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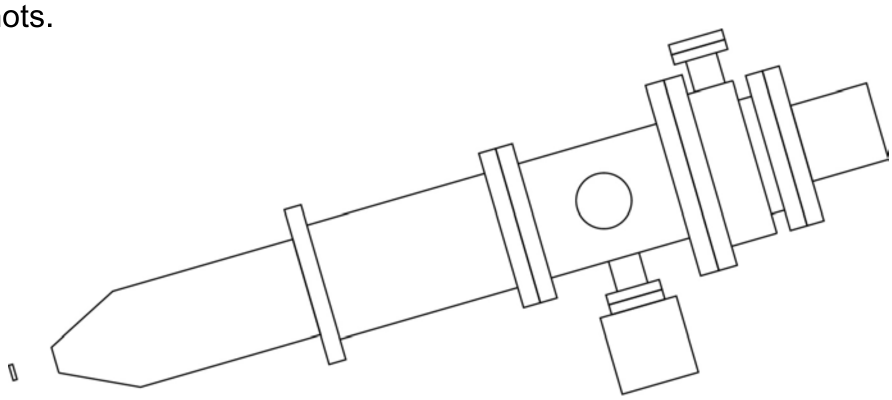
Time of Flight Spectrometers THEMIS 1000 / THEMIS 600

Technical Note

The THEMIS time-of-flight spectrometer series complements the SPECS photoemission spectrometer line with an instrument ideally suited for pulsed photon sources. The design of this state-of-the-art instrument is based on the renowned PHOIBOS 100/150/225 spectrometer series. The extensively optimized electron lens with the proven 3D-DLD detector technology enables most flexible operation, with experiments ranging from extreme resolution spectroscopy to highest transmission snapshots.



- parallel angle and energy detection with up to +/-13° and 70 eV windows
- full spectrum and full emission cone for each photon pulse
- kinetic energy ranges 0 - 40 eV, 0 - 400 eV, 0 - 3500 eV
- high energy option up to 15 kV
- energy resolution down to < 200 μeV
- angular modes with +/- 13°, +/- 7°, +/- 3.5° and +/- 2° acceptance angle
- spatial resolving modes with 10x, 5x and 2x magnification
- 3D-DLD detector with 3 MHz maximum count rate
- accelerating and retarding operation with retard ratios from 0.05 – 1000
- two sizes THEMIS 1000 or 600

The THEMIS spectrometers require a pulsed light source like e.g. a Laser or a Synchrotron. The light pulse defines the start time of the time-of-flight analysis. The 3D-DLD delayline detector at the end of the lens detects each electron's arrival time and it's position. The arrival time depends on the electron's kinetic energy, and the position is determined by the electron emission angle. This way, a full 3-dimensional data volume with polar emission angle, azimuthal emission angle and kinetic energy of the electron can be acquired in parallel.

The angular cone and the length of the energy spectrum that can be acquired in parallel depends on the lens mode. Since the THEMIS lens is optimized for minimum chromatic aberrations, a very long energy window can be acquired in parallel. By choosing the lens parameters, the performance can be varied from extremely high transmission (full spectrum per shot) up to extreme energy resolution (selected small energy window per shot).
The raw data from the detector (position and flight time for each electron) can be precisely transformed into emission angle and energy coordinates using a transformation matrix. There, the long experience gained with the optimization of the PHOIBOS lenses leads to very precise transformation matrices that can be applied to the data. Due to the high imaging quality of the THEMIS lens, the spectral and angular features of the experiment are immediately visible even in the non-transformed raw data.

To estimate the performance of the THEMIS spectrometers, the plots below show the look-up diagrams to transform time/position data into energy/angle values for the THEMIS 1000. Also given are the expected energy a resolution at different kinetic energies, the angular resolution, and the flight time for an extremely slow electron with 0.001 eV (this can be used to estimate the effect of data overlap with former laser pulses some microseconds ago).
We have chosen four typical experiments:

A) A +/- 7° overview of a femtosecond-Laser excited spectrum from 0.3 – 2.3 eV kinetic energy

B) A +/- 13° data set of a femtosecond Laser spectrum, taken in two overlapping slices from 0.35-1.05 eV and from 0.75-2.25eV

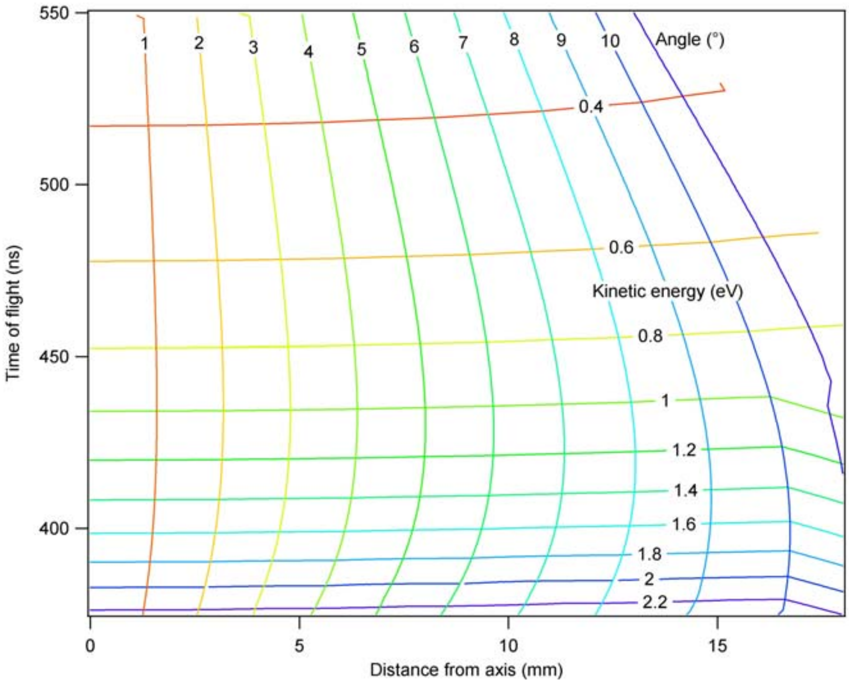
C) A +/- 7° overview spectrum of 30 eV HHG-Laser from 10 - 30 eV kinetic energy

D) A +/-7° data set of the 30 eV HHG-Laser spectrum, taken in three slices from 19.5 – 22.5 eV, 22.5 – 26 eV and 26 – 30 eV

The simulations for the look-up diagrams have been done for a 0.25 mm emission spot and a detector time resolution of 100 ps.

A) Overview, +/- 7°, 0.3 – 2.3 eV

Energy resolution:	2.7 meV @ 2 eV 1.1 meV @ 1 eV 0.8 meV @ 0.3 eV
Slow electron:	2270 nsec @ Ekin = 1 meV
Angle resolution:	< 0.2° @ 0.25 mm spot size



Conversion of time/position data into energy/angle values. Calculated for R = 0.05, +/- 7° mode.

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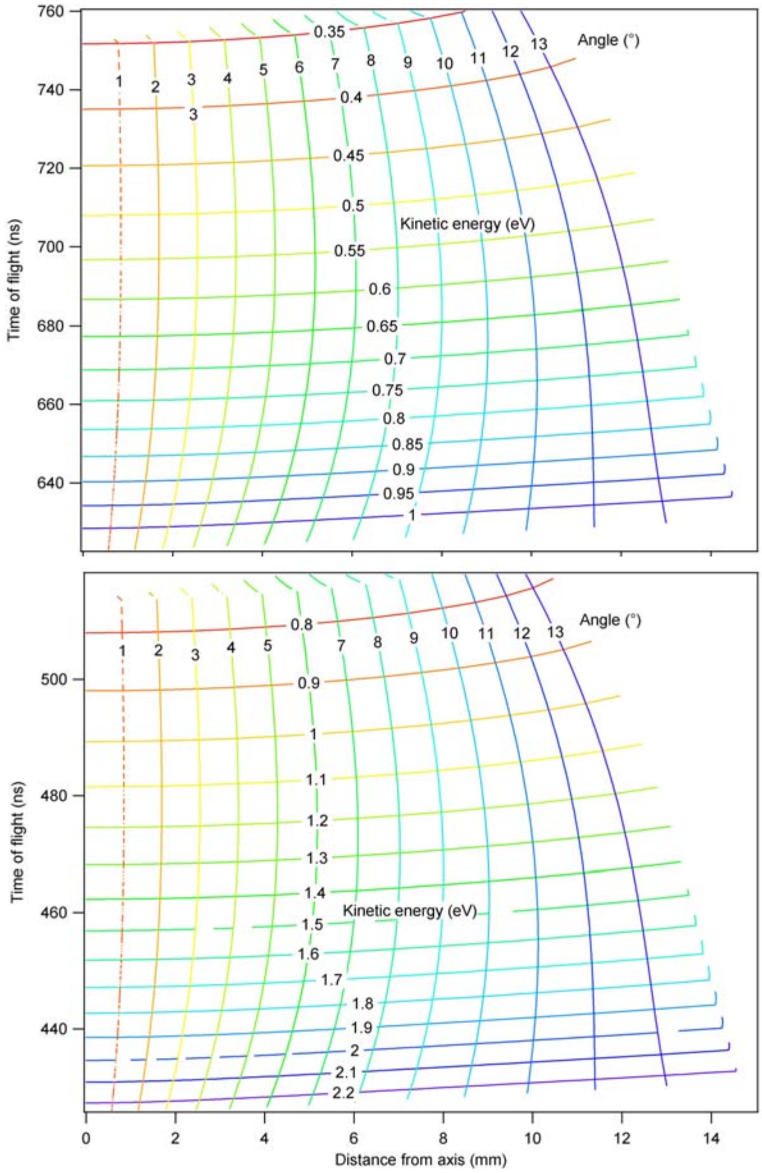
B) Two slices, +/- 13°, 0.35 - 1.05 eV and 0.75 - 2.25 eV

Energy resolution:	0.8 meV @ 1 eV 2.5 meV @ 2 eV
Slow electron:	2400 nsec @ Ekin = 1 meV
Angle resolution:	< 0.18° @ 0.25 mm spot size



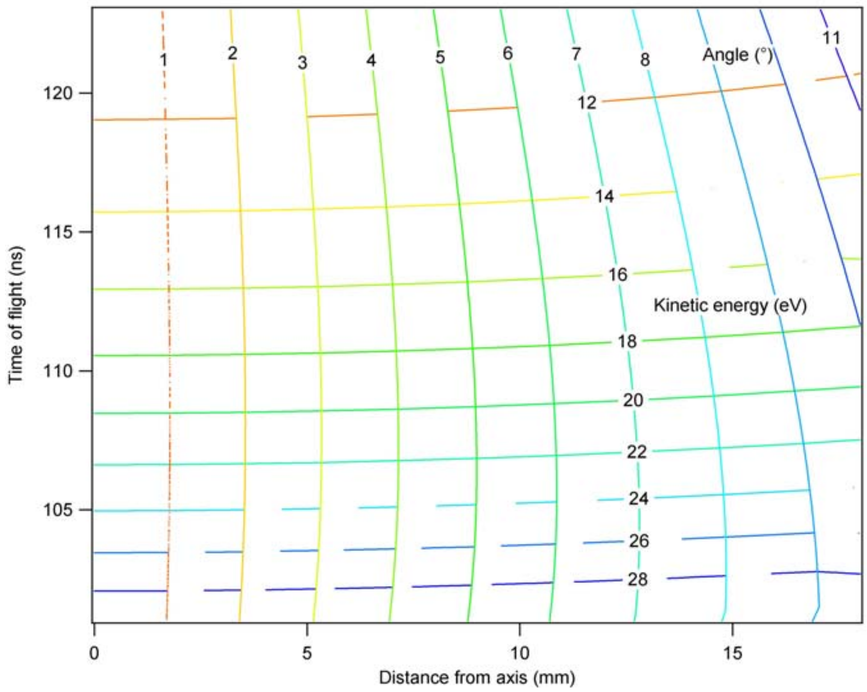
Conversion of time/position data into energy/angle values for each slice. Since both slices are calculated with R = 0.1 (+/- 13° mode), the transformation matrix is the same for both slices.

C) Overview, +/- 7°, 10 – 30 eV

Energy resolution: 38 meV @ 10 eV
150 meV @ 30 eV

Slow electron: 2100 nsec @ Ekin = 1 meV

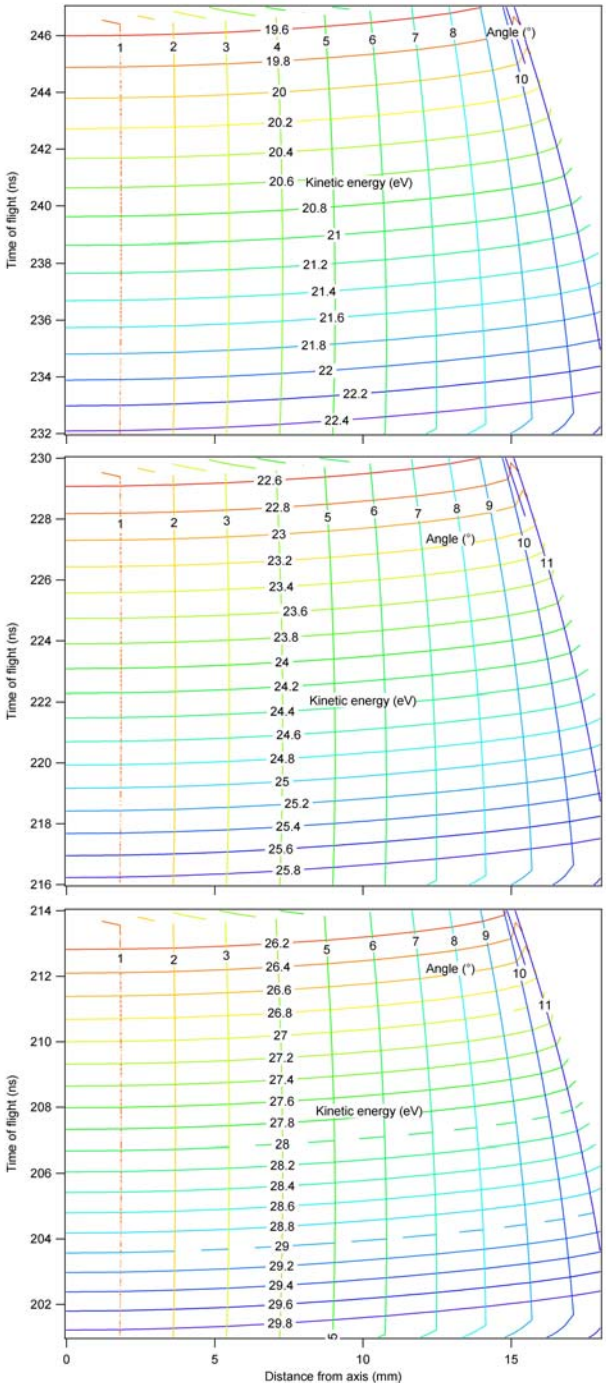
Angle resolution: < 0.16° @ 0.25 mm spot size



Conversion of time/position data into energy/angle values.
Calculated for R = 0.1, +/- 7° mode.

C) Three slices, +/- 7°, 19.5 - 22.5, 22.5 – 26, 26 – 30 eV

Energy resolution:	16 meV @ 20 eV 31 meV @ 30 eV
Slow electron:	only electrons with Ekin > 8 eV can pass the lens
Angle resolution:	< 0.07° @ 0.25 mm spot size



Conversion of time/position data into energy/angle values for each slice. Since all slices are calculated with R = 1.4, the transformation matrix is the same for all slices.

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