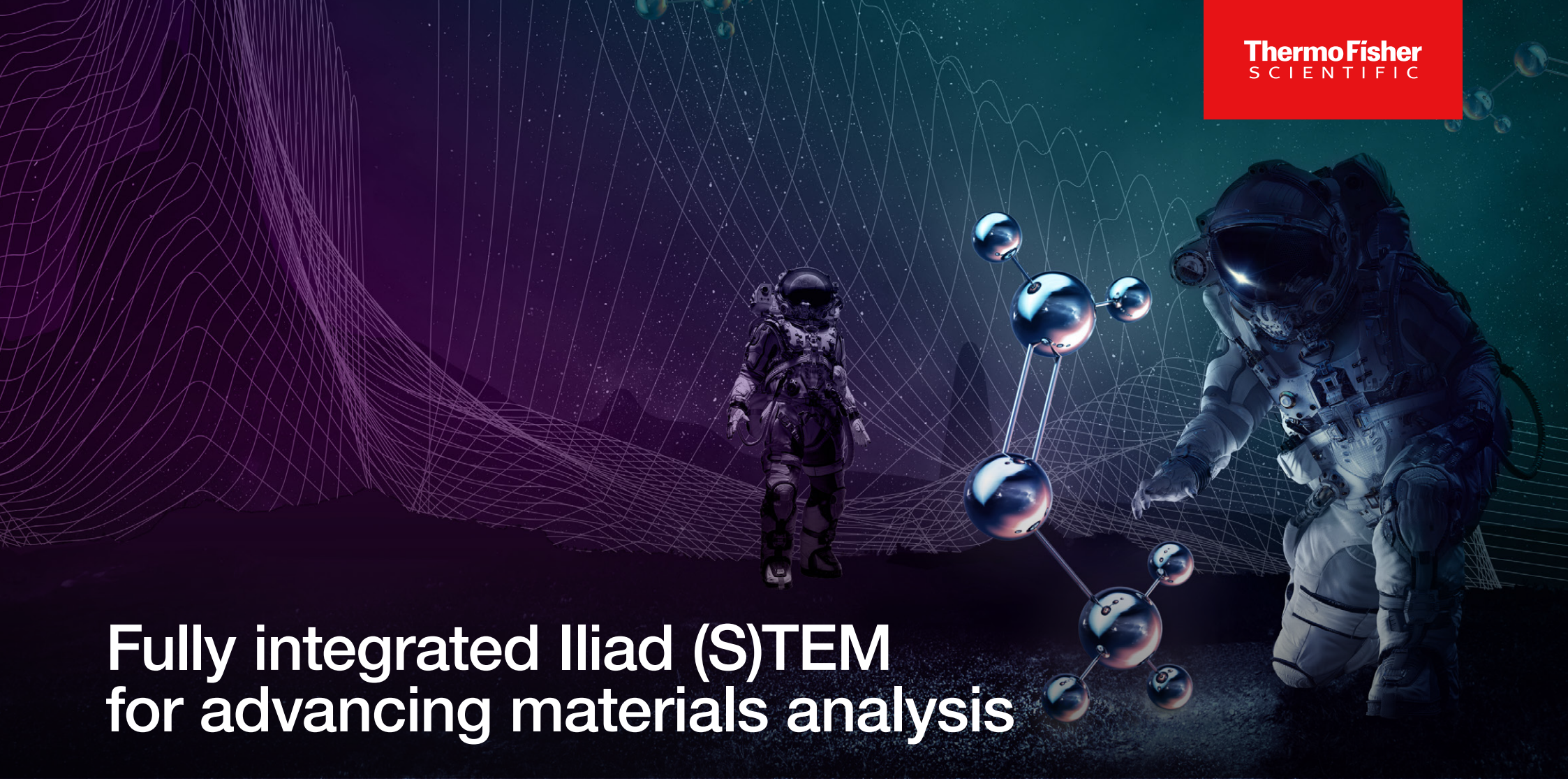


Fully integrated Iliad (S)TEM for advancing materials analysis

thermo scientific

Iliad (S)TEM

A greener, more sustainable future will rely on a circular economy that minimizes waste and maximizes the longevity of our products. Transitioning to this model will necessitate novel, optimized materials and technologies, which are actively being developed today. This critical work is being done across a variety of sectors that produce energy materials, catalysts, quantum materials, and materials for pollutant removal. Effectively utilizing these novel materials will require a highly precise understanding of their structure and chemical composition, revealed by advanced analytical microscopy. Many of these materials are, however, challenging targets for techniques such as transmission electron microscopy (TEM), as they are highly sensitive to electron beams.

To address this, Thermo Fisher Scientific is introducing the Thermo Scientific™ Iliad™ (Scanning) Transmission Electron Microscope, offering a fully integrated, advanced analytical solution with electron energy-loss spectroscopy (EELS) and energy-dispersive X-ray spectroscopy (EDX). It features a new Iliad EELS Spectrometer, the NanoPulser electrostatic beam blanker, several EDX detector options, and an operating voltage ranging from 30 to 300 kV. The unprecedented hardware and software integration of the Iliad (S)TEM, along with our future-proof approach to instrument design, support research at the frontiers of modern materials science.

In this eBook, we explore the power of fully integrated multimodal analysis with the Iliad (S)TEM, enabling advanced characterization of even highly complex and challenging modern materials.

Challenges in modern materials analysis

Cutting-edge materials science is tackling a wide variety of challenges, such as the development of sustainable energy materials, or understanding structure-property relationships in materials.

Advanced TEM characterization techniques are crucial throughout the field because they offer in-depth information about the structure and local chemistry of materials down to the atomic scale.

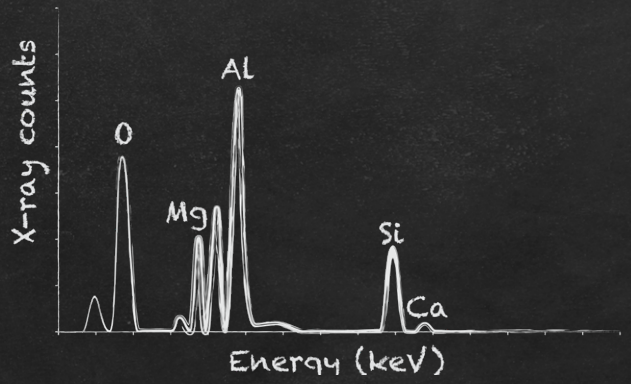
Modern transmission electron microscopes offer a variety of techniques for the precise characterization of materials, including spectroscopy down to the atomic scale with high energy resolution. To analyze materials sensitive to the TEM electron beam, these instruments often employ dose optimization strategies to minimize beam damage.

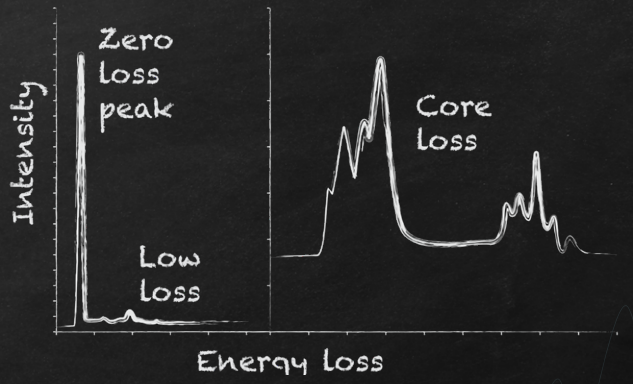
EELS provides information about the elemental composition, chemical bonding, and electronic structure of a material. It can provide both qualitative and quantitative data for a variety of applications, including the study of light elements and thin samples, or for collecting information on fine chemistry.

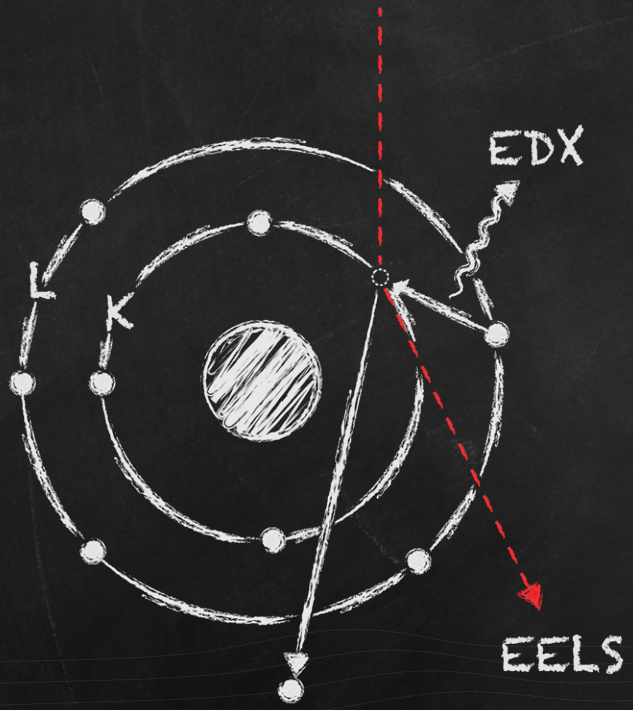
EDX (also called EDS) is a complementary technique used to analyze elemental composition across a broad range of materials, including metals and alloys, ceramics, nanoparticles, as well as novel energy and quantum materials.

How does it work?

These techniques allow for the exploration and understanding of materials at an atomic level, providing invaluable insights into their behavior and properties. This is essential for the development of new technologies and solutions to some of the world's most pressing challenges.







Energy dispersive X-ray spectroscopy

The TEM electron beam can inelastically scatter off the sample, transferring the energy of the beam electron to the specimen. The incoming electron excites an inner shell electron of the sample atom and creates a hole. To occupy the newly created hole, an electron from the outer shell lowers its energy by emitting an X-ray to balance the energy difference. The emitted X-rays are captured and used for chemical characterization of the sample, as each element and each shell has a specific energy.

Electron energy loss spectroscopy

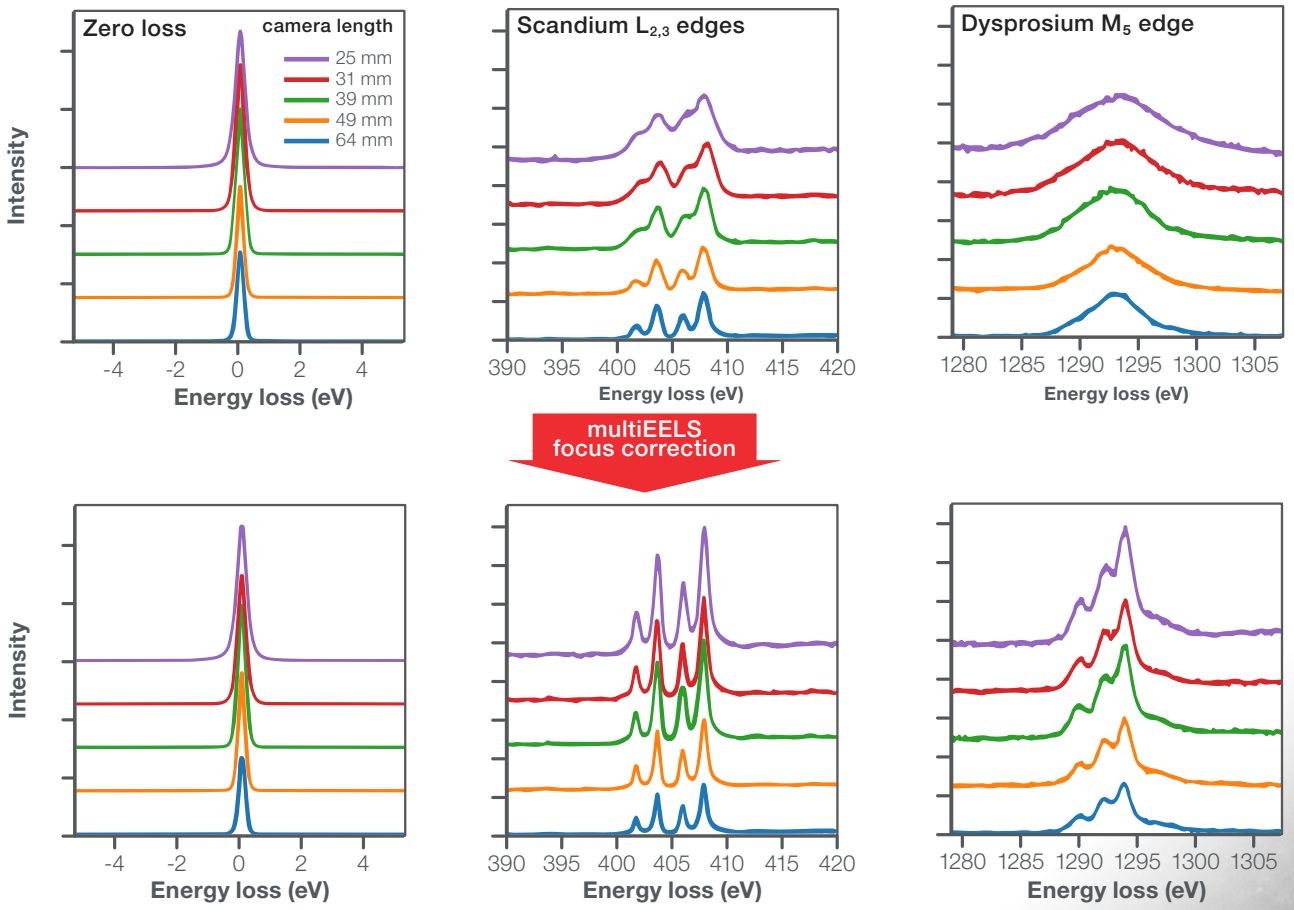
EELS is used to measure the energy of inelastically scattered electrons, as they contain information about the sample; the energy transferred to the sample atom is equal to the energy lost by the beam electrons.

An EELS spectrum can be divided into several parts. The electrons that pass the specimen without any detectable energy loss create the intense zero-loss peak (ZLP) at 0 eV. Next to the ZLP is the low-loss region, containing information on the outermost atomic orbitals that take part in inter-atomic bonding. After that is the core-loss region, which contains information on core-shell electrons and the chemical nature of the specimen. The core-loss edges correspond to excitations to the unoccupied states and are unique for every shell. The onset and shape of the core-loss edges can indicate oxidation state and the coordination of sample atoms, providing advanced chemical information.

What can EELS reveal?

EELS provides valuable information about the bonding, coordination, chemistry, and electronic properties of materials, allowing you to unravel atomic-scale information, which is crucial for designing and engineering advanced materials with tailored functionalities.

- Elemental identification: The elemental composition of the sample can be determined with spatial resolution.
- Chemical state analysis: EELS can differentiate between oxidation states, coordination environments, and bonding configurations.
- Valence state mapping: Mapping the distribution of valence electrons with EELS provides information on the electronic structure and bonding interactions.
- Fine structure analysis: Analyzing the fine structure of edges in the EELS spectra reveals information about bonding and coordination. This provides further insights into material chemistry and behavior.

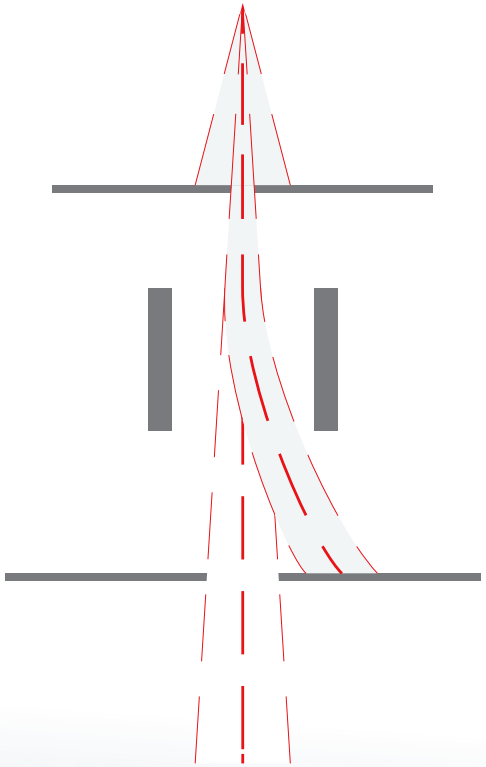


MultiEELS Mode data collection for $DyScO_3$ at 60 kV, monochromated, with a 30 mrad semi-convergence angle, and 5 mm spectrometer entrance aperture. Data obtained at five different camera lengths. Top) Without correction. Bottom) With on-the-fly auto-correction for chromatic defocus. *Data collected by Dr. Wouter Verhoeven.*

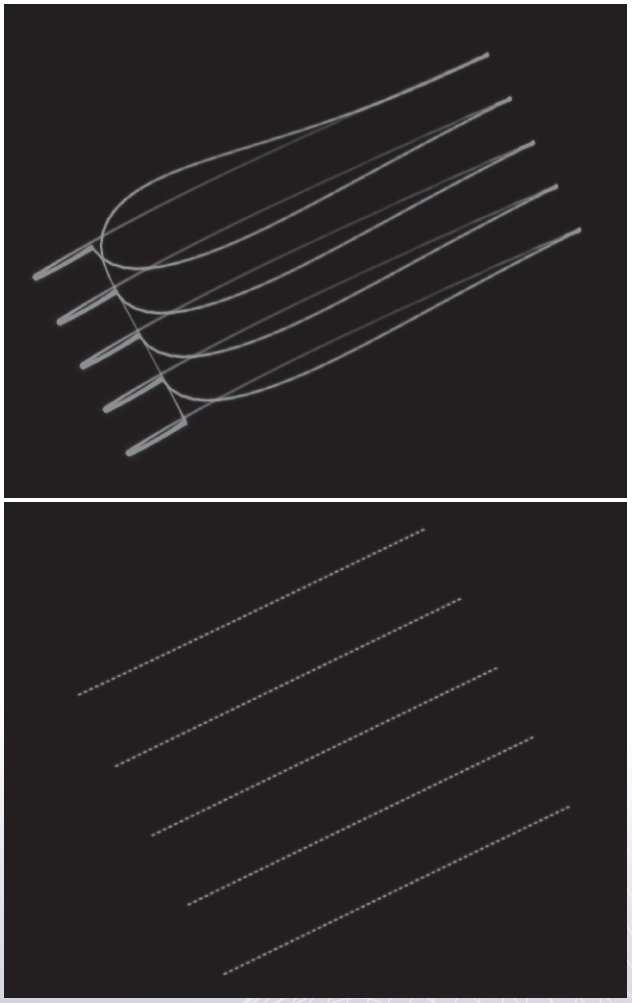
Dose optimization

The exposure of a material to an electron beam can result in a variety of beam damage, including structural alterations, heating, degradation, and even destruction, ultimately distorting TEM observations. To make sure that the data represents the actual material as accurately as possible, the electron dose should be limited to an optimal level that minimizes the effects of electron beam damage.

In particular, electrons that are not detected or that are lost due to overhead of the optical or scanning system do not give any information, while also causing unnecessary beam damage. An electrostatic pre-specimen beam blanker, such as the new NanoPulser from Thermo Fisher Scientific, can eliminate a great deal of this overhead by deflecting the electron beam away from the optical axis and the specimen on the nanosecond timescale. This helps preserve the sample's integrity, ensuring accurate and reliable measurements while minimizing the risk of irreversible damage.



Schematic of electrostatic beam blanking.



Electron beam scanning over a sample with conventional (no blanking) STEM (top) and with a pulsating beam blanker (bottom), which provided 50% blanking during the scan while also completely blanking the flyback signal. ***Data collected by Dr. Noopur Jain.***

Enabling advanced materials characterization

The Thermo Scientific Iliad (S)TEM is a fully integrated analytical platform designed for advanced materials analysis.

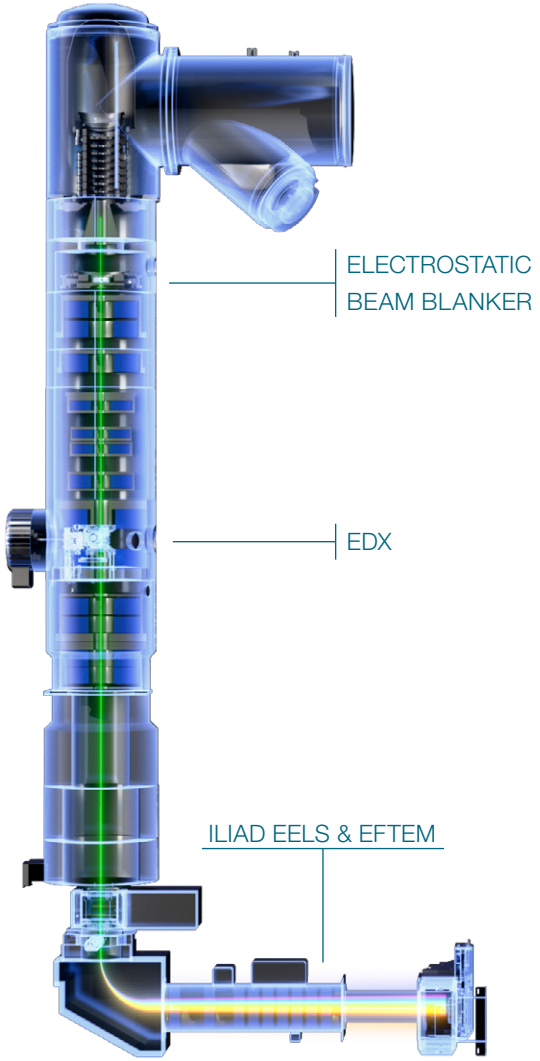
It features a new Thermo Scientific Iliad EELS Spectrometer with a dedicated Thermo Scientific™ Zebra™ EELS Camera, as well as the NanoPulser electrostatic beam blanker. EDX analysis is enabled by several detector system options; the Dual-X or Super-X EDX Detectors in the Iliad 300 (S)TEM or the Ultra-X EDX Detector in the Iliad Ultra (S)TEM. Both instrument models offer operating voltages between 30 and 300 kV. EELS data collection is extended with Thermo Scientific™ Velox™ Software, and nearly every component in the Iliad (S)TEM can be accessed via Python scripting using Thermo Scientific™ Autoscript™ Software. This allows you to create new data collection workflows, or to adopt AI-based data collection and processing strategies.

Iliad EELS Spectrometer

EELS optics must transfer a broad range of electron energies through the instrument to the detector while minimizing distortion. The advanced integration of TEM and spectrometer optics in the Iliad (S)TEM addresses this issue and elevates EELS data collection, ensuring optimized performance.

NanoPulser electrostatic beam blanker

The NanoPulser is an electrostatic beam blanker that can be used for dose optimization as well as time-resolved experiments. It operates by selectively blocking the electron beam, effectively turning it on and off over the specimen at a high frequency. The NanoPulser operates at up to 1 MHz repetition rates with a shortest pulse duration of 10 ns, enabling precise temporal control over the electron dose delivered to the sample.

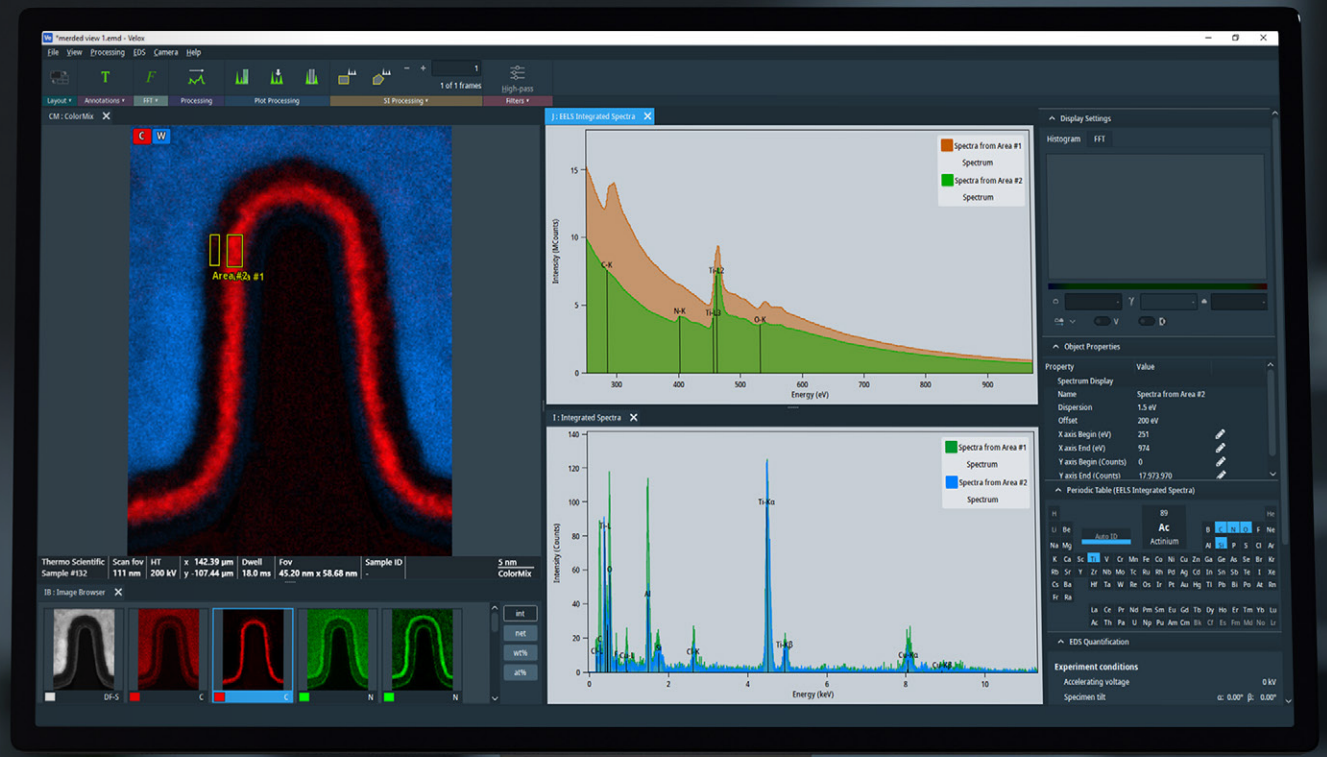


Schematics of the Iliad (S)TEM column, highlighting the locations of the integrated electrostatic beam blanker, the EDX detectors, as well as the Iliad EELS Spectrometer and Energy Filter.

Enhancing TEM analysis with Velox Software

Velox Software offers comprehensive, easy-to-use experimental control, facilitating access to (scanning) transmission electron microscope optics and detectors, thereby enhancing the reproducibility, yield, and support for quantitative material analysis. Velox Software enables high-contrast atomic imaging of light and heavy elements in various modes, as well as flexible (S)TEM movie recording for dynamic studies.

Velox Software is also equipped with unique packages for both EELS and EDX, ensuring the acquisition of optimized spectral images with high yield. The software also provides live feedback during acquisition and fast post-processing of the EELS and EDX data. Overall, Velox Software increases the control, quality, and versatility of the Iliad (S)TEM, making it an essential part of the materials analysis process.



Applications

The Iliad (S)TEM can provide crucial information for a wide range of materials science applications, from novel materials research to the optimization of material properties and performance.

With the Iliad (S)TEM, you can enhance your materials science research across a variety of fields, including:

- Catalyst development
- Metals and alloys
- Energy storage and conversion
- Semiconductor engineering
- Environmental sustainability

In each of these areas, advanced analytical microscopy offers unique insights into the structure and chemistry of materials down to the atomic scale. This can be used to discover the mechanisms that govern material properties and reactivity, guiding targeted materials design and development.

Atomistic insights for advanced materials

As materials science explores increasingly complex and advanced materials, there is a growing need for atomistic insights regarding their composition and structure.

Such intricate information requires a multimodal approach that couples microscopic and spectroscopic techniques. The Iliad (S)TEM is a novel instrument offering a combination of high-resolution (S)TEM, EELS, and EDX. The addition of the NanoPulser for dose optimization makes the Iliad (S)TEM ideally suited for even highly sensitive or fragile materials.

Instrument control with Velox Software streamlines the typically daunting process of multimodal analysis. Brought together, these capabilities will enable you to delve deeper into the atomic world, unraveling new possibilities and advancing our understanding of materials.

Seamless sub-atomic materials analysis with the fully integrated Iliad (S)TEM

The **Iliad 300 (S)TEM** provides a combination of high flexibility and high productivity to ensure accurate characterization of modern complex materials.

- Integrated, advanced EELS and EDX spectroscopy with the Iliad EELS Spectrometer and Super-X or Dual-X EDX Detection System.
- NanoPulser beam blanker enables dose optimization and time-resolved experiments.
- Operating voltages from 30 to 300 kV accommodate optimized experimental conditions for a broad range of materials and applications.

Learn more

The **Iliad Ultra (S)TEM** is an optimized solution for the characterization of even highly complex and challenging materials.

- Integrated, advanced EELS and EDX spectroscopy with the Iliad EELS Spectrometer and Ultra-X EDX Detection System.
- NanoPulser beam blanker enables dose optimization and time-resolved experiments.
- Live switching between operating voltages from 30 to 300 kV quickly optimizes experimental conditions for a broad range of materials and applications.

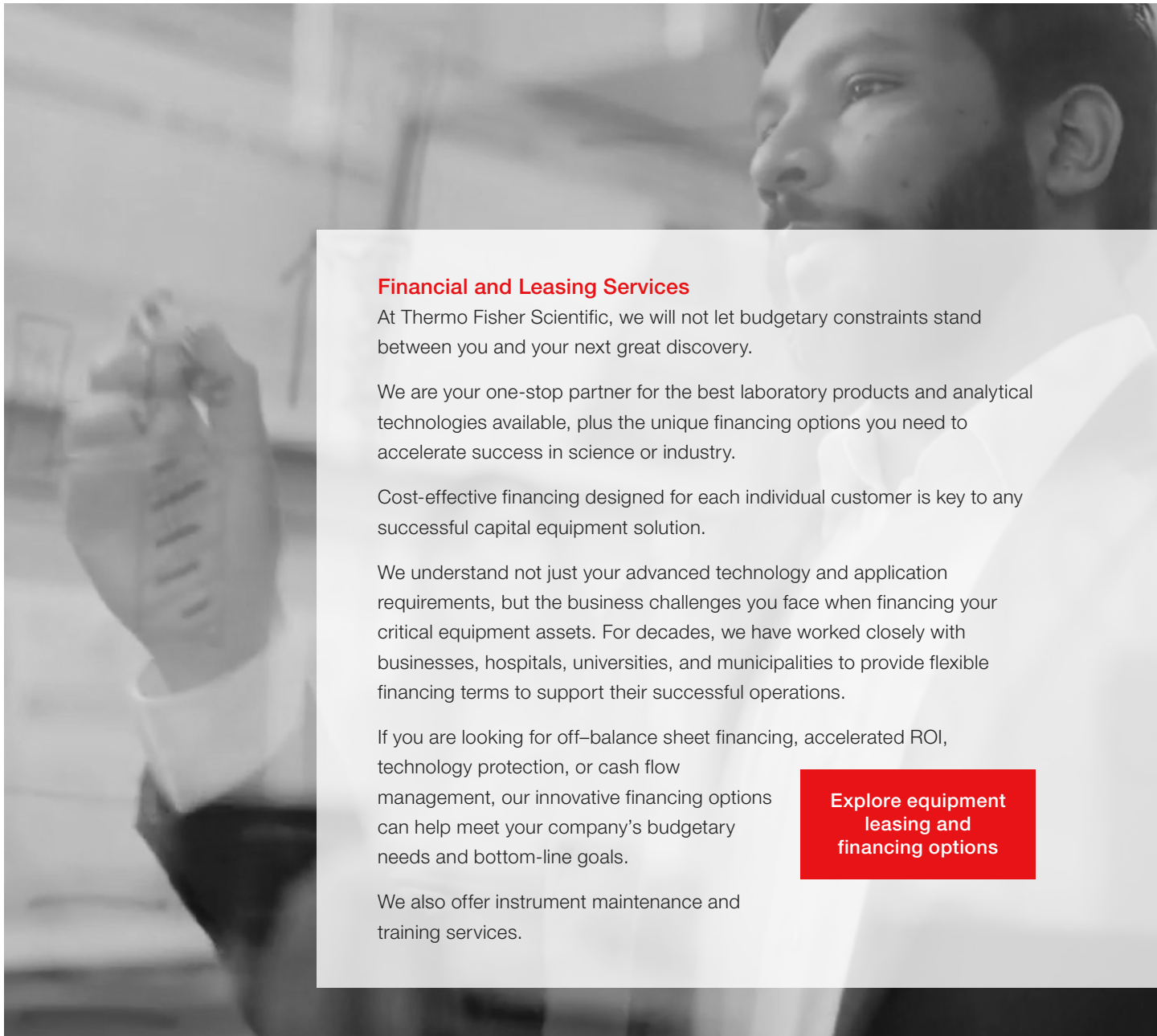
Learn more

About Thermo Fisher Scientific

We are the world leader in serving science. Our Mission is to enable our customers to make the world healthier, cleaner and safer.

Learn about the mission of Thermo Fisher Scientific. Duration 1:23.

Our innovative solutions for electron microscopy, surface analysis, and microanalysis help materials science researchers advance their sample characterization to gain deeper insight into the physical and chemical properties of materials from the macroscale to the nanoscale. Our multiscale, multimodal solutions cover a broad range of applications across dozens of industries and research fields, serving customers in academia, government, and industry. Our TEMs, DualBeam™ FIB-SEMs, comprehensive portfolio of SEMs, XPS, and microanalysis solutions, combined with software suites, take customers from questions to usable data by combining high-resolution imaging with physical, chemical, elemental, mechanical, and electrical analysis across scales and modes.



Financial and Leasing Services

At Thermo Fisher Scientific, we will not let budgetary constraints stand between you and your next great discovery.

We are your one-stop partner for the best laboratory products and analytical technologies available, plus the unique financing options you need to accelerate success in science or industry.

Cost-effective financing designed for each individual customer is key to any successful capital equipment solution.

We understand not just your advanced technology and application requirements, but the business challenges you face when financing your critical equipment assets. For decades, we have worked closely with businesses, hospitals, universities, and municipalities to provide flexible financing terms to support their successful operations.

If you are looking for off–balance sheet financing, accelerated ROI, technology protection, or cash flow management, our innovative financing options can help meet your company's budgetary needs and bottom-line goals.

Explore equipment leasing and financing options

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