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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 possibilities to separate 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 analyzed for double or multiple overlapping emissions using quite new or well known mathematical procedures (Provencher contin and discrete, www.s-provencher.com) as:

Fourier transformation, **Laplace** transformation, multiple 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 continuously done comparison with the reality, the measured signal, gives an unparalleled energy resolution for DLTS measurements without leaving the trap concentration 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 analysis modes for a separation of overlapping emission signals down to a factor of 3 in it´s time constant 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 analysis** of the temperature (tempscan) or period width (period width scan) depending emission transient measurements.

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

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

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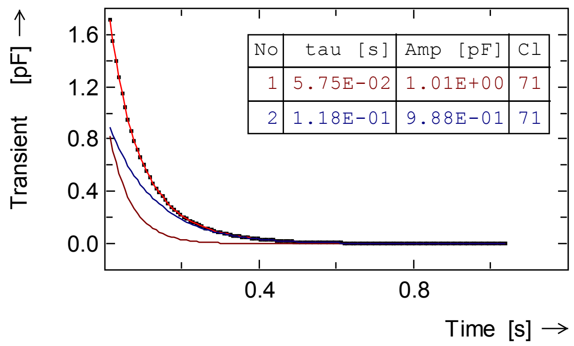
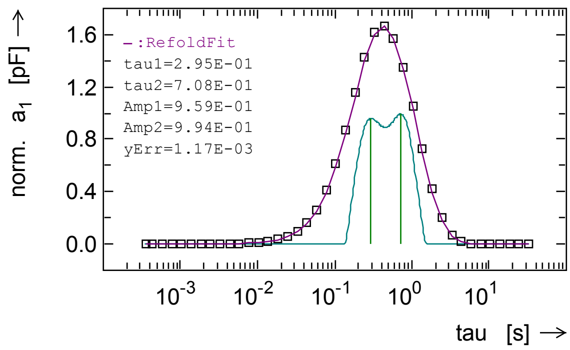
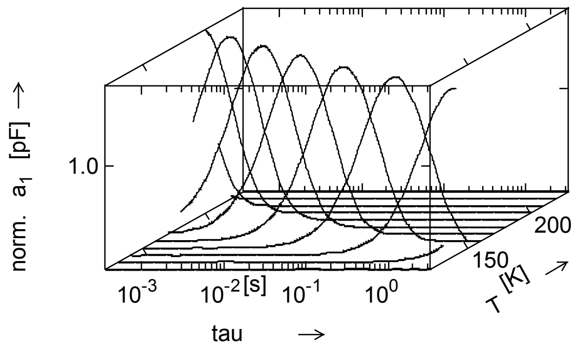
Simulated data : $E_1 = 0.34eV$, $E_2 = 0.35eV$, $\sigma_{1,2} = 1.0*10^{-14}cm^2$, Amplitude $_{1,2} = 1{,}0pF$

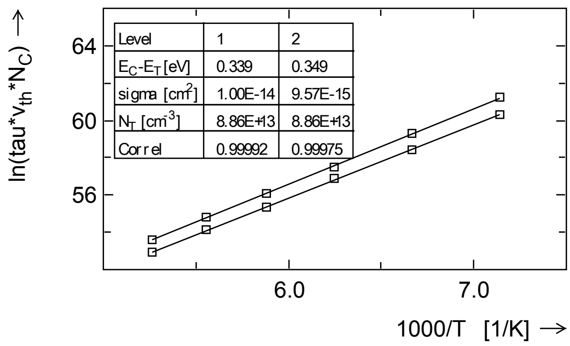
1) transient data
as measured,
separated by Laplace transformation, 2 timeconstants
recalculated and compared with measured data

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





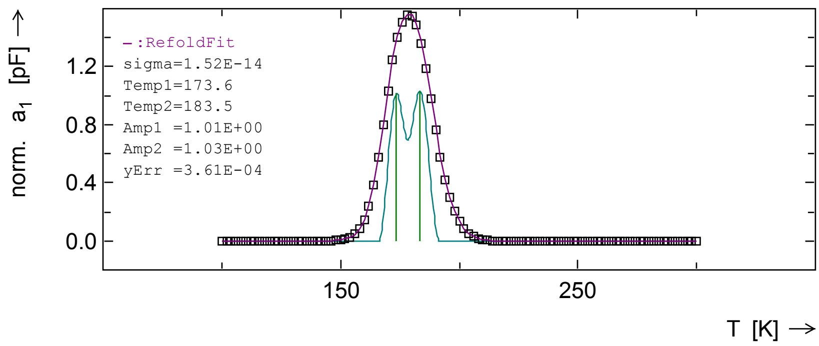




3) ITS measurement at several temperatures

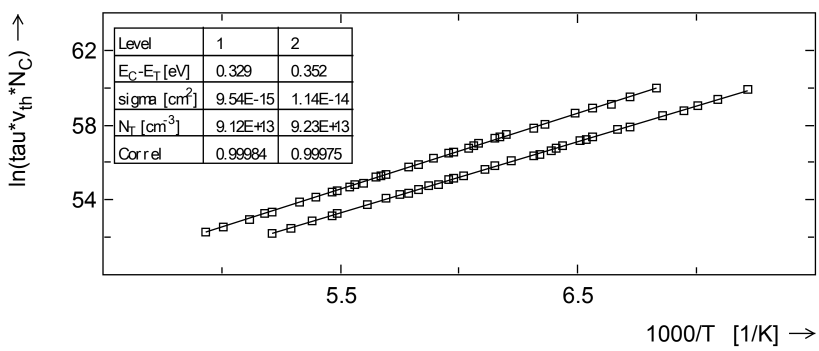
4) Arrhenius plot from plot data 2) and 3)

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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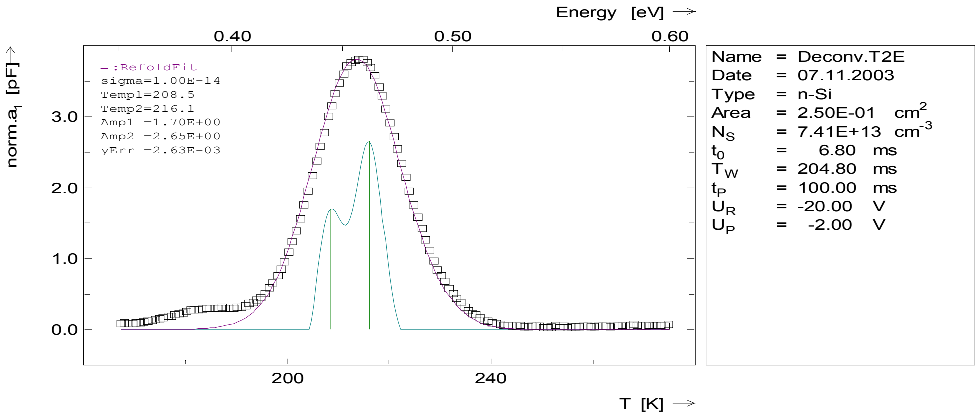
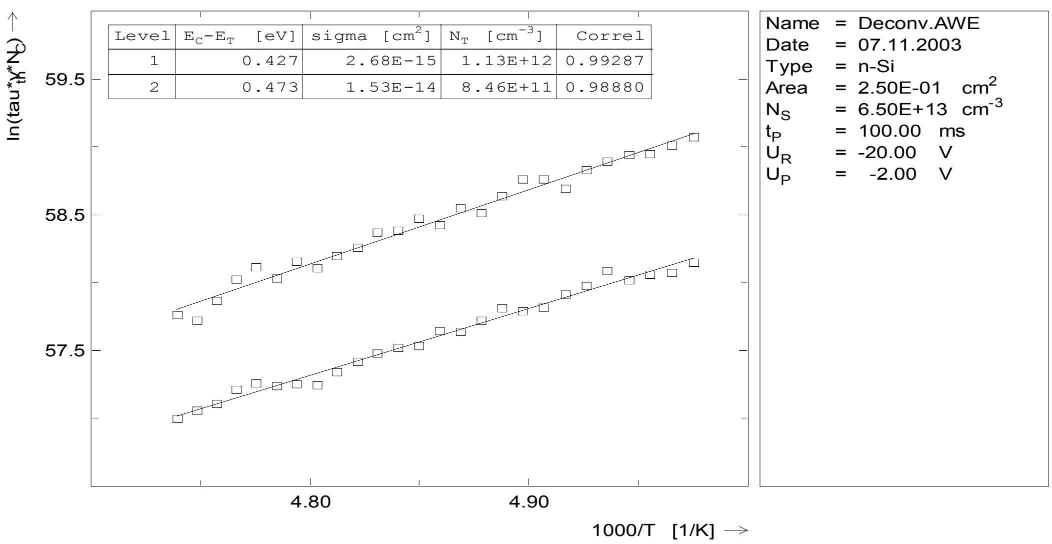
HERA - DLTS Examples

1. Deconvolution of a tempscan signal (measured tempscan)

Plot 1: Tempscan signal and deconvolved curve with evaluated time constants (vertical lines)

Plot 2: Arrhenius plot using the measurement from plot 1 with different correlation functions.





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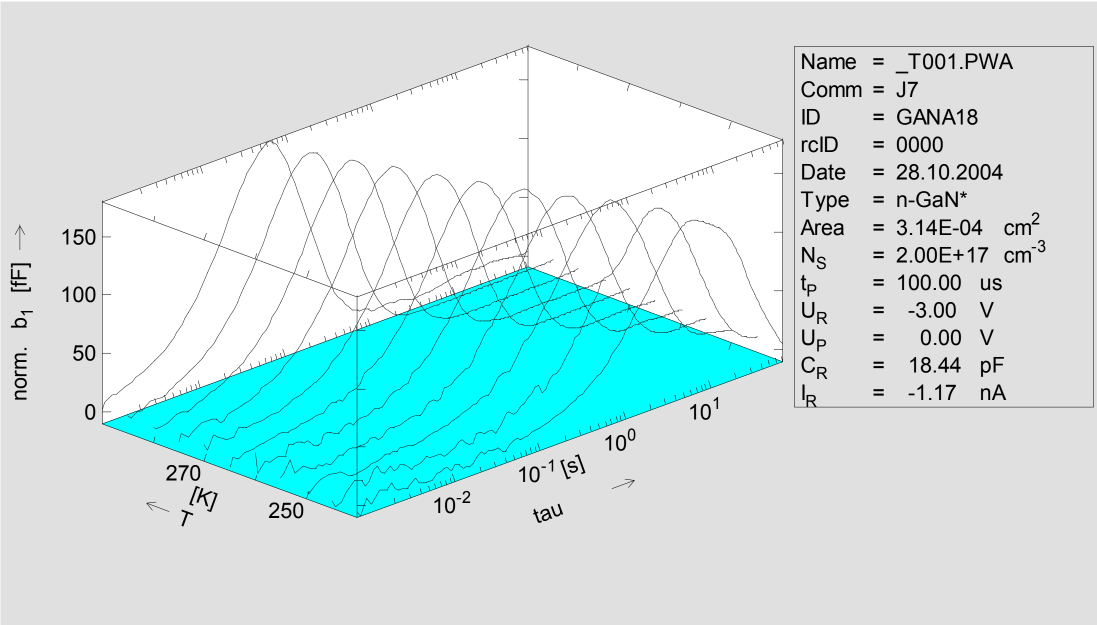
2. Deconvolution of period width scans (similar to frequency or rate window scans)

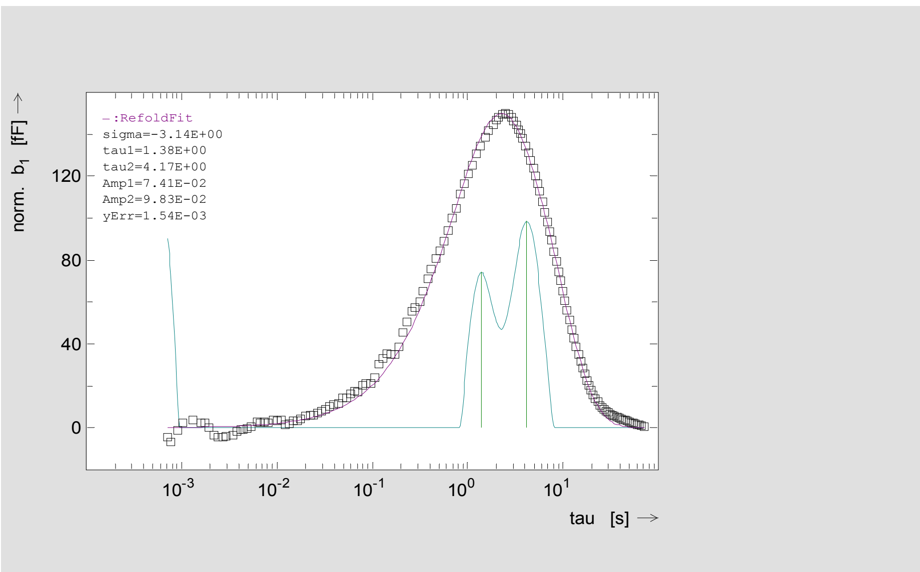
Plot 1: Period width scans at different temperatures. x-axis recalculated into emission-time constant tau (measured signals)

Plot 2: One scan of plot 1 including the deconvolved curve and evaluated time constants (vertical lines)



Plot 1

Plot 2



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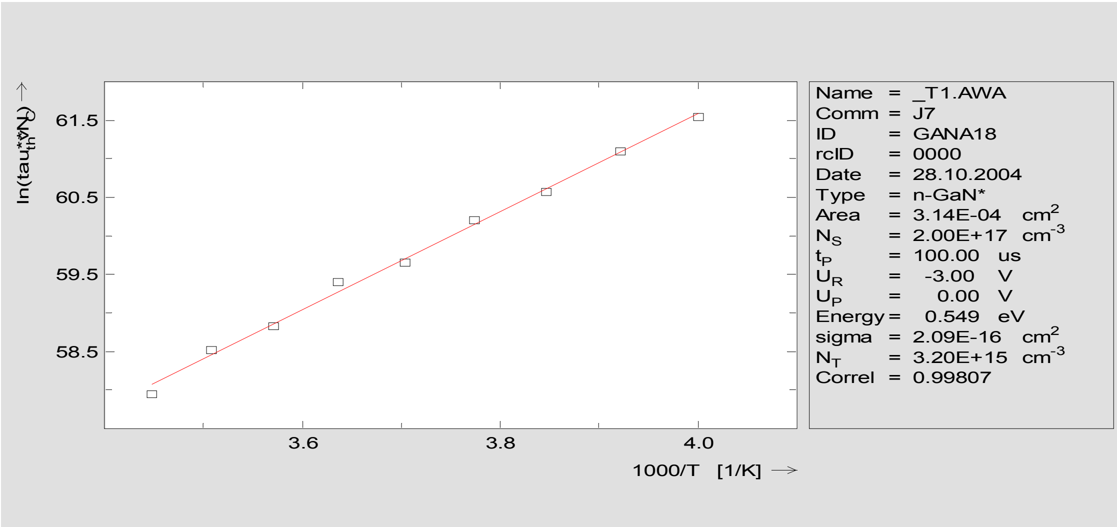
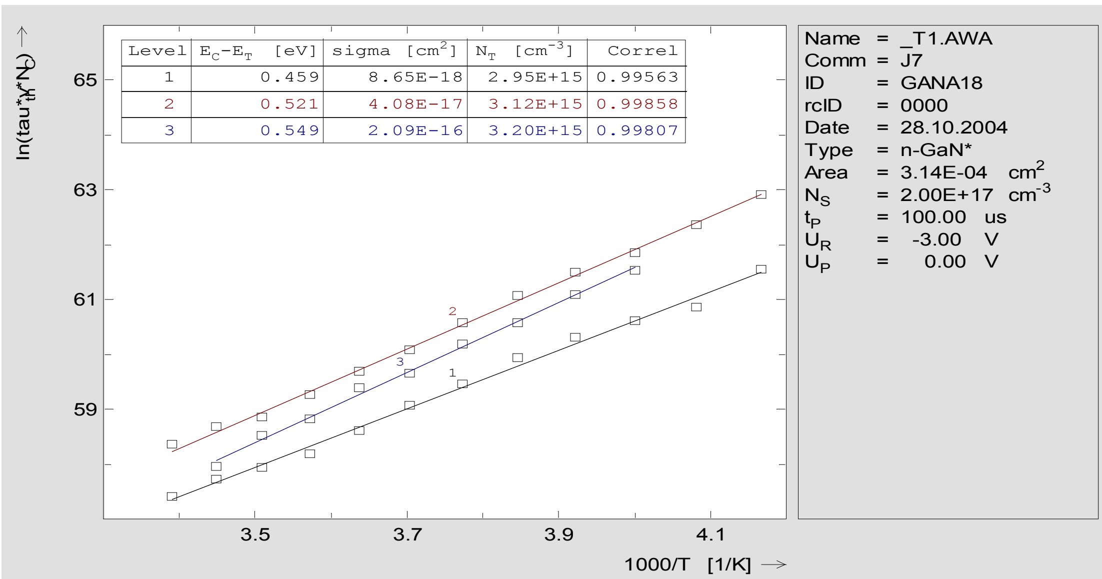
Plot 3: Arrhenius plot from plot 1 data without deconvolution option
Plot 4: Arrhenius plot as plot 3 but using the deconvolve data as shown in plot 2
(level 1 and 2) and compared to the data without the deconvolution as in plot 3.



Plot 3



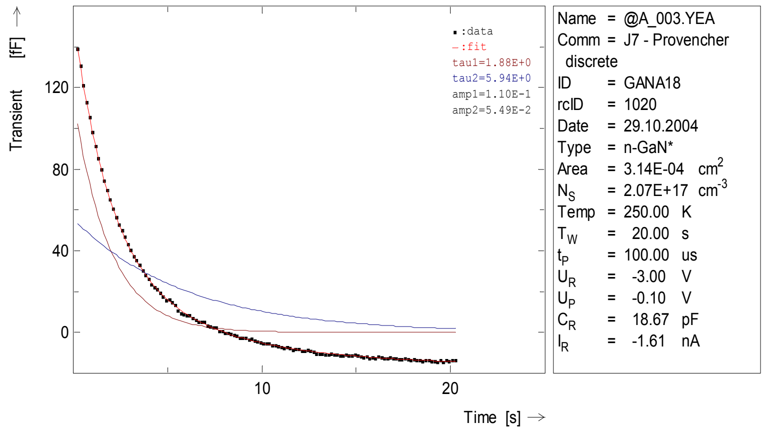
Plot 4

3.Deconvolution of transients by

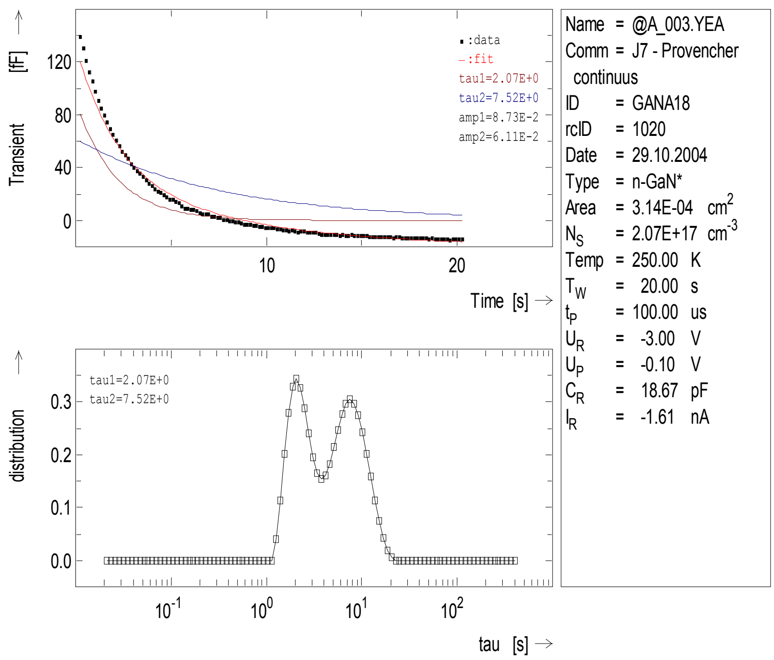
Plot 1: multiple exponential transient fit (Provencher discrete very good result).

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

Plot 1



Plot 2

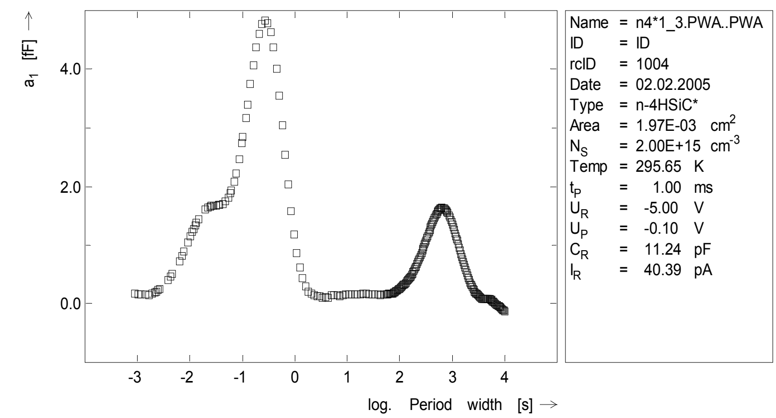


4. Long time (10000 seconds) period width scan (alternative to a tempscan)

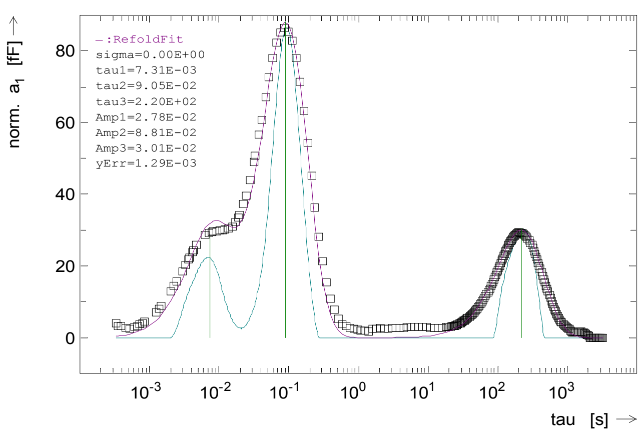
plot 1: as measured (up to 2 s: every data point = 1 transient averaged to a total time of 2 s. above 2 s: Only 1 transient measured with 64000 data points up to 10.000 seconds. Data points for the different period widths are selected from this transient then. This kind of measurement reduces the measurement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

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

Plot 1



Plot 2



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HERA - **D**eep **L**evel **T**ransient **S**pectroscopy
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 **without** cryostat content:

Bias-/Pulse voltage source
voltage range : -/+ 20V (optional +/- 100V)
voltage setting resolution : 0.3 mV (1.5mV with 100V option)

shortest Pulse width : 1 µ second
with optional external fast pulse generator : 20 ns (+/- 10V)
longest Pulse width : > 1000 seconds
optical pulse trigger available at the option port for TTL modulation inputs of laser power supplies

Computer controlled Amplifier with automatic gain setting
gain range : 1 - 1028

Anti-aliasing filter

Digital transient recorder **with variable oversampling technic**
max. samplings per transient : **64000**
fastest sampling interval : 2 µ seconds
longest sampling interval : 4 seconds

Capacitancemeter Boonton 7200
with automatic reverse bias capacitance compensation and automatic range setting
Compensation range : **1 pF - 3300 pF**
HF - frequency : 1 MHz
HF signal : **15mV, 30mV, 50mV, 100mV**
ranges : **2 pF - 2000 pF (4)**

Current measurement amplifier with automatic range setting
max. measurement current : 15 mA
current resolution : 10 pA
This amplifier can be used for I/V measurements as well as for current transient (I-DLTS) measurements
Automatic configuration change from capacitance- to current - DLTS

Nearly all cryostats are supported

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HERA-DLTS System HE 1030

available DLTS modes

- C-DLTS (Capacitance DLTS)
- CC-DLTS (Constant Capacitance DLTS , with CC option)
- I-DLTS (Current DLTS)
- Q-DLTS (Charge -DLTS)
- FET DLTS (3 term DLTS 2^{nd} voltage source included as a standard)
- DD-DLTS (Transient difference DLTS)
- ITS (Isothermal Transient (C or I) Spectroscopy)
- PICS (Photon induced transient (C or I) spectroscopy
- Capture DLTS (capturing transient measurement)
- Laplace-DLTS (Logarithmic transient measurements and evaluations)
- MIS - Nss DLTS (Surface states density measurement and evaluations)
- MIS - Zerbst DLTS (Minorier carrier generation / lifetime measurements)
- C(V), I(V), C(t), I(t)

Evaluation modes:

- Correlation DLTS

  28 different correlators (software) are used

  only **one temperature scan is needed** for 28 tempscans and 28 Arrhenius plot points for one measurement parameter set

  18 different measurement parameter sets (bias voltage, pulse voltage/width/mode, etc.) can be defined to be measured in one temperature scan

- Fourier evaluation

  our direct timecionstant evaluation

- Laplace evaluation

  inverse Laplace transformation for evaluating one or more timeconstants in a measured transient (C,CC,I,Q etc.)

- HERA DLTS

  deconvolution of strongly overlapping tempscan or ITS signals with a special refolding mathematics.

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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 height 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 implemented
- 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 **multiple 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 automatic 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 period width (rate window) and one parameter as temperature, pulse width 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 intervals. Enables a transient averaging and optimal filtering without loosing the possibilities of a log transient.
- Several ITS signal evaluations
- Trap concentration profile
- Capture cross section measurement
- Measurement of thermal activated capture cross sections
  (fast pulse option and external pulse generator e.g. HP 81101 necessary)

Trap library

dBase databank

Routine measurement module

The different refolding (deconvolution) modes of the measured transients, tempscans and period width scans enable an excellent and unbeaten separation of overlapping emission processes. Processes only differing a factor of 2 (ITS) in its time constants can be evaluated and energy, capture cross section and trap concentration can be calculated. Recalculations and comparisons with the measured signals as well as different independent measuring possibilities give a high reliability for the deconvolve and evaluated values of the overlapping processes.
HERA-DLTS combines standard DLTS (boxcar, log-in), digital DLTS (FT 1030) and time constant (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.