Spectra 300 (S)TEM for materials science

The ultra-high-resolution, “all-in-one” solution for atomic scale materials characterization

The Spectra 300 (S)TEM is the highest resolution imaging and spectroscopic platform from Thermo Fisher Scientific. Wth its wide-gap pole piece and an accelerating voltage range of 30–300 kV, it serves an expansive range of materials investigations.

High-resolution structural and chemical information at the atomic level

The Thermo Scientific™ Spectra™ 300 (Scanning) Transmission Electron Microscope combines:

- A redesigned, high-stability base
- A new ultra-high resolution (X-FEG UltiMono) source or an ultra-high brightness (X-CFEG) source
- Image and 5th order probe aberration correction (S-CORR)
- Single electron sensitive STEM detection
- Sensitive energy dispersive X-ray (EDX) detectors

By synchronizing these technologies through our advanced software and automation modules, the Spectra 300 (S)TEM makes accessing high-resolution atomic-scale information more efficient, easy and repeatable than ever.

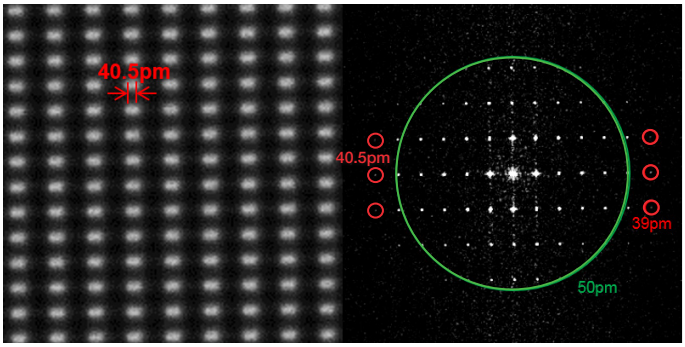


Figure 1. HAADF (DCFI) STEM image of GaN [212] at 300 kV showing 40.5 pm Ga-Ga dumbbell splitting and 39 pm resolution in the FFT on a wide gap (S-TWIN) pole piece.

Key Benefits

High-quality atomic characterization. Optimized electron optical performance and ultra-sensitive detection enables high-quality atomic imaging and analysis in 2D and 3D.

Highly repeatable data. Sophisticated software automation routines such as OptiSTEM+ and OptiMono+ optimize the system to its peak performance, resulting in more repeatable and quantifiable data.

Optimized EDS performance. Guaranteed by a portfolio of symmetric detector geometries, which contributes to our unique quantification capability, in combination with an ultra-high brightness X-CFEG to provide rapid EDS mapping across a wide range of materials.

***In situ* and dynamic research.** Fast cameras, chemical detectors, smart software and our wide gap S-TWIN lens enable *in situ* data acquisition with no compromise on resolution and analytical capabilities.

High environmental stability. The redesigned enclosure and ultra-stable Spectra 300 (S)TEM base with passive and (optional) active vibration isolation (with iVIS) minimize external environmental influences and ensure high-quality data from long-term and short-term experiments.

A wide range of materials science research in one platform. Our unique combination of optics, ultra-sensitive detection and wide-gap pole piece ensures that even light, highly sensitive materials can be characterized at the atomic scale.

Investigate a wide range of materials at the atomic scale

By combining a large-gap objective lens (the Thermo Scientific S-TWIN Lens) with superior optics and analytics, the Spectra 300 (S)TEM delivers both performance and flexibility in one tool. The six-fold astigmatism (A5) probe corrector (S-CORR) of the Spectra 300 (S)TEM delivers our highest available STEM resolution specification at 300 kV (50 pm) and 60 kV (96 pm) and provides *in situ*, dynamic and 3D EDS tomography capability without the need for non-standard holders or sample types.

When equipped with an X-FEG UltiMono, the same fully flexible system can achieve ultra-high energy resolution in the <25 meV regime.

Our powerful and advanced software allows specialized techniques like integrated differential phase contrast (iDPC) imaging for the study of magnetic and electrical properties and for optimized Z-contrast imaging from hydrogen to uranium. Higher quality atomic characterization data is available from more materials types than ever before.

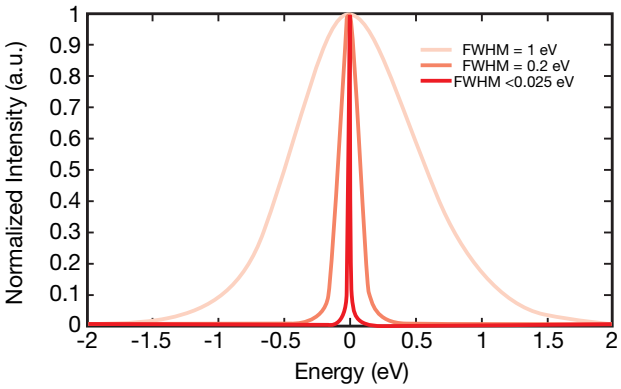


Figure 2. The energy resolution of the X-FEG UltiMono can be flexibly tuned between <25 meV and 1 eV.

High-quality atomic characterization

The new S-CORR by Thermo Fisher Scientific provides specified sub-angstrom imaging resolution from 60 to 300 kV and an order of magnitude improvement in the stability and lifetime of the corrected state, compared to previous generation DCOR technology. The S-CORR is capable of correcting A5 for all accelerating voltages. When combined with the new Auto S-CORR CEOS alignment software, the S-CORR can automatically tune all aberrations up to 5th order, which is particularly important when high spatial resolution is required at accelerating voltages <120 kV. Furthermore, the probe profile can be tuned to suit the atomic-level experiment required; it can be optimized for ultra-high-resolution STEM imaging or high-throughput spectroscopy.

High-quality atomic-level chemistry and bonding-state research of sensitive materials is enabled by simultaneous EDS and electron energy loss spectroscopy (EELS), with speeds up to 1000 spectra/s.

More reliable, quantitative analysis and imaging

Fully automated, single-click access to high-resolution STEM (<50 pm) and energy-resolution EELS (<25 meV) experiments are enabled for all users with new OptiSTEM+ and OptiMono+ software automation packages on the Spectra 300 (S)TEM. Additionally, drift-corrected frame integration (DCFI) ensures that repeatable, high-quality, atomic-resolution images are possible and that recursive mapping capabilities optimize chemical analysis. Our “look back” functionality, available within our acquisition software, ensures that you never miss anything, since results can be stored and analyzed later.

An integrated Faraday cup provides an accurate calibration of the beam current measurement, which is pivotal for quantitative and reliable imaging and analysis. The Faraday cup measurement guarantees experimental repeatability between different Thermo Scientific tools.

The Panther Detector: the next generation in low-dose STEM imaging

The Spectra 300 (S)TEM is equipped with the Thermo Scientific Panther Detector—an entirely new, segmented STEM detection and data infrastructure unit. The Panther Detector geometry offers access to advanced STEM imaging capability, combined with the sensitivity and detectability to measure single electrons. The entire signal chain has been optimized and tuned to provide unprecedented signal-to-noise-ratio-imaging capability with extremely low probe currents (<1 pA). When combined with sensitive STEM imaging techniques such as iDPC, new possibilities are enabled for imaging dose-sensitive samples that have typically been very difficult to characterize with a TEM. Additionally, the completely redeveloped data processing infrastructure offers the future capability of combining detector segments in arbitrary ways and a scalable interface to synchronize multiple STEM and spectroscopic signals.

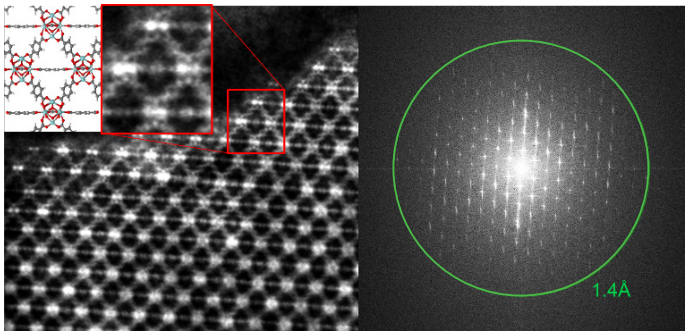


Figure 3. Extreme-low-dose imaging (166 e^-/ Å^2) of the metal organic framework (MOF) UiO 66. A probe current of <0.5 pA was used in combination with iDPC and new sensitive STEM detectors to image atomic-level details in this highly dose-sensitive material. *Specimen courtesy of Professor Y. Han, King Abdullah University of Science and Technology.*

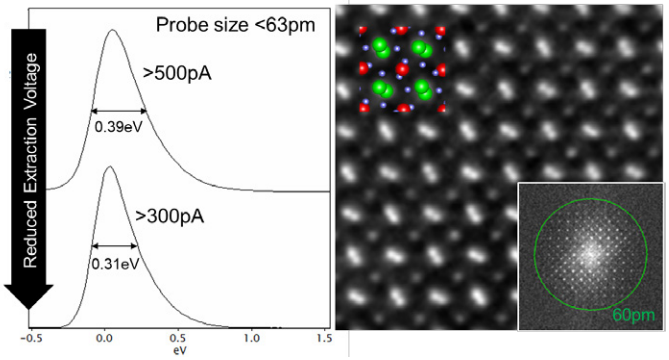


Figure 4. The energy resolution of the ultra-high brightness X-CFEG can be adjusted using the extraction voltage. In the case above, it was varied between 0.39 eV (with <500 pA of probe current) and 0.31 eV (with >300 pA of probe current). The spatial resolution, as demonstrated in the HAADF image of $DyScO_3$, remains unaffected (in this case <63 pA). *Sample courtesy Professor L.F. Kourkoutis, Cornell University.*

Spectra 300 (S)TEM	Energy spread	Information limit	STEM resolution
Image corrector	0.2–0.3 eV**	60 pm	136 pm
Probe corrector	0.2–0.3 eV**	100 pm	50 pm (125 pm at 30 kV)
Uncorrected	0.2–0.3 eV**	100 pm	136 pm
X-FEG/UltiMono double corrected (probe + image corrector)	0.025 eV***	60 pm	50 pm (125 pm at 30 kV)
X-CFEG double-corrected (probe + image correction)	0.4 eV	70 pm	50 pm (136 pm at 30 kV)

* For X-FEG/Mono unless otherwise specified.
** Depending on energy filter options.
*** Specification for 60 kV.

Note: All specifications are at 300 kV using an S-TWIN lens (unless otherwise noted).

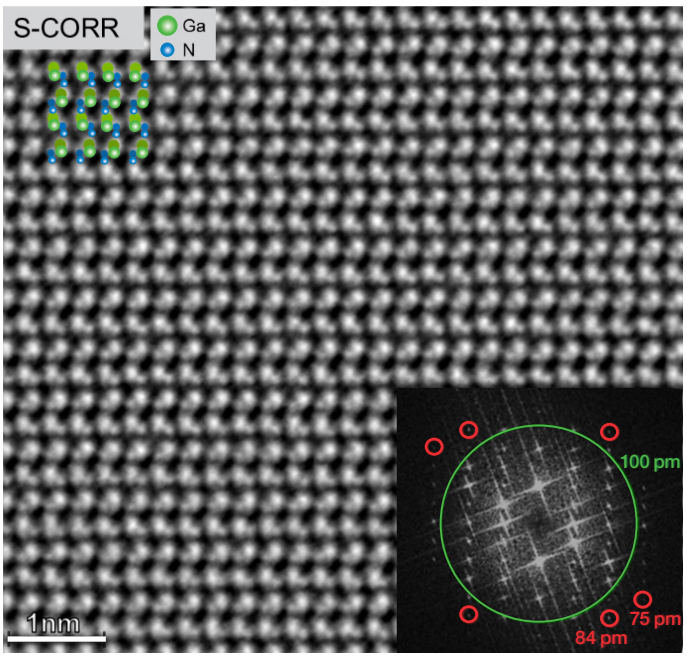


Figure 5. GaN[110] imaged with iDPC STEM at 60 kV with X-FEG/Mono on a wide gap S-TWIN pole piece. Both Ga and N columns are simultaneously revealed using iDPC at 75 pm resolution, as demonstrated in the FFT.

Technical highlights

Source

- X-FEG Mono: High-brightness Schottky field emitter gun and monochromator with a tunable energy resolution range between 1 eV and <0.2 eV
- X-FEG UltiMono: High-brightness Schottky field emitter gun with ultra-stable monochromator and accelerating voltage with a tunable energy resolution range between 1 eV and <0.025 eV
- X-CFEG: Ultra-high brightness with an intrinsic energy resolution of <0.4 eV
- Flexible high-tension range from 30-300 kV

Optical column and correctors

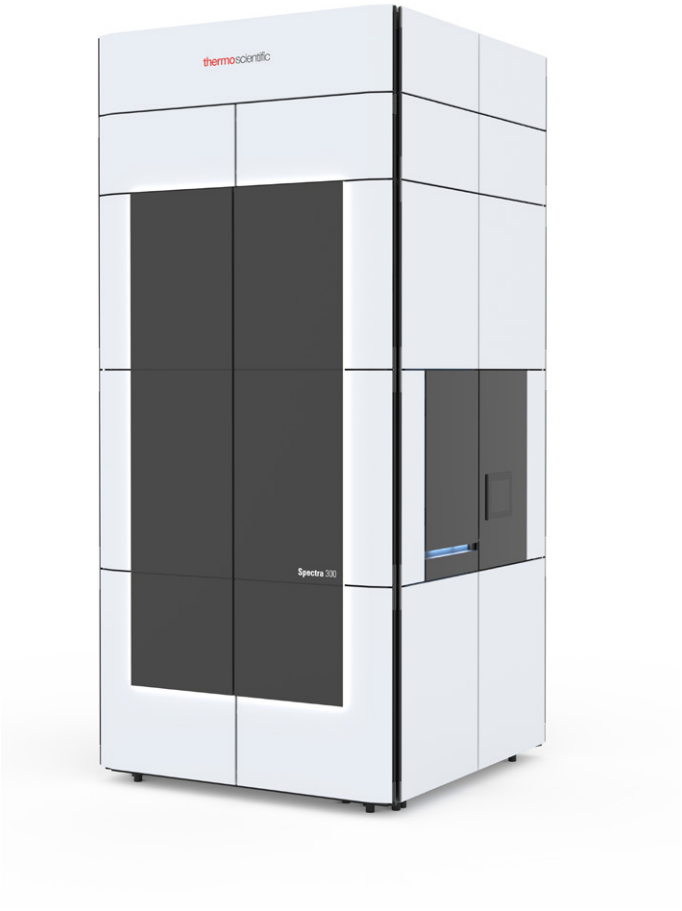
- Three lens condenser system with indication of convergence angle and size of illuminated area for quantitative measure of electron dose and illumination conditions
- New S-CORR provides sub-angstrom imaging resolution at 60 kV as specification and an order of magnitude improvement in optical stability compared to previous generation DCOR technology. The S-CORR corrects A5 for all accelerating voltages
- New CEOS Auto S-CORR auto alignment software makes probe corrector tuning fast, easy, and fully automated up to 5th order aberrations
- Patented mechanical stacking of column modules minimizes instabilities caused by excessive deflector excitations
- Thermo Scientific™ ConstantPower™ Lens and corrector design, for high thermal stability in mode switches, minimize image drift
- Low hysteresis design to minimize crosstalk between optical components for increased reproducibility
- Symmetric S-TWIN objective lens with wide-gap pole piece design of 5.4 mm with “space to do more” allows the use of special holders, such as heating, cooling, indentation and electrical probing holders
- Objective aperture in the back focal plane of the objective lens for optimized TEM dark field application work
- Automatic apertures for remote operation and reproducible recall of aperture positions during aperture change
- Field upgradeable probe and image Cs-corrector
- Rotation-free imaging for easy operation and clear orientation relationship between imaging and diffraction
- Deep sub-angstrom resolution for all accelerating voltages (60-300 kV) with low specimen drift
- Field-free imaging in TEM Lorentz mode with 2 nm resolution for magnetic property studies, and option for Cs-corrected Lorentz with <1 nm resolution
- Integrated Faraday cup and calibrated fluscreen current Readout is linear over whole beam current range

Stage

- Computerized 5-axis, ultra-stable specimen piezo stage for accurate recall of stored positions and tracking of the areas visited during sample navigation. The piezo stage allows for movements as fine as 20 pm for centering of feature of interest in the field of view
- Tilt range ±40 degrees for analytical double tilt holder* to access the maximum number of zone axes of each crystal in a polycrystalline material. With tomography holder, ±75 degrees to minimize the missing wedge in 3D reconstructions
- Linear drift compensation provided by piezo stage can be used to mitigate limitations caused by thermal drift, which is unavoidable during *in situ* heating or cooling experiments

Analytics and detectors

- Super-X/Dual-X EDS options, integrated software, and the Gatan Ultrafast EELS/DualEELS options together provide up to 1000 sp/s of simultaneous EDS and EELS data acquisition
- Live peak identification and background fitting during ultra-fast EDS acquisition
- Symmetric EDS detector design allows for combined tomographic EDS
- EDS quantification using Thermo Scientific™ Velox™ Software (featuring dynamic correction of holder shadowing as a function of tilt for both Super-X and Dual-X Detectors)
- **Super-X Detector:** high-sensitivity, windowless EDX detector system based on patented SDD technology
  - Output count rate: up to 800 kcps
  - Energy resolution
    - ≤136 eV for Mn-Kα and 10 kcps (output)
    - ≤140 eV for Mn-Kα and 100 kcps (output)
  - 0.7 srad solid angle
  - High P/B ratio (Fiori number) >4000
  - Excellent in-hole performance (<1% hole counts)
- **Dual-X Detector:** symmetric, windowless EDX detector system with high solid angle and throughput
  - Output count rate: >20 kcps/nA/detector
  - Energy resolution
    - ≤130 eV for Mn-Kα and 10 kcps (output)
    - ≤140 eV for Mn-Kα and 100 kcps (output)
  - 1.8 srad solid angle
  - P/B ratio (Fiori number) > 2000
  - Excellent In-hole performance (<1% hole counts)
  - Below 2.5% spurious peaks in EDS system background



Available detector options

- HAADF detector
- New ultra-low-noise Panther Detector; on-axis solid state, 8 segmented BF and ADF detectors (16 segments in total)
- Thermo Scientific™ Ceta™ 16M Camera (optionally with speed enhancement)
- Gatan OneView/OneView IS cameras
- Gatan energy filter series
- Electron microscope pixel array detector (EMPAD)

Software

- The Electron Dose Control (EDC) module predicts beam current, dose, and dose-rate live based on gun and optics settings. The EDC calibration is done with a built-in Faraday cup. Users can set electron dose without knowledge of TEM optics. The beam current, dose, and dose-rate are reported in Velox Software along with image metadata.
- Differential phase contrast (DPC) STEM technique enables live measurements of intrinsic magnetic and electric fields
- Integrated DPC (iDPC) software for high imaging contrast in STEM on materials across the whole periodic table. This low-dose technique expands the use cases of the instrument in materials science and replaces annular bright field as the technique of choice for light elements. Invaluable when applied to samples that are typically damaged under short exposures to the electron beam
- OptiSTEM+ software for single click correction of 1st and 2nd order probe-forming aberrations to deliver high STEM resolution to all users on our probe corrected tools**
- OptiMono+ software for completely automated monochromator alignment and tuning to the highest achievable energy resolution on monochromated systems from 1 eV down to <25 meV
- Thermo Scientific™ TrueImage™ Atlas focus series software for quantitative HR-TEM applications (For more details see separate product data sheet)
- Fully digital system for remote operation using the SmartCam suite
- Advanced, integrated software enables fast and simultaneous signal acquisition (up to five STEM signals)
- Smart scanning technology for high image quality in STEM

Available holders

- Single tilt holder
- Double tilt holder
- Tomography holder
- Thermo Scientific and third-party *in situ* holders
- Please ask for a list of functional holders

Other features

- Environmental enclosure to relax the acoustic and room temperature variation requirements
- Cold trap design for up to four days of operation to maximize up-time

Installation requirements

- Please contact your sales representative for a complete pre-installation requirement document

* Tilt range 35° with Super-X option.

** High performance guaranteed in combination with S-CORR STEM probe corrector.

Learn more at **thermofisher.com/spectra300**