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HERA-DLTS

High Energy Resolution Analysis
Deep Level Transient Spectroscopy

Since our company has launched in 1990 the first digital DLTS as a commercial system emerged from a development at the University of Kassel, we have searched for possibiltities to seperate overlapping emission processes. New and faster personal computer systems now allow to use more complicated calculations in a reasonable time. Based on the model of purely exponential emission processes, the measured transients are analysed for double or multi overlapping emissions using quite new or well known mathematic procedures (Provencher contin and discrete, sp@s-provencher.com) as:

Fourier transformation, **Laplace** transformation, muli exponential **transient fit**, **ITS** (Isothermal Transient Spectra) **signal deconvolution**, **tempscan signal deconvolution (refolding)**.

Compared to other systems, the combination of these different procedures and the continuusly done comparison with the reality, the measured signal, gives an unparalleled energy resolution for DLTS measurements without leaving the trapconcentration analysis. For every detected level, the **energy and** the **concentration** is evaluated using the results of the separation analysis, the emission time constants and the amplitudes, in Arrhenius plots.

The **windows based** software includes **all** functions and measurement modes of the FT 1030 Digital DLTS system as well as the new measurement and analysation modes for a separation of overlapping emission signals down to a factor of 3 in it´s timeconstant values (**HERA-DLTS**). This HERA-DLTS resolves overlapping emission signals for all DLTS modes (C, I, CC, ..) using the **direct** emission transient **analysis** and / or the standard **maximum anlysis** of the temperature (tempscan) or periodwidth (periodwidth scan) dependend emission transient measurements.

The **new transient recorder** using a new transient measurement technique (**variable oversampling, max. 64000 data points**) shortens the measurementtime for periodwidthscans drastically. It is reduced to app. 10% of the time using the standard transient recorder.
Therefore periodwidth scan measurements or **logarithmic** transients to long times (100s or 1000 s) can be done much more easier and more effective as with standard transient recorders.

The examples below should give some idears about the possibilities opend by this new HERA DLTS System.

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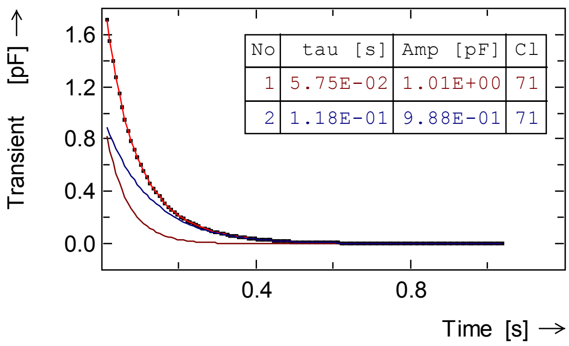
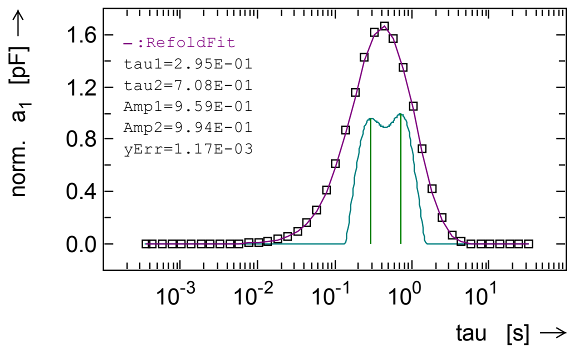
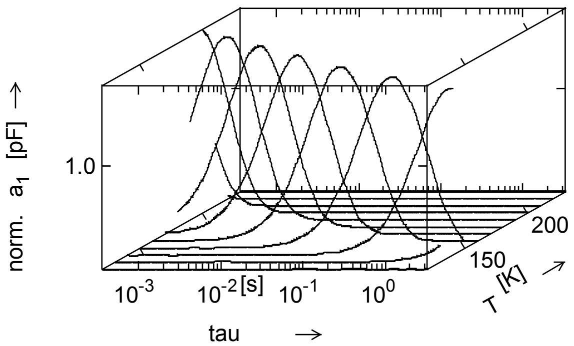
Simulated data : $E_1 = 0.34eV$, $E_2 = 0.35eV$, $\sigma_{1,2} = 1.0*10^{-14}cm^2$, Amplitude $_{1,2}$ = 1,0pF

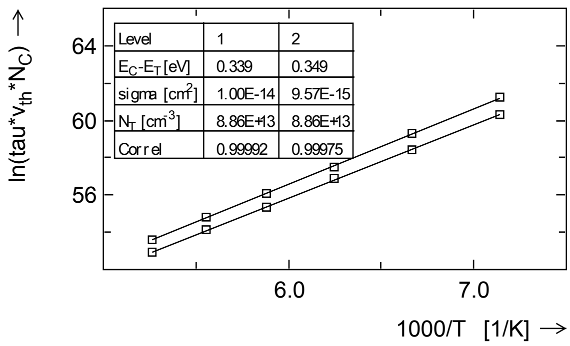
1) transient data
as measured,
separated by Laplace transformation, 2 timeconstants
recalculated and compared with measured data

2) ITS data (1 temperature)
as measured
separated by refolding
recalculated and compared with measured data





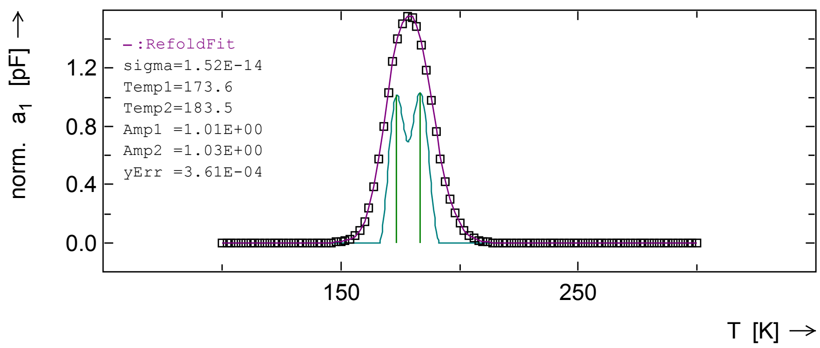




3) ITS measurement at several temperatures

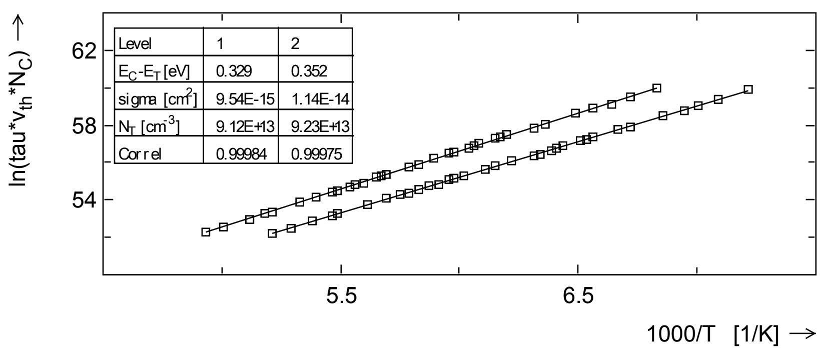
4) Arrhenius plot from plot data 2) and 3)

Simulated data : $E_1 = 0.33eV$, $E_2 = 0.35eV$, $\sigma_{1,2} = 1.0*10^{-14}cm^2$, Amplitude $_{1,2}$ = 1,0pF



Tempscan data (1 correlation function)
as measured,

refolded curve with 2 separated maxima
and eval. timeconstants and amplitudes
recalculated and compared with measured
data



Arrhenius plot from the above tempscan using several measurement files and all (28 per file) correlation functions. (Maximum analysis)

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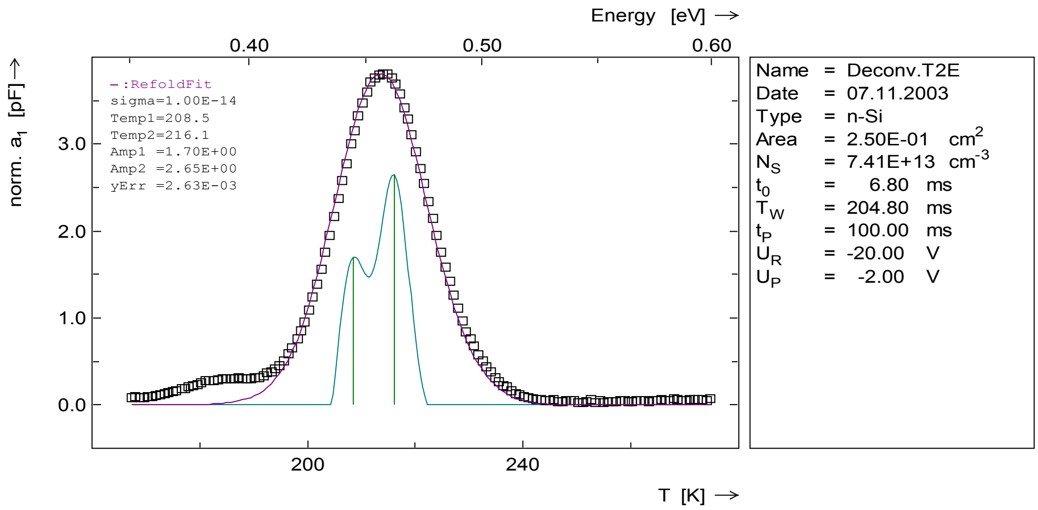
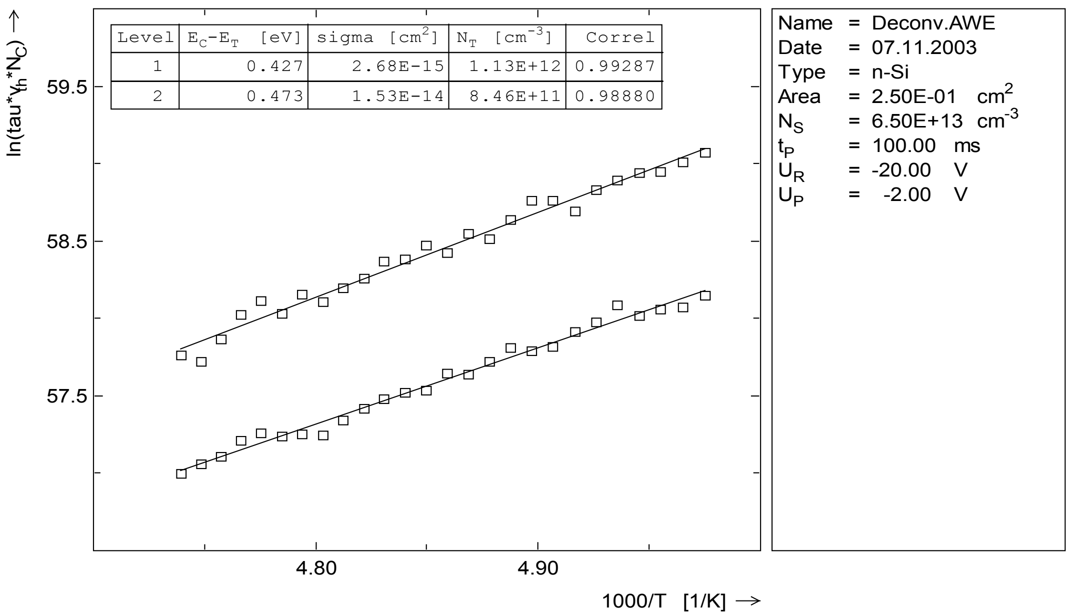
HERA - DLTS Examples

1. Deconvolution of a tempscan signal (measured tempscan)

Plot 1: Tempscan signal and deconvulated curve with evaluated timeconstants (vertical lines)
Plot 2: Arrhenius plot using the measurement from plot 1 with different correlation functions.





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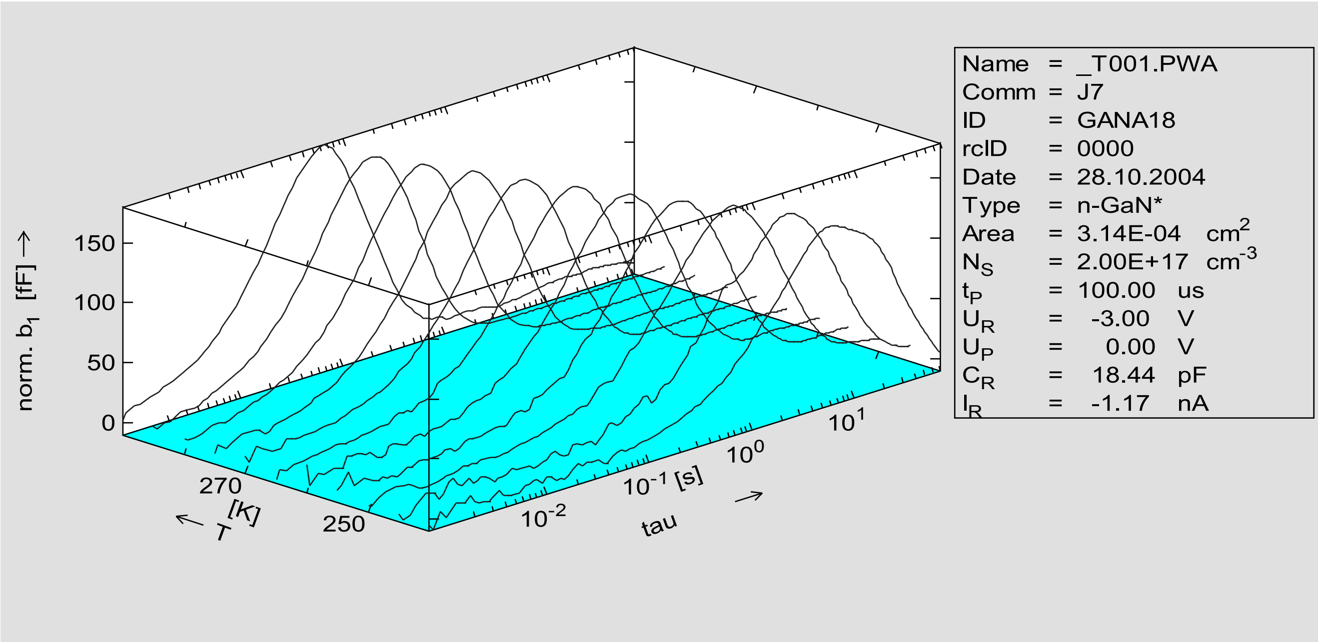
2. Deconvolution of periodwidthscans (similar to frequency or ratewindowscans)

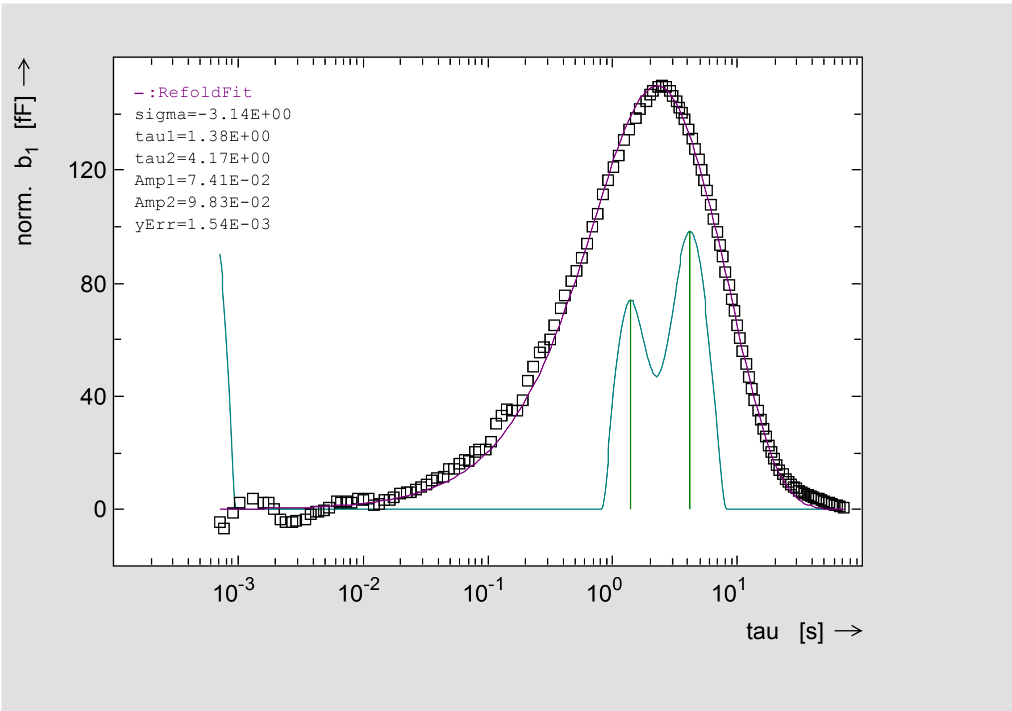
Plot 1: Periodwidthsscans at different temperatures. x-axis recalculated into emission-timeconstant tau (measured signals)

Plot 2: One scan of plot 1 including the deconvulated curve and evaluated timeconstants (vert. lines)



Plot 1

Plot 2



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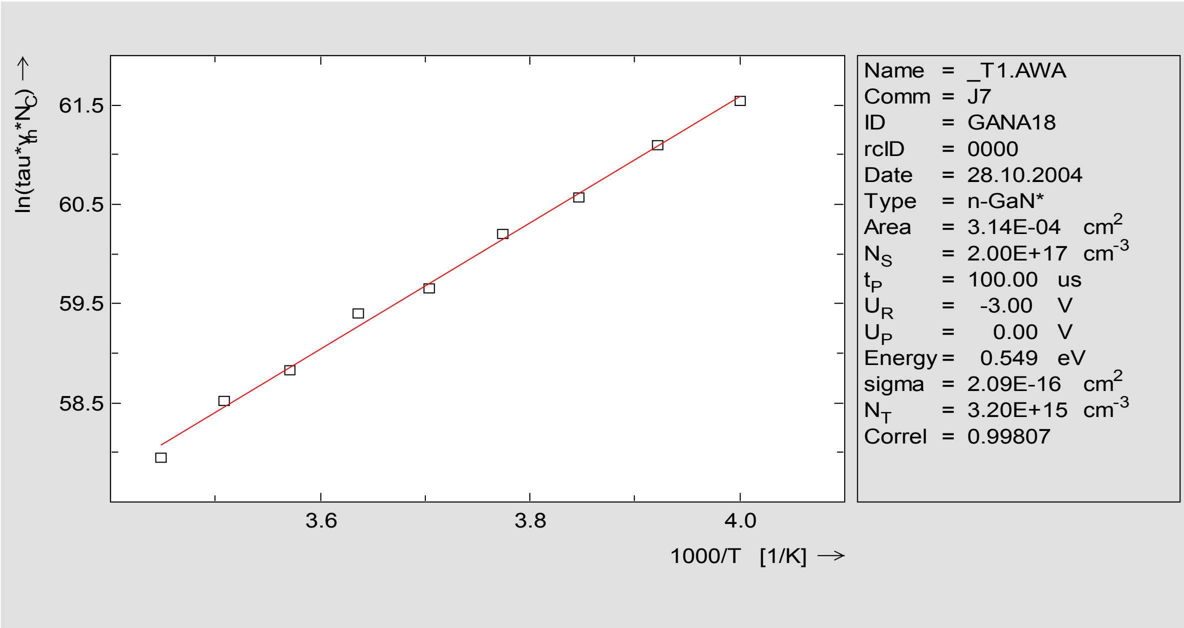
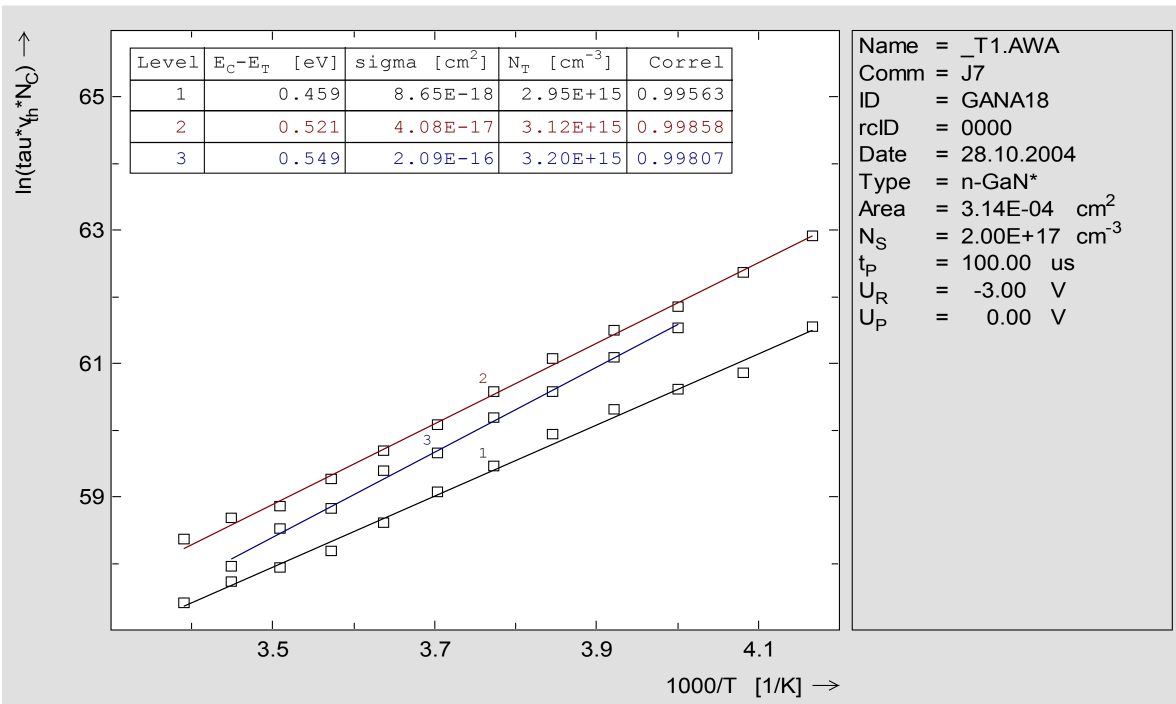
Plot 3: Arrhenius plot from plot 1 data without deconvolution option
Plot 4: Arrheniusplot as plot 3 but using the deconvulated data as shown in plot 2 (level 1 and 2) and compared to the data without the deconvulation as in plot 3.



Plot 3



Plot 4

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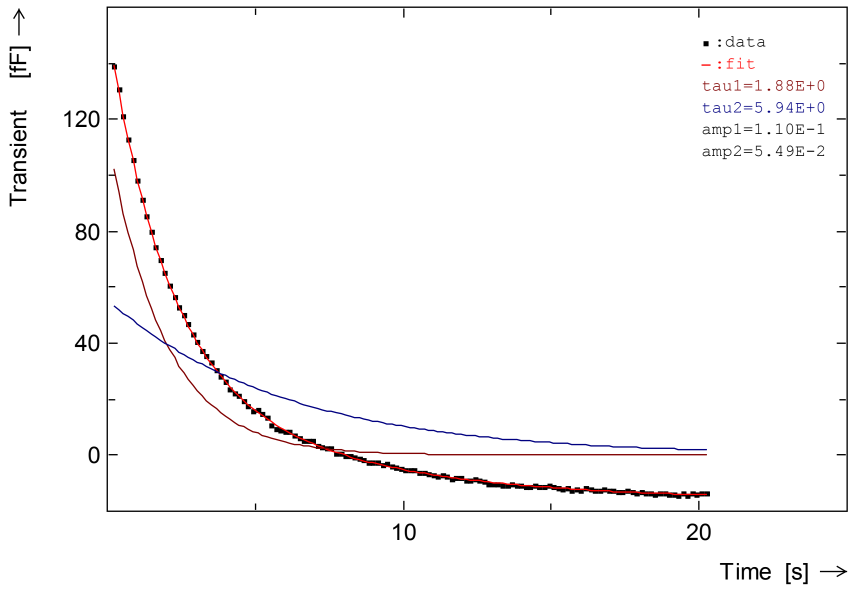
3.Deconvolution of transients by

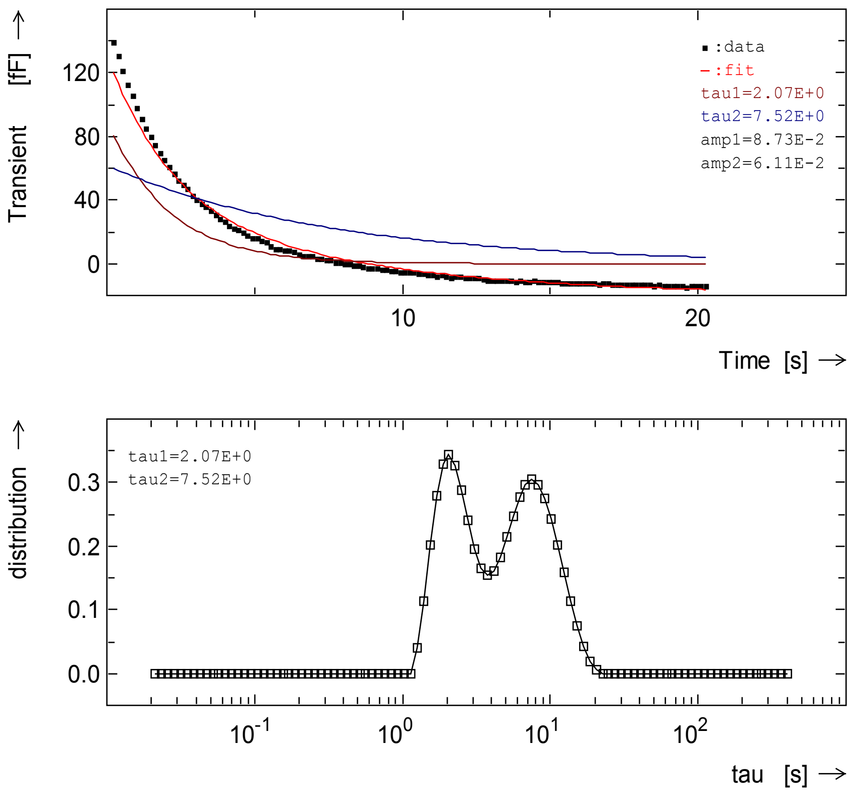
Plot 1: multi exponential transient fit (Provencher discrete very good result).

Plot 2: Laplace transformation (Provencher contin, not as good result for this transient), timeconstant distribution shown in the lower part of the plot.

Plot 1



Plot 2



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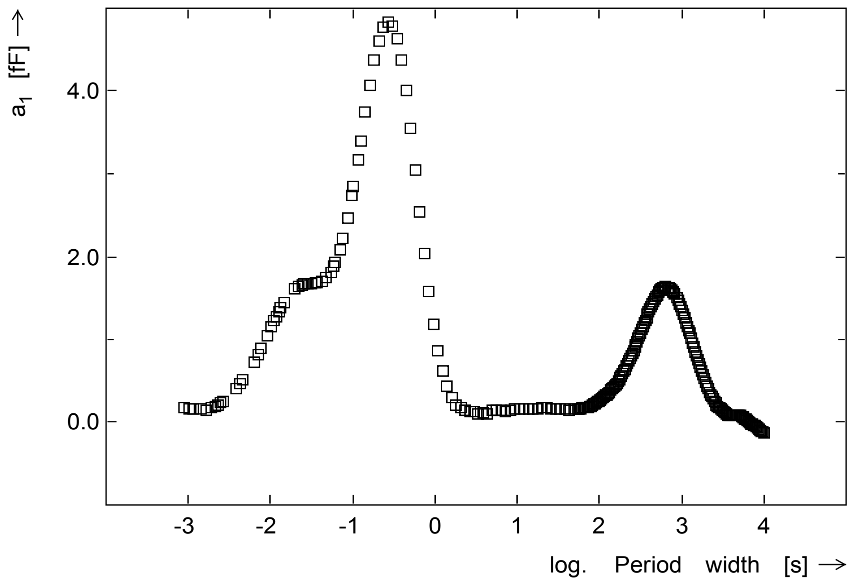
4. Long time (10000 seconds) periodwidthscan (alternative to a tempscan)

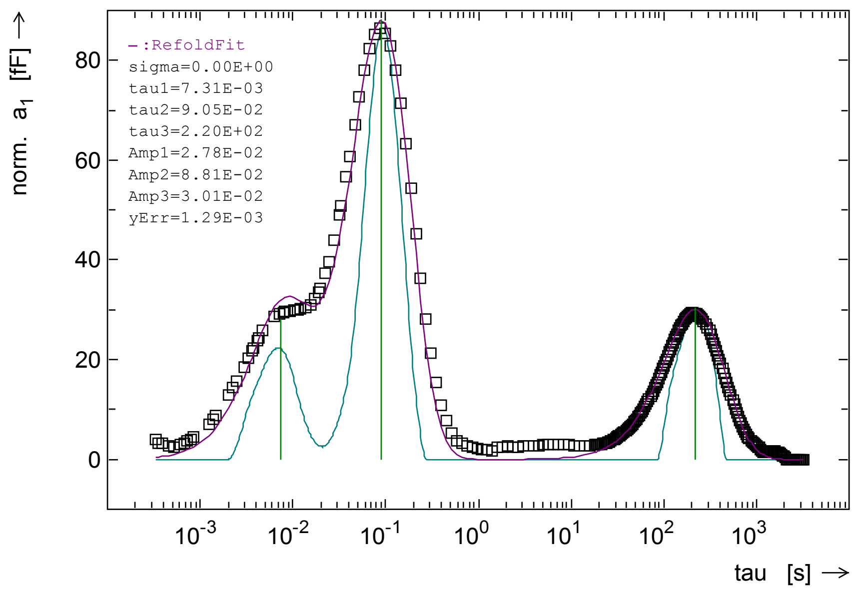
plot 1: as measured (up to 2 s: every datapoint = 1 transient averaged to a total time of 2 s. above 2 s: Only 1 transient measured with 64000 datapoints up to 10.000 seconds. Data points for the different periodwidths are selected from this transient then. This kind of measurement reduces the measurement time to 10% of the standard isothermal periodwidthscan measurement.

plot 2: as 1, but x-axis recalculated into timeconstant tau and the deconvolution used for level finding (maximum definition) and the data fit algorithm for optimizing the timeconstants.

Plot 1



Plot 2



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HERA - **D**eep **L**evel **T**ransient **S**pectroscopie
Measurement System

for determination of energy levels and concentrations of deep impurities (traps) or surface states in semiconductors (p/n junctions, Schottky diodes or MOS capacitors). The system consists of the DLTS IEEE bus controlled electronic hardware (19" bench top case **weight app. 15Kg**) a cryostat and the very powerful measurement software.

HERA-DLTS System HE 1030 electronic hardware:

Specifications:

Bias-/Pulsvoltagesource

voltage range	: -/+ 20V
voltage setting resolution	: 0.3 mV
shortest pulswidth	: 1 µ second
longest pulswidth	: > 1000 seconds

Computer controlled **Amplifier** with automatic gain setting

gain range	: 1 - 1024

Anti-aliasing filter

Digital transient recorder

max. samplings per transient	: 64000
variable oversampling technique	
max. used samples per transient	: 1024
fastest sampling intervall	: 2 µ seconds
longest sampling interval	: 4 seconds

Capacitancemeter
(modified Boonton 72b)
with automatic reverse bias capacitance compensation and automatic range setting

compensation range	: 1 pF - 4200 pF
HF - frequency	: 1 MHz
HF signal	: 100 mV (optional 15mV)
ranges	: 3 pF - 3000 pF (4 ranges)

Current measurement amplifier with automatic range setting

max. measurement current	: 15 mA
current resolution	: 10 pA

(no C-meter attached)
This amplifier can be used for I/V measurements as well as for current transient (I-DLTS) measurements.

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HERA-DLTS HE 1020
complete measurement and evaluation software

C/V , I/V , C(t) measurements

- Shallow level concentration evaluation
- Barrier hight evaluation
- Ideality factor (n-factor) evaluation (Shottky diode)
- Oxide capacitance evaluation (MIS capacitor)
- Zerbst analysis (MIS)
- Single Transient analysis
- **Fourier** transformation, **Laplace** transformation, muli exponential **transient fit,** all for deconvolution of multi emission process transient analysis
- FET-Analysis, parameterized I/V curves, 3D-plots

DLTS (Tempscan measurement / evaluation)

- Routine measurement parameter sets inplemented
- Measurement parameter sets are user definable and can be saved
- Measurements can be started with the saved parameter sets
- 8 different measurement tasks can be used in one temperature run
- Automatic (direct) and manual (maximum analysis) Arrhenius plot evaluation
- **Fourier and Laplace transformation** as well as **multi exponential transient fit Analysis** available in the **direct Arrhenius** evaluation for **signal deconvolution**
- **Tempscan signal refolding** available in the **maximum analysis** for **deconvolution of overlapping signals**
- Automatic I/V C/V measurements during tempscans possible (user definable)
- Trap concentration scan
- C(T) measured in any tempscan
- Energy plot
- Tempscan fit using DLTS algorithm
- 24 different correlation functions used for Arrhenius evaluation
- Arrhenius plot needs only one temperature scan.
- **new** Ns(T) correction, using CR(T) and CP(T) or C/V(T) data measured automatical in a separate temperature scan before the DLTS tempscan

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Isothermal measurements ITS

- Trap concentration scan
- Energy plot
- Capture cross section plot
- 3-D ITS measurement
  Transients are automatically measured under variation of the periodwidth (ratewindow) and one parameter as temperature, pulsewidth etc..
- **Arrhenius Plot evaluation from 3D-ITS measurements including refolding possibilities (as Laplace etc.) for overlapping signal separation**.
- log transient (**enhanced**)
  Linear sampling with automatic change of sampling intervalls. Enables a transient avagering and optimal filtering without loosing the possibilities of a log transient.
- Several ITS signal evaluations
- Trapconcentration profile
- Capture cross section measurement
- Measurement of thermal activated capture cross sections
  (fast puls option and external pulsgenerator e.g. HP 81101 necessary)

Trap library

dBase databank

Routine measurement module

The different refolding (deconvulation) modes of the measured transients, tempscans and periodwidthscans enable an excellent and unbeaten separation of overlapping emission processes. Processes only differing a factor of 2 (ITS) in its timeconstants can be evaluated and energy, capture cross section and trapconcentration can be calculated. Recalculations and comparisons with the measured signals as well as different independant measureing possibilities give a high reliability for the deconvulated and evaluated values of the overlapping processes.
HERA-DLTS combines standard DLTS (boxcar, log-in), digital DLTS (FT 1030) and timeconstant (Laplace-) DLTS in one system. The combination of the special possibilities of all the systems makes the HERA-DLTS much more flexible and reliable as only one of these.