QUANTAX EDS

- Slim-line Technology for SEM and TEM
Excellence in X-ray Analysis for the Electron Microscope

The new generation of QUANTAX EDS features slim-line technology and a wide range of active areas for the XFlash® 6 detector series. Combined with the new enhanced hybrid pulse processor Bruker’s EDS detectors once more set the standard in performance and functionality. Generation 6 provides hardware and software technology to deliver the fastest and most reliable results in nano-research.

QUANTAX – your powerful tool for X-ray spectrometry

- Save time – new slim-line technology detectors, large area SDDs, and high performance pulse processing get the job done faster
- Save effort – motorized detector movement and light weight design make detector handling easier
- Gain more precision – best energy resolution provides the highest quality spectra for precise analysis
- Gain more reliability – the world's most comprehensive atomic database ensures most dependable low energy peak identification
- Gain more accuracy – the most sophisticated algorithms for quantification and the unique combinability of standardless and standard-based methods provide highest accuracy results
The 6th Generation of XFlash® Detectors

Wide range of detector sizes offered with and without light element window
- 10, 30, 60 and 100 mm² active area detectors offer ideal solutions for micro- and nanoanalysis

Best energy resolution for light element and low energy analysis
- 121 eV limited edition
- 123 eV ultimate
- 126 eV premium
- 129 eV standard
- All resolutions specified exceeding ISO 15632:2012 requirements

Ultra high throughput for fastest measurements
- New signal processing unit with hybrid technology
- Over 1,500 kcps input count rate
- Over 600 kcps output count rate

Slim-line detector technology for even more counts and lower beam currents
- Shortest detector to sample distances for maximum solid angle in SEM, FIB-SEM, EPMA and TEM
- Best available take-off angle for TEM

Compact design and low weight
- High precision slider with fully integrated motor for precise positioning
- Improved heat sink geometry for stable measurement conditions
- Maximum detector weight of 3.75 kg
XFlash® 6 – the Right Choice for any Application

Every analytical task has different requirements. Bruker offers detectors in different designs and with various active areas to ensure optimal conditions for any individual application. All detectors offer best solid angle per active area.

XFlash® 6 for SEM

Bruker offers a complete range of detectors with and without light element window (without window for higher detector quantum efficiency) for SEM, FIB-SEM, and EPMA. XFlash® 6 | 10 and 6 | 30 cover the majority of applications, including high beam current analysis, low voltage (nanoanalysis) and low vacuum operation. XFlash® 6 | 60 and 6 | 100 cover less common areas, like low beam current applications or beam-sensitive samples.

XFlash® 6 | 10 – the best resolution SDD
- 10 mm² detector delivering 121 eV at Mn Kα – the best resolution in the market
- Excellent light element and low energy performance

XFlash® 6 | 30 – the highly efficient, versatile SDD
- Mid-size 30 mm² SDD for both nanoanalysis and high count rate spectral imaging
- Perfect companion for high speed EBSD analysis

XFlash® 6 | 60 – the large area SDD for nanoanalysis
- 60 mm² SDD for low beam currents
- Ideal for analysis of nanoparticles, biological samples and the like

XFlash® 6 | 100 – the largest area SDD for low current applications
- 100 mm² active area for special analytical situations
- The ideal choice for low beam current SEMs (cold field emitters) and very sensitive samples
**XFlash® 6T for TEM**

Bruker XFlash® 6T – the large solid angle detectors for TEM and S/TEM offer minimum mechanical and electromagnetic interference. They provide optimum take-off angle and avoid the necessity of sample tilt.

**XFlash® 6T | 30 – the first SDD for aberration corrected TEM**
- Allrounder for TEM analysis with mid-size 30 mm² chip

**XFlash® 6T | 60 – the large solid angle SDD for Å-scale TEM analysis**
- 60 mm² active area detector for analysis under low X-ray yield conditions

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CuO-coated multi wall carbon nanotubes with Co-catalyst particles analyzed with the XFlash® 6T | 30, spot size 1.5 nm, 400 pA beam current. The measurement was performed with two different acquisition times: 3 min (left) and 47 min (right). It can be seen that the 3 min measurement already shows almost all relevant structures, while the longer acquisition time adds detail. Sample courtesy: S. Herrmann, T. Wächtler, Chemnitz University of Technology

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**SDD**

Silicon drift detector (SDD) technology for EDS analysis on SEM and TEM was commercially introduced by Bruker. The SDD is a type of energy dispersive solid-state detector. It utilizes a special drift field structure to guide charges produced by absorbed X-rays to an extremely small readout anode. The structure is optimized for each type of SDD – smaller droplet (A) and larger round detector (B) – for efficient charge transportation. Additionally, the XFlash® uses an on-chip amplifier to achieve energy resolutions suitable for EDS element analysis with only moderate cooling, achieved with thermoelectric Peltier coolers. The drift fields, the low capacitance of the readout anode, and the integrated FET ensure the excellent energy resolution and high speed of Bruker’s detectors.
**Best Energy Resolution for Challenging Tasks**

XFlash® 6 is available with unrivaled 121 eV at Mn Kα, providing the excellent energy resolution needed to analyze complex samples – especially in the light element and low energy range below 1 keV.

Excellent energy resolution specifically in the low energy range is essential for ambitious tasks in nanoanalysis. For silicon-based detectors energy resolution typically changes with line energy. The resolution curve of a 121 eV XFlash® 6 detector exactly follows the theoretical curve of the fundamental limit for the energy resolution. Other SDDs with external field effect transistor (FET) deviate from this curve in the difficult low energy range, due to incomplete charge collection (ICC), which is commonly corrected by software.

**Energy resolution**
The power of energy dispersive X-ray detectors to resolve adjacent X-ray lines. The energy resolution is commonly measured on peaks recorded from Mn Kα radiation and expressed in terms of the full width at half maximum (FWHM). Energy resolutions for detectors are usually specified in accordance with ISO 15632:2012, where the energy resolution of the Kα peaks of manganese (Mn), carbon (C) and fluorine (F) must be given. The smaller the value, the better the energy resolution of the detector.

<table>
<thead>
<tr>
<th>Resolution at Mn Kα / eV</th>
<th>Resolution at F Kα / eV</th>
<th>Resolution at C Kα / eV</th>
</tr>
</thead>
<tbody>
<tr>
<td>121</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>123</td>
<td>54</td>
<td>46</td>
</tr>
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<td>126</td>
<td>60</td>
<td>51</td>
</tr>
<tr>
<td>129</td>
<td>67</td>
<td>57</td>
</tr>
</tbody>
</table>

The different classes of the XFlash® 6 are characterized by their energy resolution at the Mn Kα line. The best class with unrivaled resolution of guaranteed 121 eV is available for the most demanding analytical tasks. This class provides a typical energy resolution of 40 eV for C Kα! Note that a change of only 8 eV at Mn Kα results in 17 eV resolution improvement for C Kα, more than doubling the resolving power for light elements. All XFlash® 6 resolutions are specified exceeding ISO 15632:2012 requirements.
The XFlash® 6 detector with its outstanding energy resolution solves analytical challenges like never before: This boron map of a weld seam shows different borides that are distinguished by their boron content:

The phase with the highest boron content (red) is chromium boride, chromium nickel boride (green) has intermediate boron content, and trinickel boride (Ni$_3$B, blue) has the lowest boron content.

The comparison of two light element spectra obtained with a 129 eV detector (blue) and a 121 eV XFlash® 6 detector (red) clearly shows the advantage of the better resolving detector. The higher and narrower peaks provide a better basis for deconvolution and lower limits of detection.

Overlay of the low energy range of a Si and a W spectrum measured with the 121 eV XFlash® detector. Note that the excellent energy resolution of this detector is almost sufficient to separate the Si K and W M lines. Also the Si L line is clearly visible, although the excitation voltage is relatively high at 7 kV. The W N lines can be seen in the low energy slope of the carbon contamination peak. Deconvolution confirms this finding.
Versatile Signal Processing

The new signal processing unit with hybrid technology is a key component of the new QUANTAX. It offers superior pulse processing speed and guarantees reliable results at any count rate. The processor is capable of over 600 kcps output count rate at more than 1,500 kcps input.

Fast and accurate
- Noise free sensor supply
- Precise temperature control
- Ultra high throughput
- Optimum energy resolution
- Automatic operation (user control optional)

Versatile and safe
- Support of up to four detectors in one system
- Separate slider control for each detector
- Hardware and software interlock for safe detector operation

Input count rate
The number of X-ray quanta per unit time registered by the detector and converted to pulses arriving at the signal processor.

Output count rate
The rate of signal pulses/counts actually contributing to the spectrum. The output/net count rate is reduced with respect to the input count rate by the value of dead time.

Dead time
The percentage of time the signal processor is occupied with processing signals and therefore unable to accept further pulses. Dead time is inherent to all photon-counting detectors and increases with the pulse load.

Output vs. input count rate for selected shaping times, specified by the maximum output count rate they deliver

X-ray signal processors typically provide a variety of shaping times to adapt to different signal conditions. QUANTAX frees the user of the task of searching for the right selection by always choosing the optimum shaping time automatically.
With the 6\textsuperscript{th} generation Bruker’s well proven signal processing technology is taken to the next level, providing the perfectly optimized signal analysis setting for any combination of

- Detector size
- Input count rate, and
- Energy resolution requirement

Tiled high count rate map of a pitchblende sample. The complete image was recorded using an XFlash\textsuperscript{®} 6 | 30. The extracted map shows the richness of detail attainable in less than an hour total acquisition time.
High Count Rates for More Productivity

Many applications like mapping or particle analysis require high count rates. With XFlash® 6 their adverse effect on energy resolution is minimal or even nonexistent. XFlash® 6 provides best energy resolution up to 100 kcps count rate and still delivers reasonable resolution at an outstanding input count rate of 1,500 kcps.

Advanced Si(Li) detectors show fairly good energy resolution at low count rates, but even medium count rates can only be processed at the cost of poorer energy resolution. SDDs generally expand the range of count rates with optimum energy resolution (BERR) while detectors with an integrated amplifier (internal FET) take this to the limit.

XFlash® 6 combines the best available detector technology with an optimized and well adapted hybrid signal processor.

Solid angle
A most important performance figure for a detector since it determines the portion of the total of X-rays emitted by the sample that can be registered. It is defined as the section of an imaginary sphere around the sample that is covered by the active area of the detector when it is in working position. Solid angle is measured in steradian (sr) and roughly proportional to active area divided by the square of the sample-detector distance. This stresses the importance of the detector to sample distance:
A detector with small active area close to the sample can achieve the same or a better solid angle than a detector with large active area but longer distance to the sample.

Take-off angle (TOA)
The mean angle at which the part of the X-rays that is recorded by the X-ray detector leaves the sample surface. A higher TOA reduces self-absorption and sensitivity to surface contamination or coatings.

Best energy resolution range (BERR) of different detectors

<table>
<thead>
<tr>
<th>Input count rate (kcps)</th>
<th>Si(Li)</th>
<th>SDD, external FET</th>
<th>XFlash® 6, internal FET</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>100</td>
<td></td>
<td></td>
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</tbody>
</table>
**Slim-line, Compact and Flexible**

All XFlash®6 detectors feature slim-line technology and compact, light-weight design. The advantages are optimum acquisition conditions, including large solid angle and high take-off angle, as well as low load on the column, highly efficient cooling and convenient use.

**Slim-line technology means ultra-thin detector fingers, providing**
- Maximized solid angle
- Clearance of other detectors
- Optimized take-off angle

**Advantages of compact and light-weight design**
- Minimal interference on the electron microscope
- Reduced weight of less than 3.75 kg
- Reduced overall height
- New high precision motorized slider
- Exact repositioning of the detector
- New larger surface area heat sink
- Optionally available with welded bellows (standard for XFlash® 6T)

**Maximum measurement flexibility through VZ (variable Z)-Adapter**
- Tilt and move the detector into the optimum working distance
- Maximized solid angle and count rate
- Optimized in-situ adjustment of combined EDS and EBSD measurements

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**Working distance**

A SEM parameter defined as the distance between the sample and the lowest part of the pole piece. It is normally chosen to optimize the electron optical properties but with EDS, it also has to accommodate the fixed detector position. VZ allows a new degree of freedom.
ESPRIT – the Ideal Analytical Software Suite for SEM and TEM

Real-time spectrometry
- Instant spectrum visibility
- Live quantification

HyperMap
- The database contains a spectrum for each pixel
- Enables on- and offline processing
- Live background removal and peak deconvolution

Light element / low energy analysis
- Most comprehensive database containing K, L, M and N element lines for accurate identification
- TQuant – optimized standardless low energy range quantification

Automation of routines
- Automate virtually any measurement and analysis procedure
- Optimization of instrument usage
- Unattended operation during the day, at night or over the weekend

Hybrid quantification
- Unique combination of standardless and standard-based quantification
- Customizable for most accurate quantitative results
Every analysis begins with the selection of the point or area of interest. The QUANTAX real-time spectrometry capabilities facilitate this process. In the preview mode the spectrum is updated at intervals down to 100 milliseconds. The user can easily recognize changes in the spectrum as the measurement spot is moved across the sample.

Live quantification

While the acquisition is running, ESPRIT can perform live quantification and update results as statistics improve. Everything is done automatically, but if desired, intermediate results can be reviewed or quantification can be done interactively.

Taking advantage of the new XFlash® 6 detectors’ speed, the real-time spectrometry function offers instant information on local sample characteristics.

Real-Time Spectrometry – See Composition Changes Immediately

Real-time spectrometry and live quantification in ESPRIT

Viewing the spectrum at different spots in real-time

Performing quantification interactively

Results review

Spectrometry is supported by ...

- Automatic or user controlled acquisition
- Automatic or manual element identification
- Accurate background fitting
- Peak deconvolution using either peak fitting or probability theory based approaches
- State-of-the-art quantification routines

P/B-ZAF

Fundamental parameter quantitative analysis, based on evaluating characteristic X-rays (peaks) as well as bremsstrahlung background. The local peak to background (P/B) ratios are input to a modified ZAF matrix correction. The P/B-ZAF analysis is self-calibrating. Because characteristic X-rays and bremsstrahlung undergo the same absorption, P/B-ZAF is relatively insensitive to local sample tilt and the surface condition of the specimen.

Matrix correction

Algorithm that relates the recorded spectrum to the primary rate of X-ray generation. Matrix correction takes into account atomic number effects (Z), absorption effects (A) and secondary fluorescence effects (F).
Unsurpassed Light Element and Low Energy Analysis

Producing reliable analytical results is a challenge, especially at low X-ray energies. Building on the excellent low energy performance of the XFlash® detectors, the ESPRIT software contains several features supporting nanoanalysis in the light element / low energy range.

Correct element identification based on the most comprehensive atomic database

Bruker continuously updates the ESPRIT atomic database, adding further lines and improving accuracy of line energies and intensities. The result is the most comprehensive atomic database containing all confirmed K, L, M and N lines of all elements that can be analyzed with EDS, enabling reliable element identification even at low energies.

TQuant for accurate standardless results

The TQuant standardless low energy quantification procedure provides excellent results. It is now possible to perform reliable quantitative EDS analysis not only in the light element / low energy range but also with spatial resolution at the nanometer scale. Low beam energies in the electron microscope, which produce only small excitation volumes, can now be safely used for quantitative analysis.

The importance of N-lines

The importance of N-lines is demonstrated by analyzing a Pt-containing sample. At 3 kV, the carbon peak is broadened and unusually high, indicating possible contamination. Deconvolution results show that the carbon peak is broadened due to the overlap with the Pt N peak.

Quantitative light element analysis results

The following table compares the analysis results at 3 kV and 5 kV, showing the carbon (C), nitrogen (N), and oxygen (O) content in atomic percent for carbon (C), nitrogen (N), and oxygen (O) in comparison to theoretical concentrations (hydrogen (H) content neglected).
Hybrid Quantification for Maximum Accuracy

Standardless and standard-based quantitative analysis are both common in the world of X-ray spectrometry. Bruker's unique hybrid quantification is the customizable combination of both.

While using the true standardless quantification as default method, the standard-based analysis can be assigned to elements for which reference standards are available. This provides the most reliable and precise quantification possible.

ESPRIT uses the most advanced methods for quantification

- True standardless P/B-ZAF for rough and polished surfaces and true standardless \(\Phi(\rho z)\) with XPP matrix correction
- Standard-based P/B-ZAF and standard-based \(\Phi(\rho z)\) with XPP matrix correction
- Cliff-Lorimer quantification for TEM and thin samples, both standardless and standard-based

Configuration of quantification and deconvolution using a standard library.

\[ \Phi(\rho z) \]
A matrix correction formalism based on mathematical expressions for the ionization depth distribution function \(\Phi\) in relation to mass density \(\rho\) and the depth of X-ray origin in the sample \(z\).

XPP (eXtended Pouchou & Pichoir)
A specific \(\Phi(\rho z)\) correction method developed by Jean-Louis Pouchou and Francoise Pichoir.

Cliff-Lorimer
This quantification method relates the measured peak intensities to calculated or measured intensities of standards. It can be applied for systems where absorption or fluorescence effects can be neglected, which is normally the case for thin samples as analyzed in TEMs.
HyperMap allows acquiring an advanced type of element map, in which a complete spectrum is stored for every pixel in the map. The collected database, or spectrum image, permits further processing and analysis of the data at any time during or after the measurement.

Processing tools include extracting, quantifying and comparing EDS spectra of selected regions in the map, calculating a Maximum Pixel Spectrum, obtaining line scans, displaying a map for any element, as well as automatic phase analysis.

ESPRIT HyperMap is one of the most versatile tools for EDS analysis. Select an area of interest, set up the acquisition, collect a map – even without any prior knowledge of sample composition – and analyze it offline.

A sum spectrum was extracted from a circular region (green outline) in the upper right corner of the HyperMap. A line scan (yellow line) was extracted and broadened, visible by the narrow yellow outlines, for improvement of statistics.
During scanning, the image is displayed in color by combining X-ray and electron information in real-time. ColorScan provides instant qualitative information on sample composition, homogeneity and even on different phases.

**Maximum Pixel Spectrum – the perfect tool for trace analysis**

The highest count rate recorded in each energy channel, for each pixel in the map, is displayed in a synthesized spectrum. If a certain element has a high concentration, the corresponding peak becomes visible in the Maximum Pixel Spectrum, even if this element is present in only a single pixel of the map.

**Phase analysis using Autophase**

ESPRIT’s Autophase function determines the present chemical phases using an automated principle components analysis (PCA) algorithm. The conditions for analysis are either set by different thresholds (automatically or manually) or by defining objects in a map.
Powerful Automation

Automation of routine analyses is easily set up and performed with ESPRIT. Return to the lab after a night’s unattended measurement run, to find all results on disk or compiled into a report.

Full analysis automation with ESPRIT Jobs

Virtually any analytical function can be automated using Jobs (including feature analysis):

- Unattended multiple sample analysis
- Analysis of multiple regions of interest on a single sample
- Utilizing the StageControl function allows defining an area or storing multiple stage locations
- Measurement results are automatically stored
- Optional automatic report generation

ESPRIT Jobs

Easy setup of automated analyses
Analysis Method Coupling

The open architecture of Bruker’s QUANTAX system allows easy coupling of analytical methods. For the latest generation of QUANTAX the truly simultaneous EDS and EBSD analysis has been further refined. Other analysis techniques are supported via ESPRIT as well.

Enhanced integration of EDS and EBSD analysis

Since 2008 EBSD has been fully integrated with EDS in Bruker’s QUANTAX system, offering truly simultaneous data acquisition under one single user interface. Now, with the latest generation of QUANTAX the simultaneous determination of chemical compositions and crystalline microstructures is even more powerful and efficient.

Simultaneous acquisition of EBSD/EDS data sets enables:
- EDS-supported crystalline phase identification and discrimination
- Offline advanced phase ID using HyperMap

Further important integration options

Other analysis techniques and supported options are:
- Micro-XRF in SEM
- Integration with EELS for TEM
- Eight counter inputs for mapping, e.g. for third party WDS
## Specifications

### Detector configurations for QUANTAX systems

| Available detectors with and without light element window for SEM and TEM | XFlash® 6 | 10  
| XFlash® 6 | 30  
| XFlash® 6 | 60  
| XFlash® 6 | 100 |

### ESPRIT software

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<tr>
<th>Module</th>
<th>Description</th>
<th>Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrum</td>
<td>Spectra acquisition, element identification</td>
<td>Map</td>
<td>Ultra high speed digital X-ray mapping</td>
</tr>
<tr>
<td>Quant</td>
<td>Automatic standardless quantification</td>
<td>QMap</td>
<td>Quantitative mapping</td>
</tr>
<tr>
<td>EQuant</td>
<td>Extended spectrum analysis options</td>
<td>HyperMap</td>
<td>Mapping with hyper spectral database</td>
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<tr>
<td>UQuant</td>
<td>User defined quantification strategies</td>
<td>MaxSpec</td>
<td>Element trace determination for HyperMap</td>
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<tr>
<td>TQuant</td>
<td>Optimized low energy quantification</td>
<td>AutoPhase</td>
<td>Automatic phase analysis</td>
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<tr>
<td>HSQuant</td>
<td>Combined $\Phi$ (pZ) and standardless analysis</td>
<td>Feature</td>
<td>Feature analysis (optionally automatic)</td>
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<tr>
<td>CLQuant</td>
<td>Cliff-Lorimer quantification</td>
<td>DriftCorr</td>
<td>Correction of beam drift</td>
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<td>SpecMatch</td>
<td>Spectrum matching, search similar spectra</td>
<td>StageControl</td>
<td>Motorized stage control</td>
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<tr>
<td>SEMLink</td>
<td>Data communication with microscope</td>
<td>Jobs</td>
<td>Automatic task processing</td>
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<tr>
<td>Scan</td>
<td>Image acquisition</td>
<td>Project</td>
<td>Data management and filing system</td>
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<tr>
<td>ColorScan</td>
<td>Acquisition of X-ray induced color images</td>
<td>TChart</td>
<td>Histograms, binary and ternary charts</td>
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<tr>
<td>Vision</td>
<td>Digital image processing and enhancement</td>
<td>Report</td>
<td>Result presentation and report generation</td>
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<tr>
<td>ImageStitch</td>
<td>Automatic stitching of overlapping images</td>
<td>User</td>
<td>Multi-user operation and administration</td>
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<tr>
<td>MultiPoint</td>
<td>Automatic multi-point and object analysis</td>
<td>LAN</td>
<td>Client/server architecture</td>
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<tr>
<td>Line</td>
<td>Spectrum data based line scan</td>
<td>Support</td>
<td>Application support and remote diagnosis</td>
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<tr>
<td>QLine</td>
<td>Quantitative line scan</td>
<td>EMSA</td>
<td>Spectra import and export in EMSA format</td>
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For further information please scan the QR code or visit www.bruker.com/quantax

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