



# M4 TORNADO

- High performance Micro-XRF spectrometer

# M4 TORNADO – New Standards in Micro-XRF



Micro-XRF is the method of choice for highly sensitive and non-destructive elemental analysis of diverse samples, including inhomogeneous and irregularly shaped specimens.

The M4 TORNADO is a versatile instrument for fast and accurate high-resolution analysis of both small and large specimens. Samples require little or even no preparation at all for examination.

- 20 µm Spot Size**
  - Excellent spatial resolution using polycapillary X-ray optics for smallest spot sizes < 20 µm for Mo-K
- Dual Tube Excitation**
  - Flexible excitation through use of up to 2 X-ray tubes and 5 filters
- XFlash® Technology**
  - Ultra fast spectrum acquisition with XFlash® SDD technology
- Dual Detector**
  - Additional speed and information through an optional 2<sup>nd</sup> detector
- Turbo Speed Stage**
  - TurboSpeed X-Y-Z stage for distribution analysis “on the fly”
  - Sample positioning supported by simultaneous display of 2 sample images in different magnifications
- EasyLoad Chamber**
  - Vacuum sample chamber for optimized light element performance
  - EasyLoad function for fast and convenient sample exchange
- M-Quant**
  - Reliable quantification of bulk material using a standardless FP model

# Instrument Highlights

## Efficient sample excitation

The use of polycapillary X-ray optics allows to generate high fluorescence intensities even on smallest sample areas. The X-ray optics allow to focus tube radiation from a large solid angle and concentrate it on spots < 20 µm for Mo-K radiation.

The optional use of two X-ray tubes permits very effective excitation of special groups of elements by choosing different target materials or by using one tube with a collimator.

## Fast spectrum acquisition

The M4 TORNADO is equipped with our XFlash® silicon drift detector (SDD) technology. This ensures count rates of > 310 kcps (single detector setup) combined with an energy resolution < 145 eV. The 30 mm<sup>2</sup> active detector area allows to collect radiation from a large solid angle. An optional second detector speeds up data acquisition even more.

## TurboSpeed stage

The large sample stage travels at a maximum speed of up to 100 mm/s. Combined with “on the fly” measurement, this ensures fastest possible mapping, as the detector is continuously collecting radiation.

Information on element distribution can already be obtained with an acquisition time < 1 ms per pixel. This allows a first overview of the sample composition within minutes. Additional frames can add details for refined analysis. Due to the high precision of the TurboSpeed stage, such multi-frame measurements can be carried out routinely. Longer acquisition times provide even more analytical details.

## Convenience and ease of use

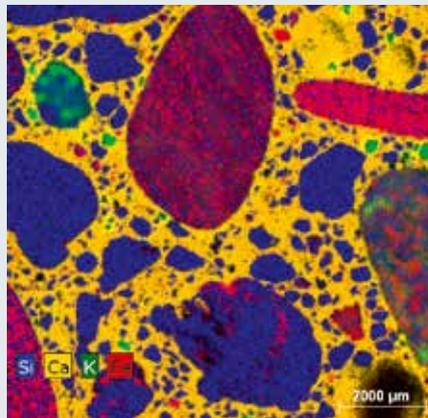
Convenience and easy handling are provided for the user through:

- The EasyLoad function for fast sample exchange
- The large sample chamber, enabling a stage travel of 200x160x120mm
- Sample positioning supported by a fish eye camera and two optical video microscopes that show approx. 1 mm<sup>2</sup> and 10mm<sup>2</sup>
- Auto focus function for setting the sample height correctly
- Mosaic (tiled) images of high quality (stitching, shadow correction) for large area maps
- Distribution analysis with HyperMap, which collects complete data sets, supporting offline data evaluation.

## Accurate and flexible quantification

Because samples are usually inhomogeneous, the M4 TORNADO uses standardless analysis based on fundamental parameter (FP) models. Based on such a FP model our software module M-Quant provides reliable results on the composition of bulk samples.

### Fast mapping



Fast mapping of a concrete sample (1 cm<sup>2</sup>) with 1 ms dwell time per pixel. Total measurement time: 3 min.

# Applications

## Multi-element distribution analysis of a hidden painting



Left – Backside of a painting by Max Klinger (1872, approx. 14,5 x 32 cm<sup>2</sup>) on a piece of wood (approx. 8 mm thick) covered with paper.

Right – A hidden painting is “uncovered” by multi-element distribution analysis: the distribution of Cr, Fe, Cu, Ca, Pb and Hg, contained in pigments used, produces a false-color representation of the picture.

The M4 TORNADO is very versatile. Applications focus on material sciences, in particular on forensics, geology, RoHS measurements, archeometry, bioscience and many other applications are supported as well.

## Forensics and archeometry

The M4 TORNADO is especially suitable for forensic analysis. This includes examination of layer systems like paint, extremely small material fragments and gunshot residue. It is also the ideal instrument for non-destructive analysis of documents and small works of art, e.g. for authentication.

## Geology

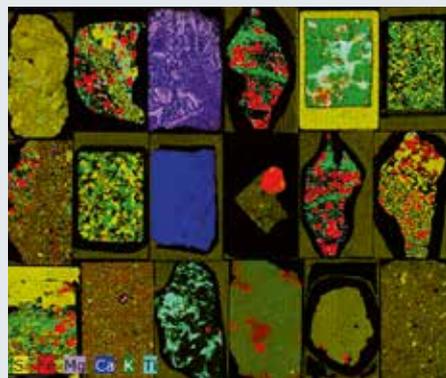
The large sample stage of the M4 TORNADO is predestined for the analysis of geological samples. Phase analyses or searches for trace elements can be performed easily to study geological processes such as rock formation or to assess ores for their mineral content. The M4 TORNADO software offers multiple options for analysis and data representation.

## Restriction of the use of hazardous substances – RoHS

With the increased awareness of environmental and health hazards, detection of substances imposing such risks has become increasingly important. Analyses to determine compliance with the Restriction of the Use of Hazardous Substances regulation can be performed with the M4 TORNADO.

It can be used to determine heavy metal and other harmful element content – even if it is in the ppm range.

## Thin sections with high resolution



Screening of mineralogical samples. Image size: 166 x 140 mm<sup>2</sup>, scan resolution: 3320 x 2800 pixels, step size: 50 µm, dwell time: 1 ms/pixel.

### Mosaic image and hot spots of a PCB

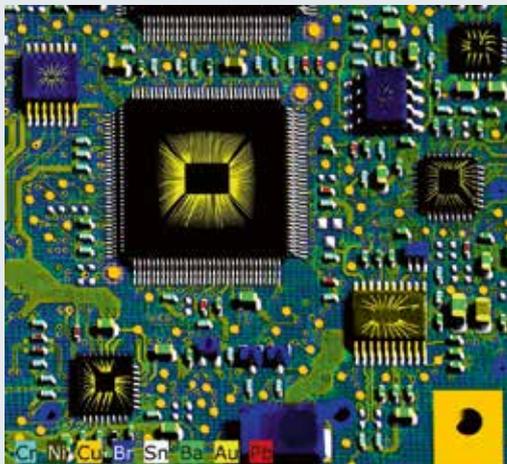
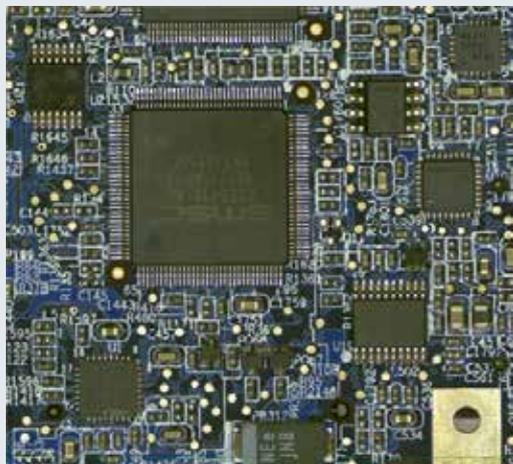


Image size: 44 x 40.6 mm<sup>2</sup>, scan resolution: 2750 x 2538 pixels, step size: 16 μm, dwell time: 5 ms/pixel.  
Left – Mosaic image of the analyzed PCB.  
Right – Element distribution for hazardous elements (Br, Pb, Cr) and for Au (showing the bond wires of the integrated circuits).

Qualitative analysis of single points or examination of element distributions is possible for various sample types. These include electronic components, toys, consumer products and others. The high excitation efficiency of the M4 TORNADO allows fast screening and the detection of smallest traces.

### Bioscience

The examination of the metabolism of biological samples can provide valuable information on environmental conditions, health or diseases.

Important indicators are the distribution of essential elements. Their distribution in plants and in animal organs can be examined with high spatial resolution and with high sensitivity using the M4 TORNADO. The fast data acquisition also permits screening of sensitive samples without causing any damage.

### Element maps of an autumn leaf

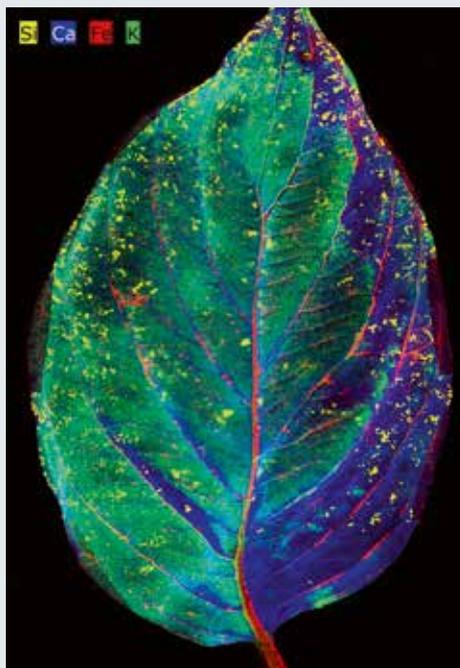


Image size: 110 x 74.6 mm<sup>2</sup>, scan resolution: 2200 x 1492 pixels, step size: 50 μm, dwell time: 10 ms/pixel.

# The Powerful Software

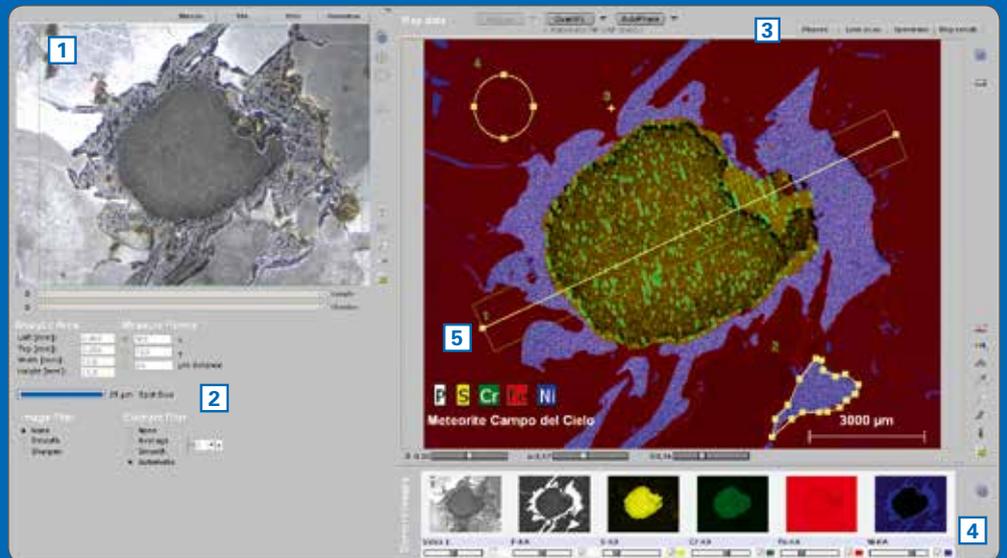
## Getting the most out of your measurement data

Our longstanding expertise in EDS analysis has been incorporated into the M4 TORNADO's powerful analysis software, which provides maximum functionality and ease of use.

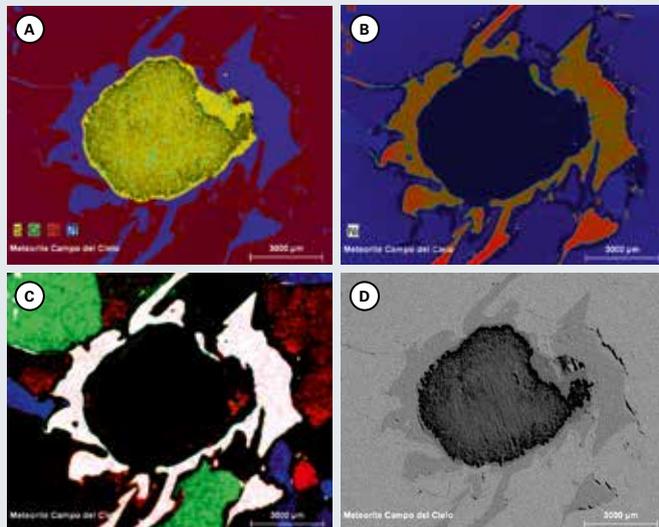
Besides point and line scans our position tagged spectrometry option HyperMap allows high speed scans of areas. The complete spectroscopic information for each measured location is collected and saved in a multidimensional data cube, which allows comprehensive data evaluation. HyperMap supports extremely convenient data mining, both on- and offline.

### HyperMap example performed on an iron meteorite

- 1 Video control with mosaic image, 10x/100x magnification
- 2 Mapping acquisition controls
- 3 Data evaluation tabs
- 4 Single element distributions
- 5 Data display with definable data access tools: line, point and objects



### Data display options



## Analytical tools for mining the HyperMap data cube

### Data display

Variable display options allow an optimized display of specific sample features: from multi-element display to variable intensities, crystal domain or density variations based on X-ray backscatter behaviour.

Data display: Multi-element mapping (A), false color element display (B), diffraction map showing the distribution of Bragg diffraction lines from specific crystal domains (C), total X-ray intensity map (D).

## Information from points, lines and objects

Spectroscopic information can be extracted from a HyperMap data cube by using different data access tools such as definable objects, points or lines to analyze compositional differences within a measured area.

### Point

This option provides a quick overview of major constituents at selected positions. Individual points can be set by placing crosshairs in the HyperMap image. The respective spectrum is displayed under the Spectrum tab.

### Line scan

Within the HyperMap image arbitrary lines can be drawn to calculate the elemental composition. To improve statistics and to smooth element distribution lines, the software allows to broaden the scan line by adding adjacent pixels. The results of a scan are displayed under the Line scan tab.

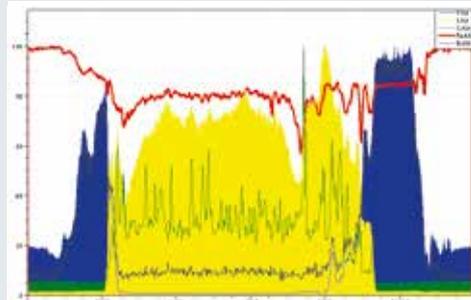
### Objects

Arbitrarily shaped objects (rectangles, circles, polygons) can be drawn in the map, resulting in a sum spectrum over the selected area. This function is extremely helpful to improve count statistics for quantification and for comparing similarly composed regions.

### Phase analysis and chemometry

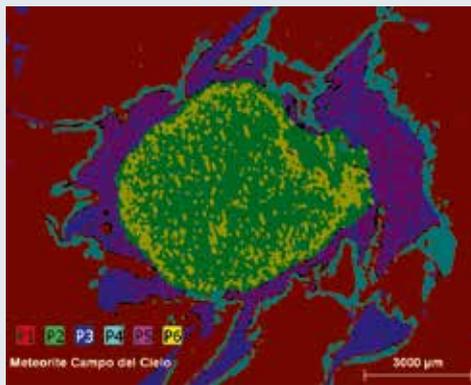
The phase analysis feature allows to determine the distribution and proportion of different phases within the scanned area.

#### Line scan



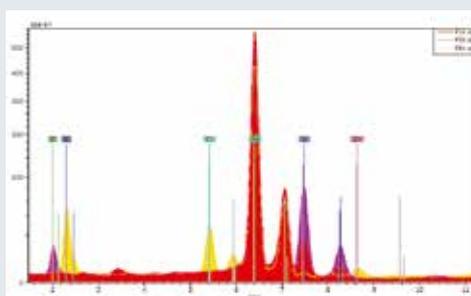
The line scan shows the relative intensity distribution of selected elements over the inclusion of an iron meteorite.

#### Phase analysis



Phase analysis clusters similar compositions as phases. The percentage share of each phase is calculated.

#### Spectra comparison



Spectra comparison between the phases of the figure above:  
P1 – red  
P5 – pink  
P6 – yellow

#### Quantification

	Series	Net	[wt.%]	[wt.%]	Atom C [at.%]	Error [%]
Iron	K series	214751713	94,59	93,82	93,76	3,66
Nickel	K series	6274049	5,76	5,71	5,43	0,01
Copper	K series	7388	0,01	0,01	0,01	0,00
Zinc	K series	2017	0,00	0,00	0,00	0,00
Phosphorus	K series	89042	0,36	0,35	0,64	0,00
Sulfur	K series	37785	0,08	0,08	0,14	0,00
Chromium	K series	99229	0,03	0,03	0,03	0,00
	<b>Total</b>		<b>100,82</b>	<b>100,00</b>	<b>100,00</b>	

Quantification results of phase P1.

# Technical Specifications



<b>Sample types</b>	Solids, particles, liquids
<b>Sample chamber size</b>	WxDxH: 600 mm x 350 mm x 260 mm
<b>Stage</b>	WxD: 330 mm x 170 mm Max. weight load: 5 kg
<b>Measurement media</b>	Air or oil free vacuum, ready for measurement within 100 s
<b>Sample travel</b>	Max. travel Mapping travel Travel speed
	WxDxH: 200 mm x 160 mm x 120 mm WxD: 190 mm x 160 mm Up to 100 mm/s with TurboSpeed stage
<b>Sample view</b>	2 simultaneous live images from above with different magnifications for sample overview and precise positioning Lateral fisheye camera for the sample chamber overview
<b>Excitation</b>	High brilliance X-ray tube with polycapillary X-ray optics Optional: second tube with collimator
<b>Excitation parameters</b>	Target material Tube parameters Spot size Filters
	Rh, optional: Mo, Ag, Cu, W 50 kV, 30 W (40 W for collimator) Less than 20 µm for Mo-K with polycapillary lens Up to 5 filters
<b>Detection</b>	XFlash® silicon drift detector Optional: simultaneous use of 2 detectors
<b>Detector parameters</b>	Sensitive area Energy resolution
	30 mm <sup>2</sup> < 145 eV at 300,000 cps (count rate Cu > 400,000 cps)
<b>Instrument control</b>	State-of-the-art PC, Windows 7
<b>Instrument control functions</b>	Complete control of tube parameters, filters, optical microscopes, sample illumination and sample positioning
<b>Spectra evaluation</b>	Peak identification, artifact and background correction, peak area calculation, quantification with standard-based and standardless models
<b>Distribution analysis</b>	"On the fly" measurement, HyperMap capability
<b>Result presentation</b>	Quantification results, statistical evaluation, element distribution (line scan, mapping)
<b>Power requirements</b>	100–240 V (1P), 50/60 Hz
<b>Dimensions</b>	WxDxH: 815 mm x 680 mm x 580 mm, 130 kg*
<b>Quality &amp; safety</b>	DIN EN ISO 9001:2008, CE certified Fully radiation protected system; radiation < 1 µSv/h

\*Depending on configuration

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