M6 JETSTREAM

- Large Area Micro X-ray Fluorescence Spectrometer

Micro-XRF

Innovation with Integrity

Spatially Resolved Elemental Analysis of Large Objects

The Bruker M6 JETSTREAM is designed for the non-destructive elemental analysis of large samples. The mobility of the instrument allows it to be placed at the site of the object of interest, such as a gallery, museum or the shop floor. The performance parameters enable scanning areas of 800 mm x 600 mm with a variable spot size down to 100 µm and speeds of up to 100 mm/s.

Fields of applicaton

- **Cultural heritage science** – the ability to scan objects in-situ saves the user from having to transport – and possibly jeopardize – objects of immeasurable value
- **Geoscience** – supports the analysis of large drill core sections or other mineral samples
- **Failure analysis** – screening of big parts for flaws, inhomogenities and other features of interest.

Setting Standards in Micro-XRF Analysis

High performance element distribution analysis of large samples

- The M6 JETSTREAM allows samples to be scanned either horizontally or vertically
- The instrument supports extremely fast measurement based on high excitation intensity and fast stage movement. “On-the-fly”measurement provides even further acquisition time optimization
- The spot size of the M6 JETSTREAM can be adapted in five steps to match the structure of the sample and the desired spatial resolution
- Bruker’s advanced XFlash® silicon drift detectors (SDD) are used for the detection of fluorescence radiation. They feature high count rate capability and best energy resolution over a wide count rate range
- Special safety circuitry provides optimal user protection against exposure to X-rays
- Ultrasound distance measurement safeguards against collision with the measurement object
- Regardless of sample size, the M6 JETSTREAM can be easily positioned due to its mobility. It can be dismantled into four parts which makes it transportable.

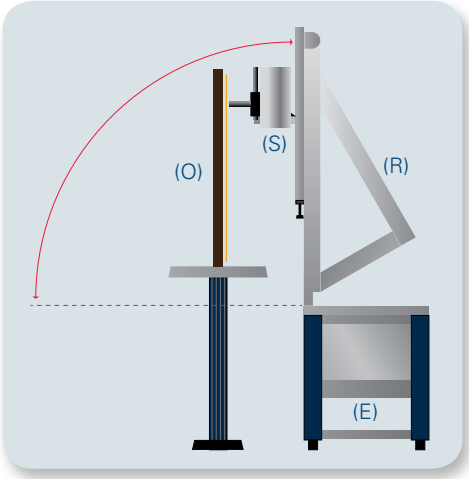


Diagram of the M6 JETSTREAM set-up in the upright measurement position, showing analysis object (O), spectrometer head (S), rig (R) and electronics compartment (E)

The M6 JETSTREAM provides

- Highest excitation efficiency with microfocus tube and polycapillary X-ray optics with variable spot size
- Flexible acquisition programs for measuring single and multiple points and for distribution analysis in one or two dimensions – line scan and mapping – with flexible area size
- Distribution analysis with HyperMap, i.e. for saving a complete spectrum for every pixel, offering a wide variety of options for data post processing.

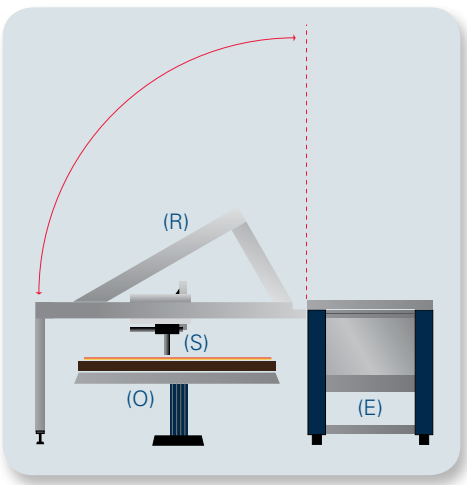


Diagram of the M6 JETSTREAM set-up in the horizontal measurement position, showing analysis object (O), spectrometer head (S), rig (R) and electronics compartment (E)

Examination of Vertical Samples

The analysis of works of art can provide valuable information about their history and authenticity, about required conservation procedures and previously performed restoration on the work of art.

The transportion of valuable paintings has to be avoided due to their vulnerability, security issues and the resulting costs.

Additionally, paintings are not available to the public if they are removed for analysis. Similar problems arise if the works of art are very large and heavy or even immobile, like murals.

In these cases it is necessary to investigate works of art on site. This requires transport of the instrument to the site and its positioning in front of the work of art. The M6 JETSTREAM is constructed for this purpose.

Application example

Investigation of Rembrandt's „Homer", dated 1663

Paintings by old masters often darken over time. An important question for the conservation and restoration of such a valuable historical painting is, whether the dark colors are caused by contaminations or if they are due to changes in pigment chemistry? If indeed changes have taken place, the original appearance of a painting was not only lighter but the colors may also have been different.

The figure shows the painting "Homer" by Rembrandt and the element distributions of cobalt (Co) and lead (Pb). For lead the distributions of Pb M radiation and Pb L radiation are displayed. These types of radiation have a different energy which means they come from a different depth in the painting – the Pb L radiation comes from deeper layers than the Pb M radiation.

"Homer" by Rembrandt
82 cm x 107 cm
Measured in 4 stitched sections with a step size of 500 µm (total approx. 3.5 megapixel)
Pixel dwell time: 20 ms

Analysis of Pigment Distributions

Cobalt pigments are typically blue. Depending on additional components this blue can have different shades. Pb oxide is a white pigment (white lead). The examination of the element distributions provides following results.

Cobalt distribution
The Co intensity is high at the location of the cap on Homer's head and also on his waist belt. In the painting these parts appear in a yellowish brown. It is quite likely that the paint in these areas originally had a more bluish tone.

Lead distributions
While the Pb L distribution shows the presence of white lead through all paint layers, the low energy Pb M distribution shows the presence of lead only at the paint's surface.

This is of interest, because oil paint has the tendency to become more transparent over time. Pb M radiation can therefore give an impression of the modeling of light and dark areas in paintings that have changed over time.

The alteration was caused by a change of the PbO pigment on the surface due to environmental influences. The degradation resulted in an overall dulling of the painting. Pigments in deeper layers were less affected by the degradation and therefore resemble the original white pigment distribution of the painting more closely.

Co K

Distribution of Co K radiation (blue pigment)

Pb L

Pb L radiation (high energy – white pigment)

Pb M

Pb M radiation (low energy – white pigment)

Picture of "Homer" by Rembrandt Courtesy of Mauritshuis, Den Haag.

Measurement data courtesy of Prof. J.Dik, G. van der Snickt, TU Delft

Examination of Horizontal Samples

Very often samples need to be positioned horizontally for analysis. This can be the case either for cultural heritage samples like manuscripts as well as for large material analysis objects like solar cells, geological samples, etc. For this purpose the upper part of the instrument with the spectrometer head can be tilted by 90° for measuring in a top-down geometry. In this mode the sample has to be positioned on a stage, the height of which has to be adjusted according to the thickness of the sample.

Application example

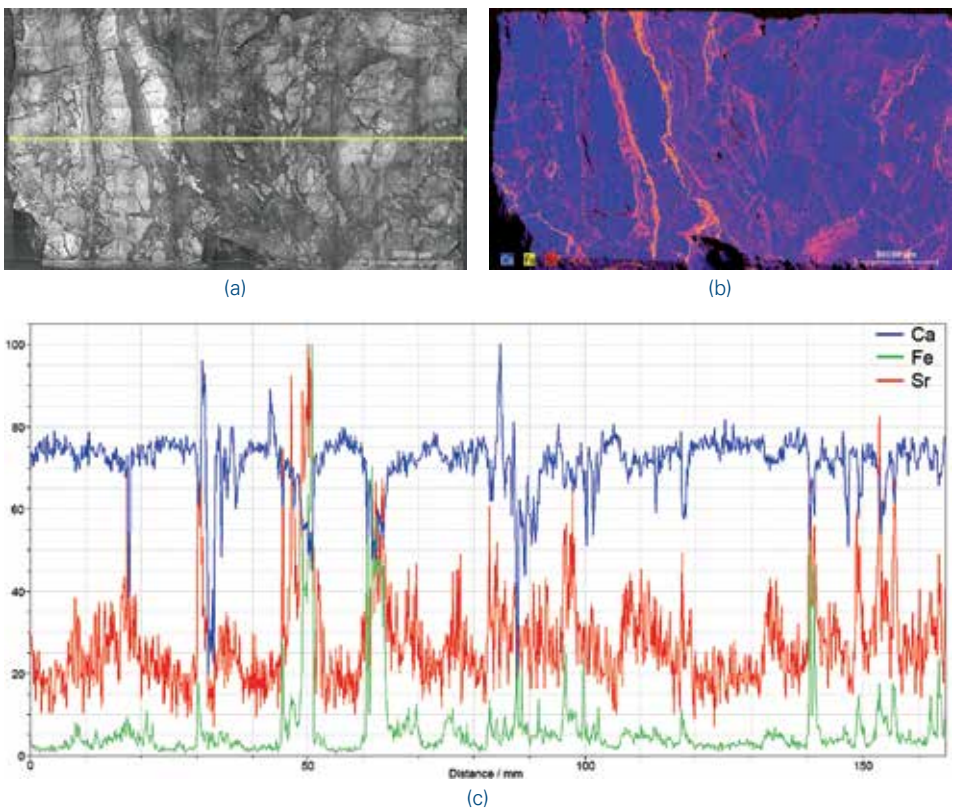
Analysis of a drill core

Drill cores are collected for various purposes and from different sites. Their examination can provide information on e.g.

- geo-history through their structure
- the sequences of rocks and sediments
- the paleo-climatological development through sediment layers.

Both line scan and mapping measurement modes are useful for the analysis of drill cores, as shown in the figure below.

Analysis of a drill core sample



(a) (b)

(c)

(a) Video mosaic image of a drill core with a size of approx. 17 cm x 9.5 cm. The line in the center indicates the position of a line scan extracted from the HyperMap database and shown in (c)
(b) Map of the elements Ca, Fe, and Sr. The step size is 1.5 mm, resulting in a map of 1120 x 631 pixels, acquired within 90 min. (5 ms pixel dwell time) at an input count rate of 85 kcps (output count rate 65 kcps).
(c) Line scan extracted from the HyperMap. The line was broadened by 5 pixels on each side to improve statistics. Note that the sharp increases in the Fe and Sr concentrations coincide with visible features in the map in (b).

Built for Speed

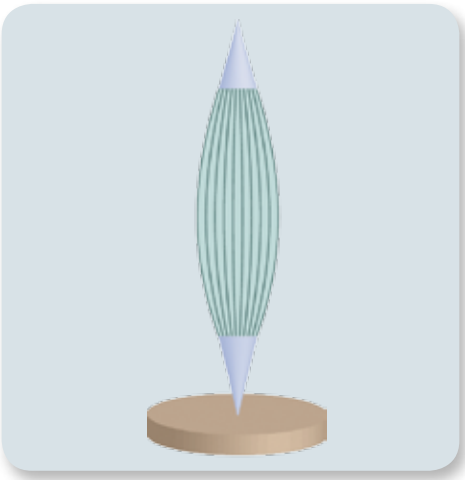


Diagram of the polycapillary optics used for X-ray beam focusing

Video mosaic image of a Slavonic icon

Sample view with two magnifications

Two optical microscopes offer sample images of different sizes (approx. 30 x 22 mm² and 11 x 8 mm²) for orientation on the sample and for positioning of single point measurements.

Analysis with various spot sizes

The spot size can be changed without significant loss of excitation intensity by varying the working distance. The working distance is determined by the adjustable focal plane of the high resolution optical microscope.

Mosaic images for large samples

A complete video mosaic image can be collected for samples of all sizes. This allows fast orientation on the sample (by point & click) and exact definition of the measurement area.

Rapid analysis with small step size

The step size needs to be small to attain high resolution. The exceptional speed of the M6 JETSTREAM – based on high excitation intensity and detection efficiency in combination with the fast stage – enables short measurement times. A dwell time of 0.1 ms can be selected in combination with the minimum step size of 10 µm. This results in a maximum stage speed of 100 mm/s! Translated into real world conditions, this means that, depending on sample size and required spatial resolution, high quality measurements can be performed within several minutes to a few hours.

Largest pixel numbers for large area mapping with small step sizes

The M6 JETSTREAM supports single maps with multi-megapixel resolution. This results in a spatial resolution of approximately 100 µm for the largest possible scan area.

An Exceptional Micro-XRF Spectrometer for Exceptional Samples

Technical specifications

Excitation	Rh-target microfocus-X-ray tube, 50 kV, 600 µA Polycapillary optics Filter wheel with 5 filters
Spot size	Adjustable in 5 steps from 100 to approx. 500 µm
Detection	30 mm² SDD, energy resolution < 145 eV for Mn Kα
Sample view	2 color cameras, capturing images with a size of 30 x 22 mm² and 11 x 8 mm², respectively. The high magnification camera permits setting of the focal and working distance
Scanning range	W x H x D: 800 x 600 x 90 mm³ Minimum step size 10 µm
Measurement direction	The measurement rig can be tilted by ± 10° in vertical measurement direction or to horizontal position for top-down measurement
Software package	Sophisticated software including instrument control, data acquisition, data evaluation and presentation, report generation
Functionality	Single point analysis Customizable automatic MultiPoint analysis Distribution analysis with HyperMap in one or two dimensions (linescan, mapping)
Instrument size	W x D X H: 1400 mm x 1800 mm x 1560 mm (horizontal position) W x D X H: 1400 mm x 650 mm x 2250 mm (vertical position) Weight: 200 kg The instrument can be dismantled into 4 parts for transportation
Mains	100/240 V; 50/60 Hz; max. power consumption 400 W

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