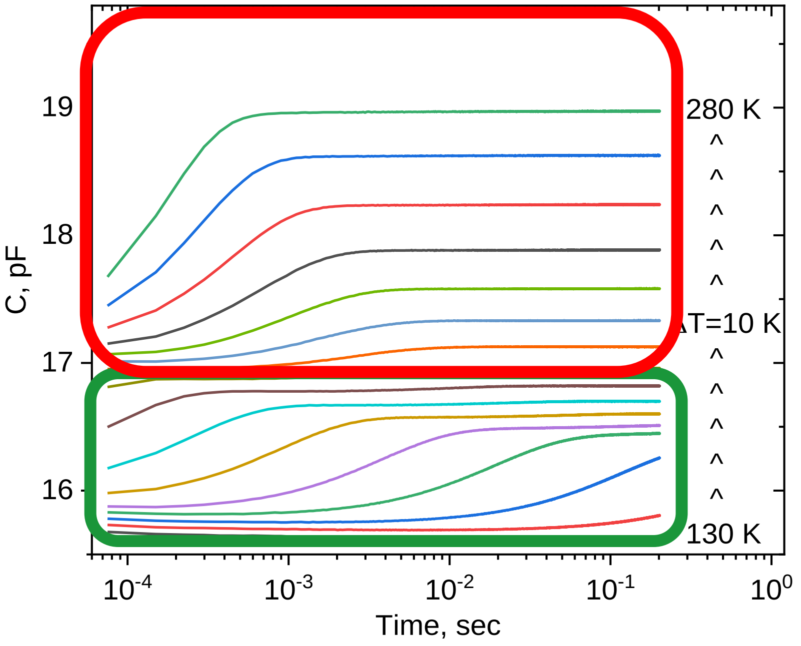
Transients under various MFIA settings

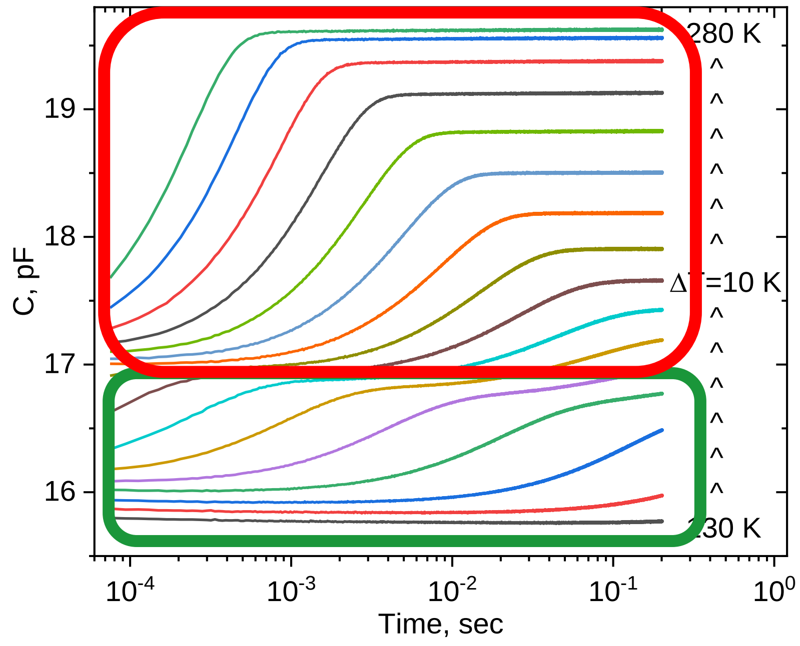
MBW=6.6 kHz, SR=6.6 kSa/s, t_{DEL}=2 ms, t_W=1.02 s



MBW=13.4 kHz, SR=13.4 kSa/s, t_{DEL}=75 µs, t_W=0.2 s

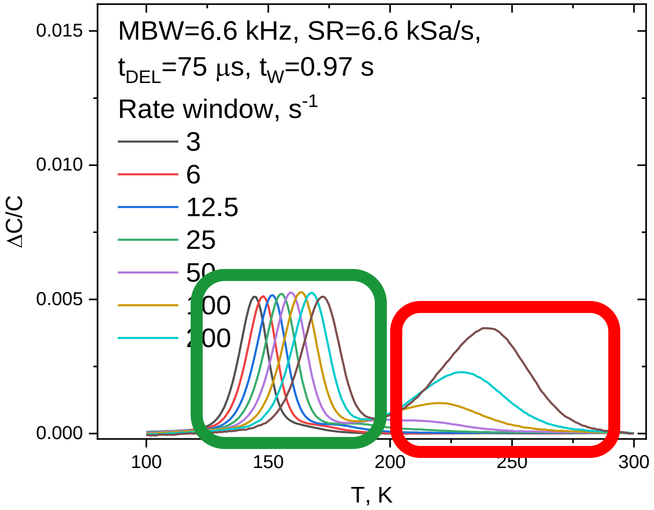


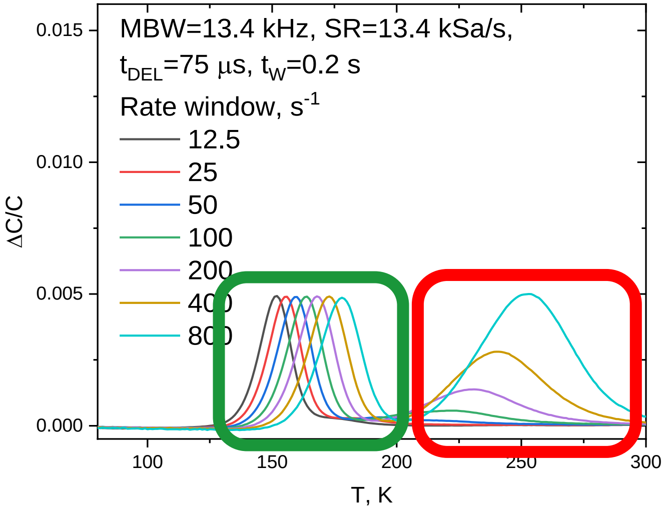
MBW=54 kHz, SR=53.6 kSa/s, t_{DEL}=75 µs, t_W=0.2 s

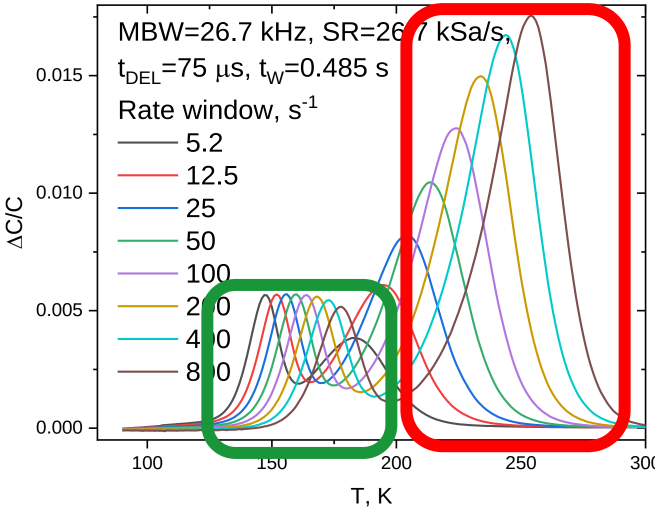


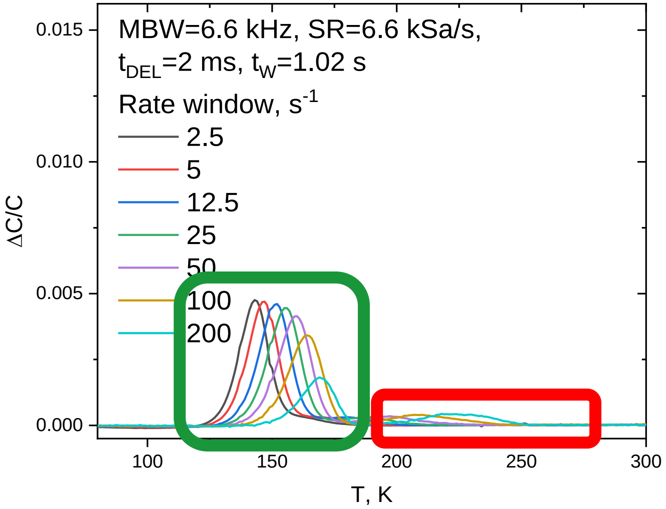
MBW – maximal bandwidth
SR – Sampling rate
t_{DEL} – delay time
t_W – total sampling time

Variation of MFIA settings







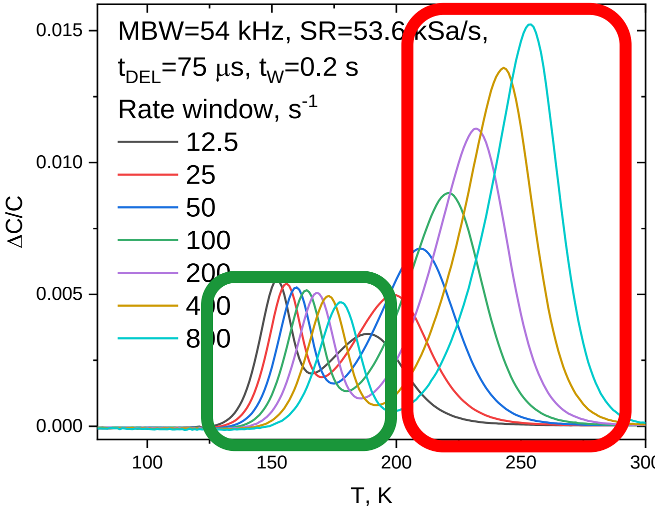


MBW – maximal bandwidth

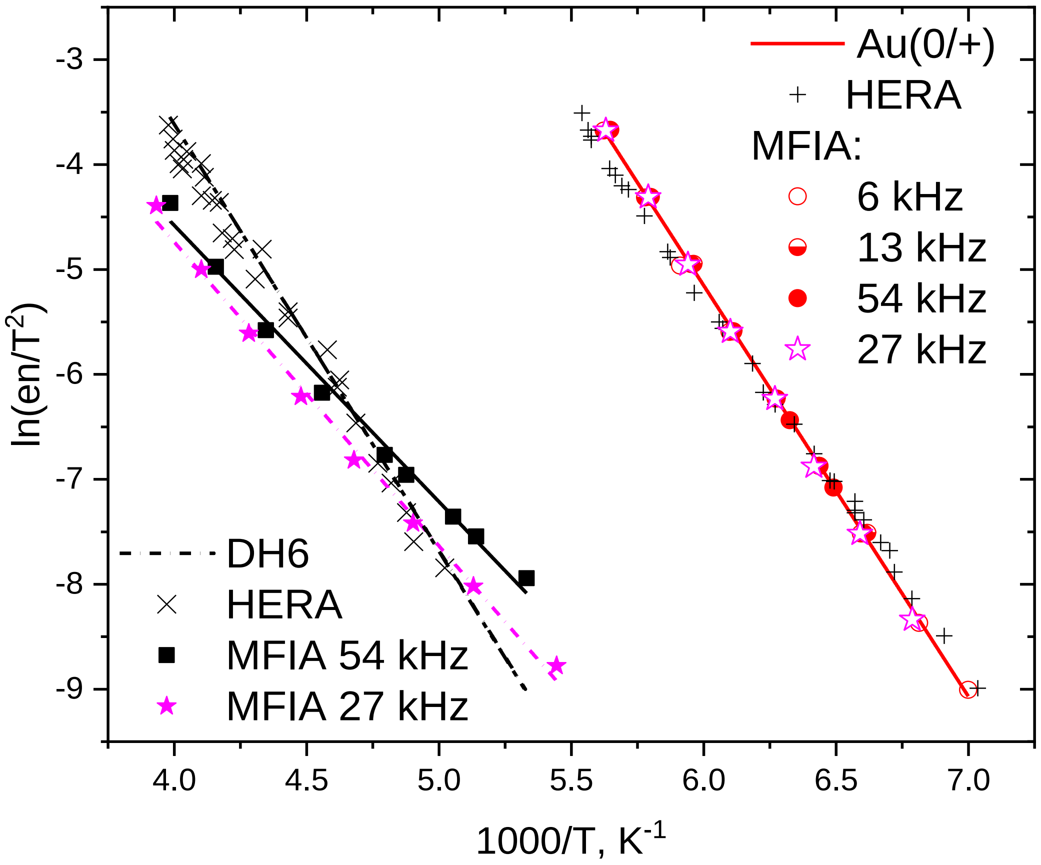
SR – Sampling rate

t_{DEL} – delay time

t_W – total sampling time



Extracted trap parameters



TRAP	E_{na}, eV	σ_{na}, cm^{-2}	C_t, cm^{-3}
Au(0/+) MFIA	0.34	6.2×10^{-14}	9.8×10^{12}
Au(0/+) HERA	0.334	7.5×10^{-14}	8×10^{12}
DH6 MFIA (107 kHz)	0.23	1.9×10^{-19}	2.7×10^{13}
DH6 MFIA (54 kHz)	0.23	2×10^{-19}	2.9×10^{13}
DH6 MFIA (27 kHz)	0.25	5×10^{-19}	3.1×10^{13}
DH6 HERA	0.33	3×10^{-16}	1×10^{13}
DH6 [REF] [1]	0.35	1.7×10^{-16}	Unknown

[1] V. Kveder, Et al., PSS(a), 1982, 72, 701.

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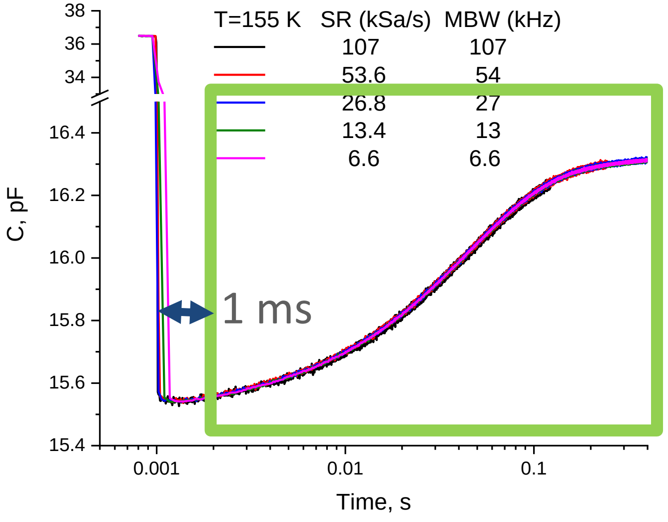
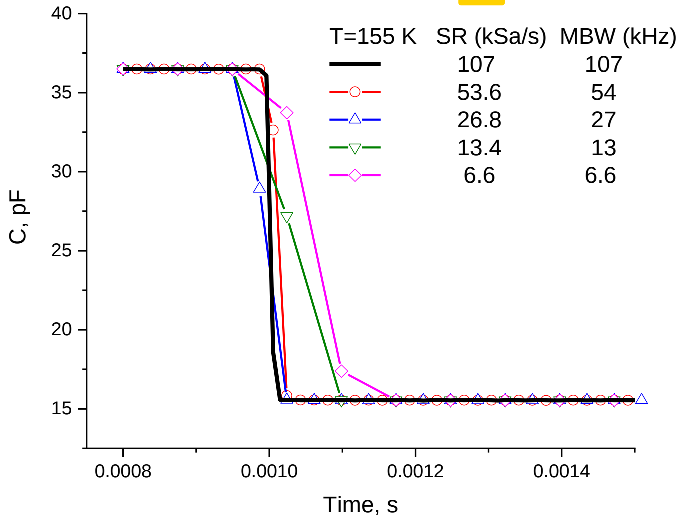
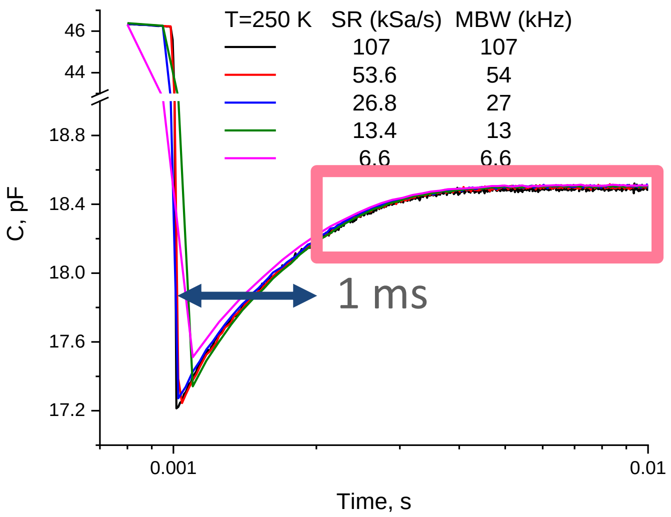
The edge between pulse/transient for various settings

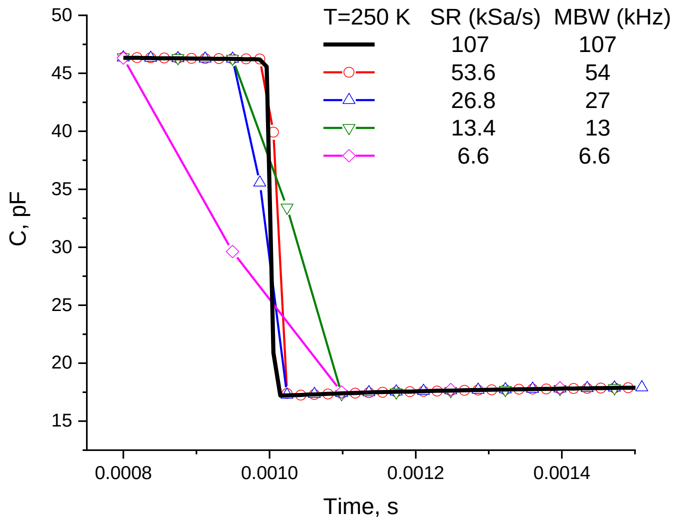
155 K



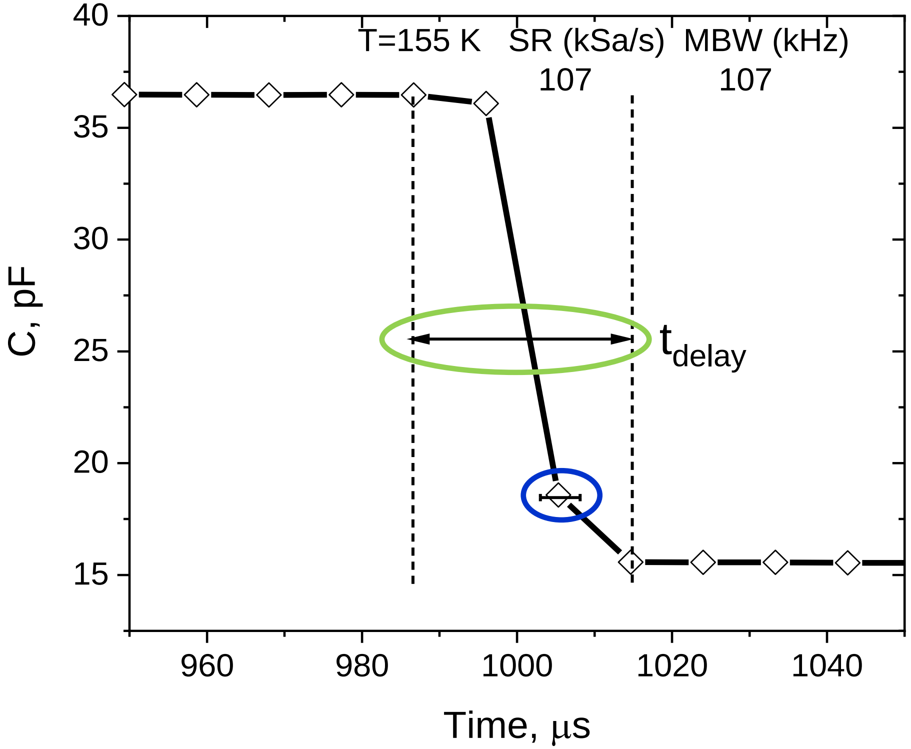


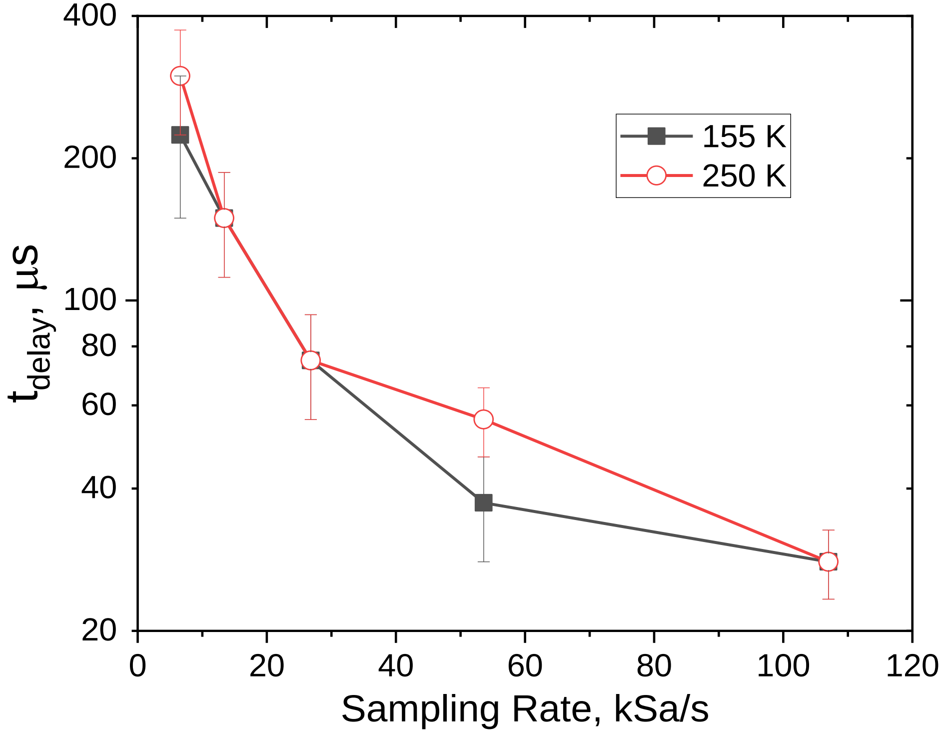
250 K



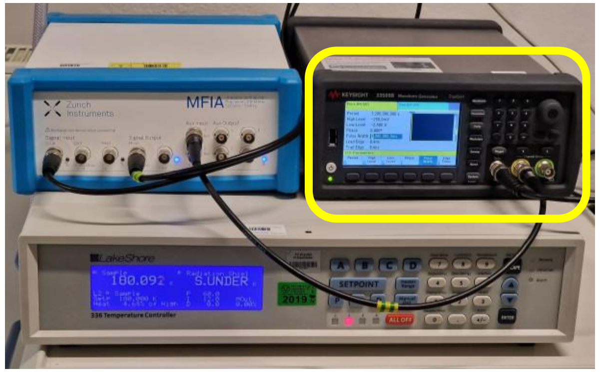


The edge between pulse/transient for various settings

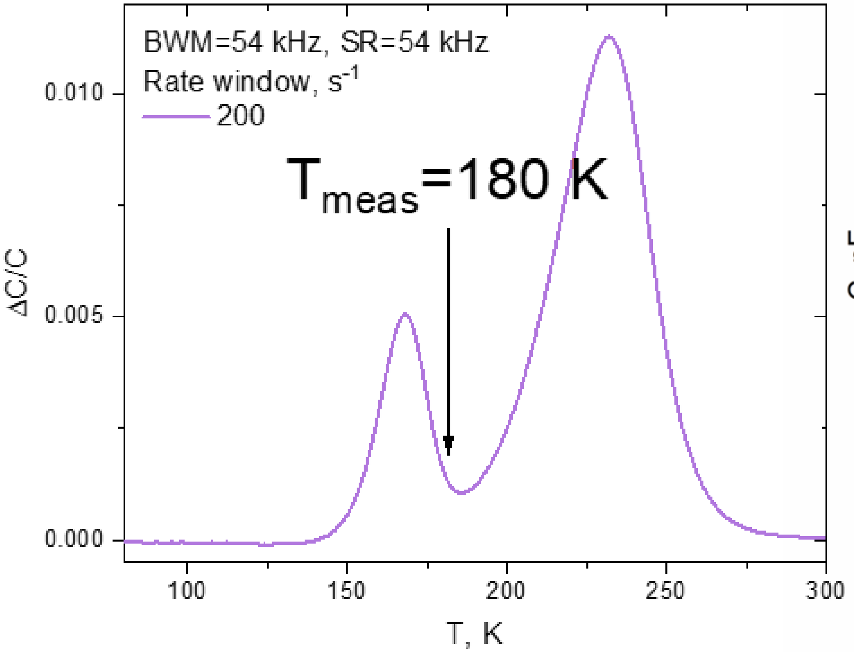


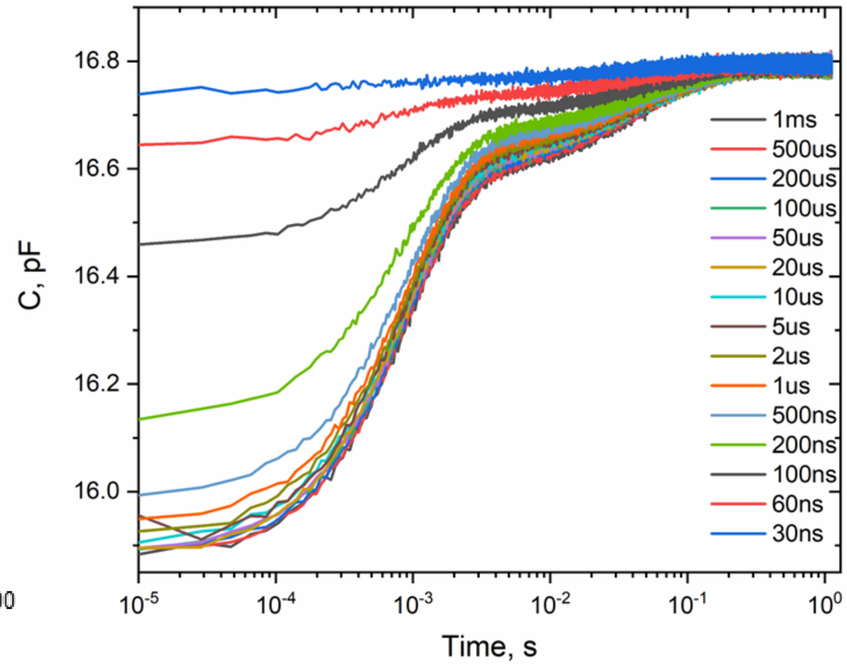


Dependence of signals on filling pulse duration



Experimental setup with the external pulse generator Keysight 33500B





Fitting:

$$C(t) = C_S + \Delta C_{Au}\left(1 - e^{-\frac{t-t_d}{\tau_{Au}}}\right) + \Delta C_D\left(1 - e^{-\frac{t-t_d}{\tau_D}}\right)$$

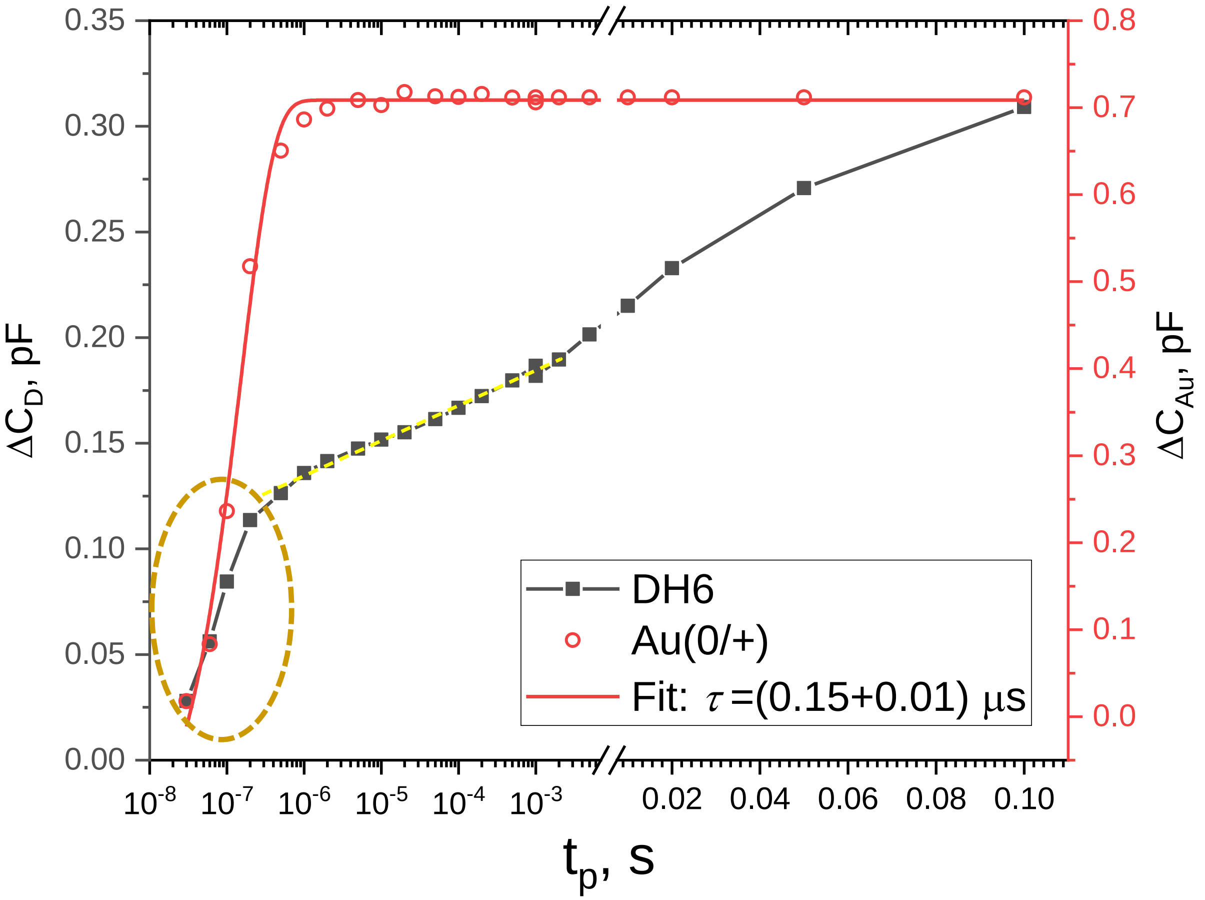
$C_S + \Delta\, C_{Au} + \Delta C_D = C_0$

τ_{Au}= const.

τ_D= const.

Dependence of signals on filling pulse duration

T_{meas}=180 K



Fitting for point defects, i.e., Au(0/+):

$$\Delta C(t_p) = \left[\frac{C_0 p_T(t_p)}{2N_D}\right]\left[\exp(-t_2 e_p) - \exp(-t_1 e_p)\right] =$$

$$= \Delta C_{MAX}\left[1 - \exp(-p\langle v_{th}\rangle \sigma_p t_p\right], \tau_p = 1/p\langle v_{th}\rangle \sigma_p$$

[R. Wu and A.R. Peaker, Sol.St.Electr. 25(1982)643]

[H. G. Grimmeiss and C. Ovren, J.Phys.E 14(1982)1032]

For extended defects, i.e., DH6, The DLTS peak amplitude increases linearly with the logarithm of the filling pulse duration (yellow dotted line in the figure).

[V. Kveder et al., PSSa 72(1982)701]
[T. Wosiński, J. Appl. Phys. 65(1989)1566]

Summary

- One can set up a DLTS system from scratch using MFIA from ZI in a couple of months.
- Above all, the system is revealing and instructive with powerful interface and a lot of possibilities. It even can be used to teach DLTS to students.
- The system allows measurements shortly after the filling pulse, minimizing the delay time used in the standard DLTS setups from 1-2 ms to 40-80 µs.
- The short delay time opens new possibilities for accurate measurements of trap signatures for defects with the strong temperature dependence of the carrier capture cross-section and defects with extended structure.
- New possibilities and higher precision can be achieved also for various types of transient measurement and evaluation, e.g. measurements of dependence on filling pulse duration, etc.

Acknowledgements

- We highly appreciate the help and support from the group of Prof. **Eduard Monakhov** (University of Oslo, Norway).
- Thanks are due to **Katrin Gwozdz** (Wroclaw University of Technology, Wroclaw, Poland) for supplying gold-contaminated silicon samples.
- Thanks to the ZI team (**T. Ashworth, K. Esat, and G. Ciardi**) Zürich, Switzerland for their instant support.
- Thanks to **Thomas Behm, Alexander Schmid, and others** (IAP TUBAF, Freiberg Germany) for support and technical assistance.

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Page on RG:

Materials of this study and, later, these slides can be found on my page at ResearchGate:

https://www.researchgate.net/profile/Teimuraz-Mchedlidze-2