MICRO-XRF

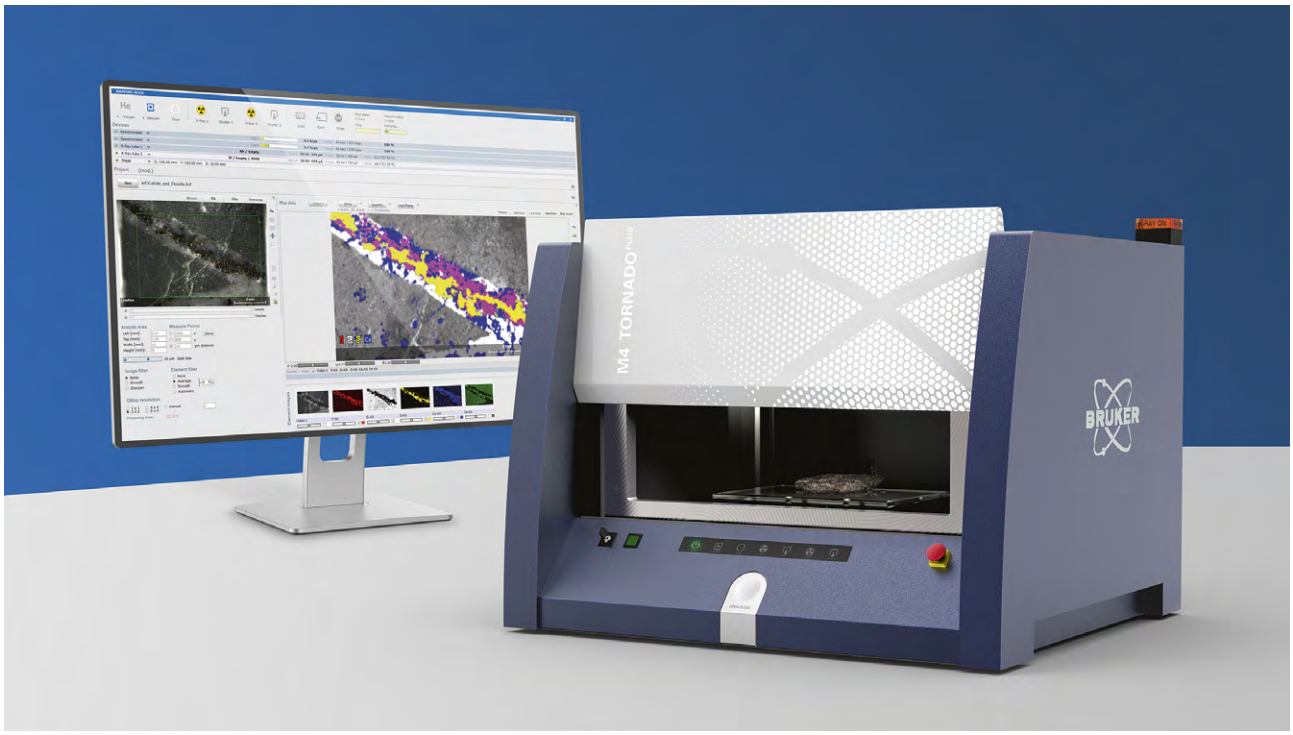
M4 TORNADO PLUS

Super Light Element Micro-XRF Spectrometer

Innovation with Integrity

M4 TORNADO – A New Era in Micro-XRF

M4 TORNADO PLUS is the world's first micro-XRF spectrometer capable of detecting and analyzing the entire element range from carbon to americium. As the latest member of the proven, market-leading family of M4 TORNADO micro-XRF analyzers, the M4 TORNADO PLUS offers additional unique features, such as an innovative aperture management system, an ultra-high throughput pulse processor and a flexible quick-change sample stage.



Features

- Dual, large area silicon drift detector (SDD) with super light element window
- High X-ray tube with increased low-energy excitation
- High throughput pulse processor
- Patented Aperture Management System (AMS)
- Quick-change stage with optional specimen holder
- Second X-ray tube with automatic four position collimator changer (optional)
- Programmable He-purge system (optional)

Benefits

- Detection of light elements down to carbon
- Increased efficiency of light element detection
- Reduced acquisition time, increased productivity
- High depth of field to keep more features and details in focus when investigating topographic samples
- Reduced sample exchange and setup time
- More flexibility for the analysis of high energy lines
- Ultimate light element analysis at atmospheric pressure

Instrument Highlights

The M4 TORNADO PLUS enables the detection of light elements down to carbon by using large-area silicon drift detectors (SDD) with super light element window and offering vastly increased acquisition speed with its ultra-high throughput pulse processors. Its patented aperture management system (AMS) provides unrivaled depth of field and allows analysis of samples with highly topographic surfaces.

The strongly increased sensitivity in the low-energy range also improves the detection of the elements Na to Cl, with a typical increase in cps by a factor of up to 20 compared to entry-level micro-XRF systems.

Thanks to this performance improvement, new fields of research and development can benefit from high-speed micro-XRF mapping.

Super light element detection down to carbon

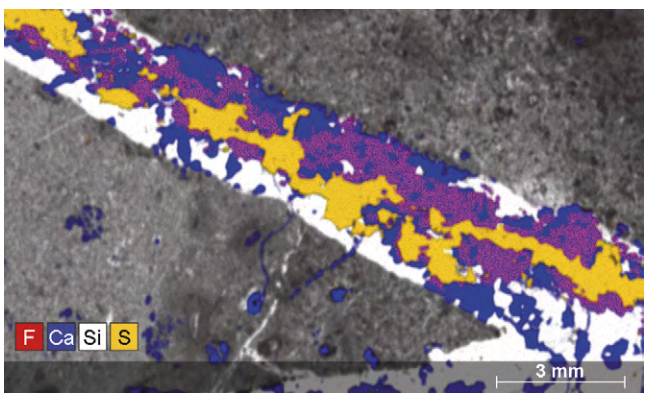
Using two large-area silicon drift detectors with super light element window and a specifically optimized Rh X-ray tube (Ag as an option), the M4 TORNADO PLUS is the first micro-XRF spectrometer ever to enable the analysis of light elements.

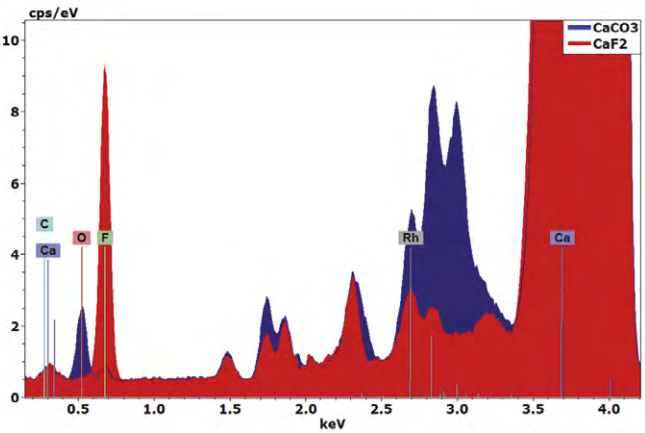
In contrast to conventional micro-XRF systems, which are suitable for the detection of elements from sodium or heavier, the M4 TORNADO PLUS can also be used to measure elements with atomic numbers Z < 11 such as fluorine, oxygen, and carbon without compromising the performance and sensitivity in the higher energy ranges.

Challenging analysis of mineral samples

Fluorite (CaF_2) and calcite ($CaCO_3$) are minerals with calcium as the main element and the light elements fluorine or oxygen and carbon as accompanying elements. Most micro-XRF systems cannot distinguish between these two minerals as they are unable to detect elements below sodium, and both the fluorite and calcite spectra would only show the calcium lines.

With its super light element detectors and the optimized light element X-ray tube, the M4 TORNADO PLUS can detect fluorine, oxygen and carbon and thus reliably identify the two minerals.





Differentiating fluorite and calcite

Left: Element map of a rock with fluorite and calcite. Both minerals contain calcium (blue), but fluorine (red) is only detected in fluorite, which can be seen as purple areas.
Right: Spectrum in the light element range of the two mineral phases fluorite (red) and calcite (blue). The carbon of $CaCO_3$ is detectable, but is obscured by the Ca L lines.

Your Sample Counts

Estimating the sensitivity of M4 TORNADO PLUS using a NIST 620 glass sample

Sensitivity and detection limits are always based on the counts in the element peak. With an increasing count rate (counts per second, cps), one can save measurement time to obtain a usable element peak, which is particularly important for area scans. The table shows typical count rates and sensitivity values of the M4 TORNADO PLUS.

These values were obtained by averaging measurements of a NIST 620 test glass sample on 40 M4 TORNADO PLUS instruments with standard configuration: LE[1] tube with Rh anode at maximum power setting, polycapillary lens with < 20 µm spot size, 60 mm² SLEW[2] detectors.

Element	Element line	Intensity / cps	Concentration / wt%	Sensitivity / cps/wt%
O	Kα	338	46.72	7.2
Na	Kα	1535	10.70	143
Mg	Kα	736	2.19	336
Al	Kα	808	0.95	850
Fe	Kα	870	0.0325	26761

1) LE = light element, 2) SLEW = super light element window

Ultra-high throughput pulse processor for fastest measurements

The M4 TORNADO family has been continuously optimized to get the most out of the high-brilliance X-ray tubes and high-flux polycapillary optics. The M4 TORNADO PLUS is at the top of this development.

With its unique ability to process up to 1,200 kcps and deliver an output count rate of up to 550 kcps during live mapping, the M4 TORNADO PLUS pushes the limits of micro-XRF acquisition, enabling unmatched acquisition speed and productivity.

Even if the nature of the sample does not allow the generation of correspondingly high X-ray fluorescence intensities, the pulse throughput is better due to the short dead time of the pulse processor.

This means that the the M4 TORNADO PLUS delivers more data in the same time or requires less time to acquire the same amount of data than any other micro-XRF instrument in any measurement situation.

AMS – Increasing depth of field and spatial resolution

Many specimens to be investigated with micro-XRF have topographical surfaces and are not perfectly flat. As in photography, the depth of field is therefore an important parameter for the optical X-ray system used to generate the small excitation spot on the sample surface. Usually, with higher resolution of the capillary optics, the working distance and depth of field decreases.

The innovative, software-controlled aperture management system (AMS) of the M4 TORNADO PLUS enables a significant increase in the working distance and produces sharp mapping images on samples with a surface topography of up to ± 5 mm. This means that the spatial resolution is preserved and sample features are kept in sharp view even if the sample surface varies by several millimeters.

This makes the M4 TORNADO PLUS the instrument of choice for the analysis of specimens with strong topography, e.g., in electronics, forensics or geoscience.

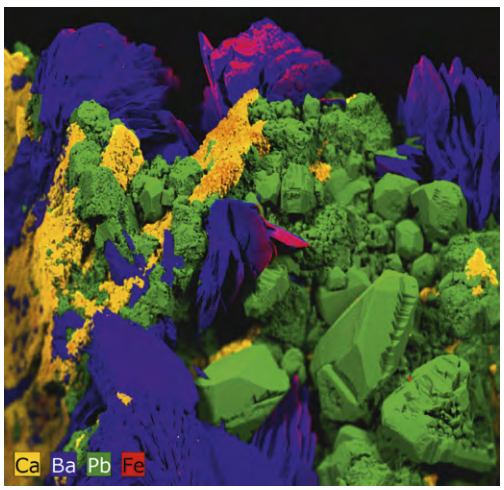
Analysis of topographical samples

Sample preparation is not only time-consuming, but also not always possible. The samples to be analyzed with micro-XRF systems are not always flat, but topographical. When measuring with a focusing polycapillary lens, the generated element distribution could suffer from beam divergence.

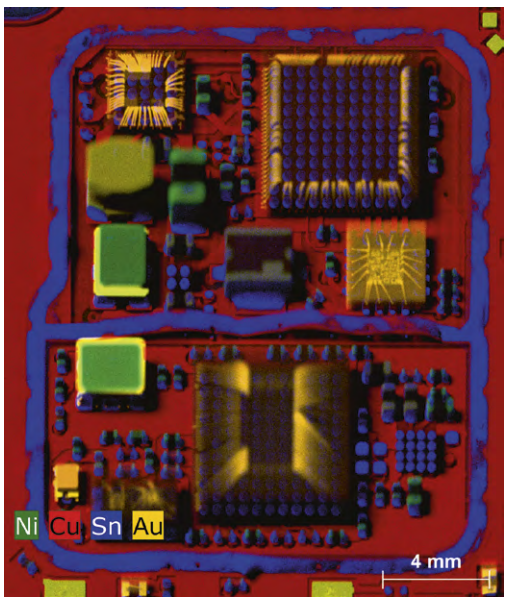
The patented AMS solution in the M4 TORNADO PLUS reduces the beam divergence and thus enables sharper X-ray maps on non-flat samples.

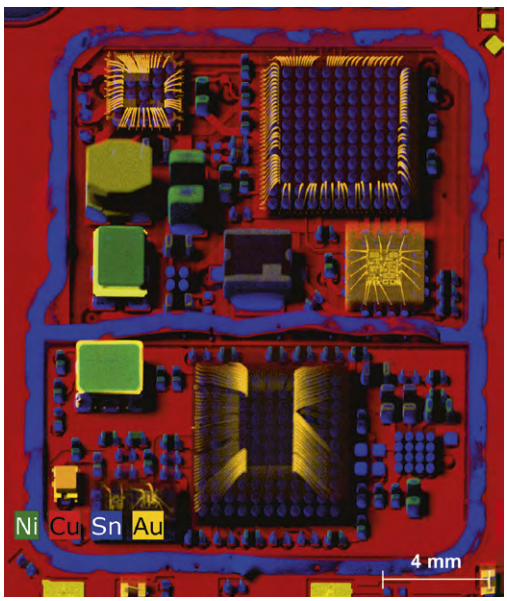
The two examples shown here underline the efficiency of the AMS in the analysis of highly topographical samples: a mineral sample with large crystals and a printed circuit board (PCB) measured with and without AMS.

Due to the extremely high depth of field with AMS, the corresponding X-ray image of a mineral with crystals in the centimeter range can be captured without blurring on the base material. Similarly, the map of a cell phone circuit board has far more details in focus than the image of the same circuit board acquired without AMS. In addition, the energy dependence of the spot size is less pronounced due to the reduced entrance and exit angles of the excited X-ray photons.



Mineral analysis
Left: photograph of a cerussite with bladed barite on galena, found in Morocco.
Right: AMS image showing the different crystals represented by certain elements: cerussite containing Ca (yellow), barite containing Ba (blue), and galena containing Pb (green).





Circuit board analysis
Left: The standard polycapillary spot was focused on the board level of the PCB, hence the tall components and bond wires are out of focus and appear blurred.
Right: AMS image showing high depth of field with all components in focus over a larger depth range.

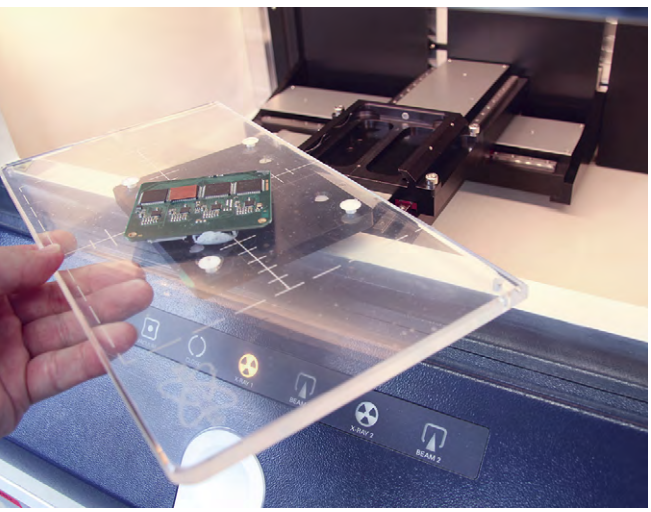
Extend Your Analytical Range

The M4 TORNADO PLUS simplifies the exchange, positioning and fixing of samples with the quick-change stage, extends the spot size and intensity range of the optional second X-ray tube with a collimator changer and expands the application range in light element analysis for sensitive or hydrated specimens using helium purging.

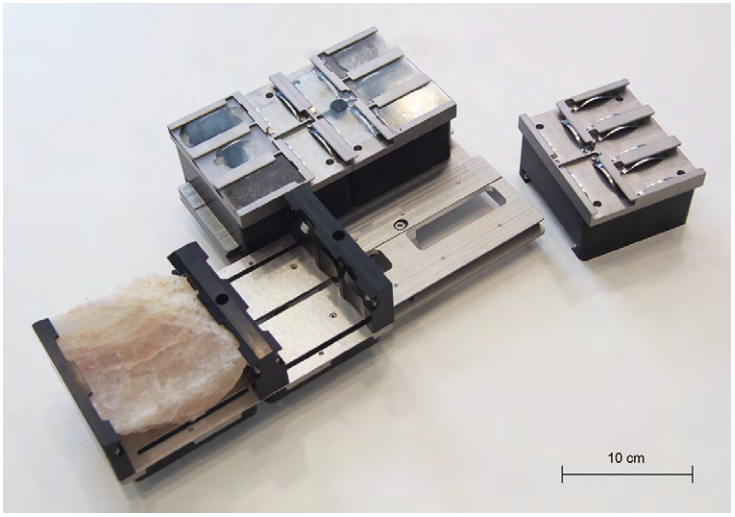
Quick-change stage for fast and easy sample exchange

Maximizing sample throughput and minimizing the time the instrument is not in use is a key benefit in planning and operating an analytical laboratory. In addition, the secure attachment of large, irregularly shaped specimens or a large number of thin sections in a repeatable manner can be a challenging and time-consuming tasks.

The M4 TORNADO PLUS is equipped with a modular quick-change stage interface that complements the functionality of the motorized chamber door. The dovetail coupler enables the stage plate to be removed and reinserted from the front without any tools and even enables automatic loading procedures.



Standard quick-change stage interface
Easy placement of a sample outside the sample chamber.



Optionally, there is an additional base plate, which supports drill core holders or thin section carriers. The drill core sample holder is configurable and can be adjusted to hold up to HQ sized (2.5 inch) drill cores. It can be set up with one or two halves, each of which can hold two or three half or quarter cores as well as end pieces or plugs. Alternatively, the base plate can be fitted with up to four thin section carriers, each being able to hold and secure five thin sections.

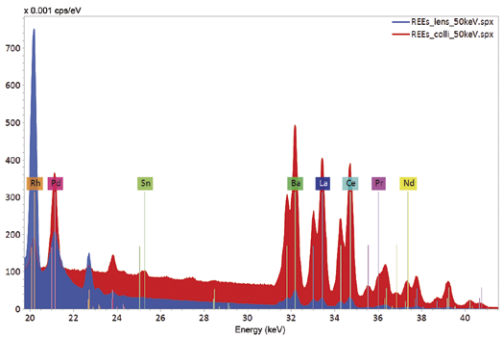
Regardless of the use of drill core holders, thin section carriers or a combination of both, the measuring plane is always the same, meaning less time spent setting up measurements. The entire stage load can be analyzed without changing the focus position.

Adjustable sample holder
with whole, half or quarter plugs for drill cores and other irregular shaped samples as well as for thin sections.

Second X-ray tube with collimator changer for intensity gain at higher energies

A high power X-ray tube equipped with collimator is the best choice to effectively excite the high-energy lines of heavy or Rare Earth Elements (REE) as it does not suffer from the attenuation of the higher energy part of the tube emission as can be observed with capillary lenses. For analyzing larger specimen volumes, it can also be advantageous to have a larger spot size.

The M4 TORNADO PLUS can therefore be equipped with a second X-ray tube (W) in combination with a fully software-controlled four-position collimator changer. The collimator changer can be set to sizes of 500 µm, 1 mm, 2 mm, and 4.5 mm, allowing either a small spot analysis, albeit with lower intensity, or close to bulk XRF analysis with a large spot of high intensity.



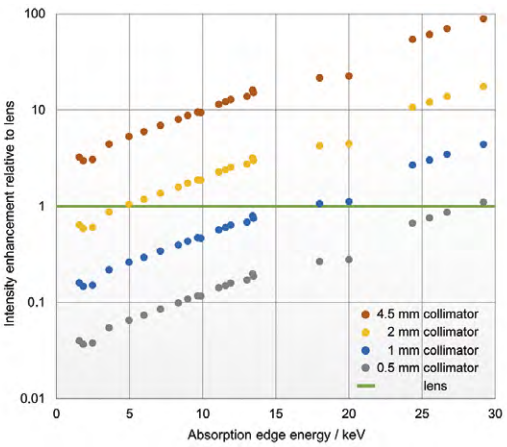
Collimator vs. lens sensitivity on REEs
Comparison of rare earth element lines excited with polycapillary lens (blue) and collimator (red). The excitation with collimator yields higher sensitivity for the high energy lines.

Helium purge system for increased intensity at lower energies

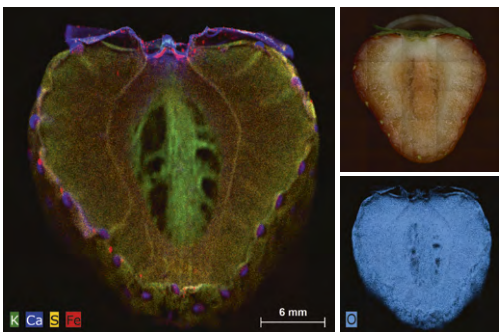
For certain specimens, measurement under vacuum poses an issue as they are sensitive to pressure variations or can dry out. Even if working at ambient air is always possible, the X-ray fluorescence of elements below Ca is strongly attenuated or even completely absorbed. To detect light and super-light elements from samples sensitive to vacuum, the M4 TORNADO PLUS can be equipped with a computer-controlled helium purge system, increasing the range of specimens that can be analyzed under atmospheric pressure.

Different purging modes can be used depending on the specific analytical requirements. For a fast single or multi-point analysis, a local high-flow purging of the measurement position is sufficient to reliably detect the low-energy X-rays.

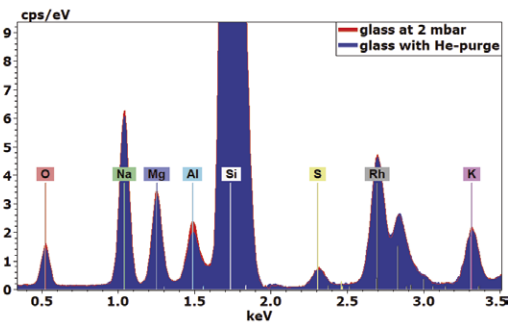
When performing X-ray mapping, the movement of the stage influences the local helium concentration, resulting in unstable detection conditions. In this case, a second purging mode can be configured to fill the entire measurement chamber with helium, ensuring constant and repeatable conditions for the detection and analysis of light elements during the mapping process.



Intensity gain with collimator
Gain of the primary X-ray intensity for the different collimator sizes in comparison to a polycapillary lens (line at 1).



Element mapping with He-purge
Mosaic image and single element maps of a strawberry. Image size: 31.2 x 30.5 mm², scan resolution: 1560 x 1525 pixels; step size: 20 µm; dwell time: 10 ms/pixel; excitation: Rh tube, 50 kV, 600 µA.



Analysis of glass
Spectra comparison of a glass sample measured in vacuum (2 mbar, red) and in He atmosphere (800 mbar, blue). The sensitivity for light elements is almost identical, even for oxygen.

Technical Data	
Sample types	Solids, particles, liquids
Sample chamber size	W x D x H: 600 mm x 350 mm x 260 mm
Stage	W x D: 330 mm x 170 mm, max. weight load: 7 kg
Measurement atmosphere	Air or adjustable vacuum with oil-free pump, 2 mbar in ~3 min, optional helium purge system
Sample travel	Max. travel: W x D x H 200 mm x 160 mm x 120 mm Mapping travel: W x D 190 mm x 160 mm Travel speed: up to 100 mm/s with TurboSpeed stage
Sample view	Two simultaneous live images from above with different magnifications for sample overview and precise positioning, lateral fisheye camera for the sample chamber overview
Excitation	1st tube: high brilliance, light element micro-focus X-ray tube with polycapillary X-ray optics and aperture management system (AMS) Target material: Rh (optionally Ag) Tube parameters: 50 kV, 30 W Spot size: < 20 µm for Mo Ka (17.5 keV) with polycapillary lens Filters: 8 excitation filters Optional 2nd tube: fine focus X-ray tube with four position collimator changer from 0.5 mm to 4.5 mm Target material: W (optionally Rh, Mo, Cu, Cr) Tube parameters: 50 kV, 40 W Filters: 8 excitation filters
Detection	XFlash® super light element silicon drift detectors, detection from C to Am, simultaneous use of two detectors Sensitive area: 2 x 60 mm^2 Energy resolution: < 145 eV at 600,000 cps input count rate Throughput: up to 550,000 cps output count rate
Instrument control	State-of-the-art PC, Windows® 10
Instrument control functions	Complete control of tube parameters, filters, optical microscopes, sample illumination and sample positioning
Spectra evaluation	Peak identification, artifact and background correction, peak area calculation, FP quantification, calibrated quantification with standard-based and standardless models using XMethod
Distribution analysis	"On the fly" measurement, HyperMap capability
Result presentation	Quantification results, statistical evaluation, element distribution (line scan, mapping)
Power requirements	100 - 240 V (1P), 50/60 Hz
Dimensions	W x D x H: 815 mm x 680 mm x 580 mm, 130 kg*
Quality & safety	DIN EN ISO 9001:2015, CE certified, UKCA certified; Fully radiation protected system; radiation < 1 µSv/h

*Depending on configuration

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