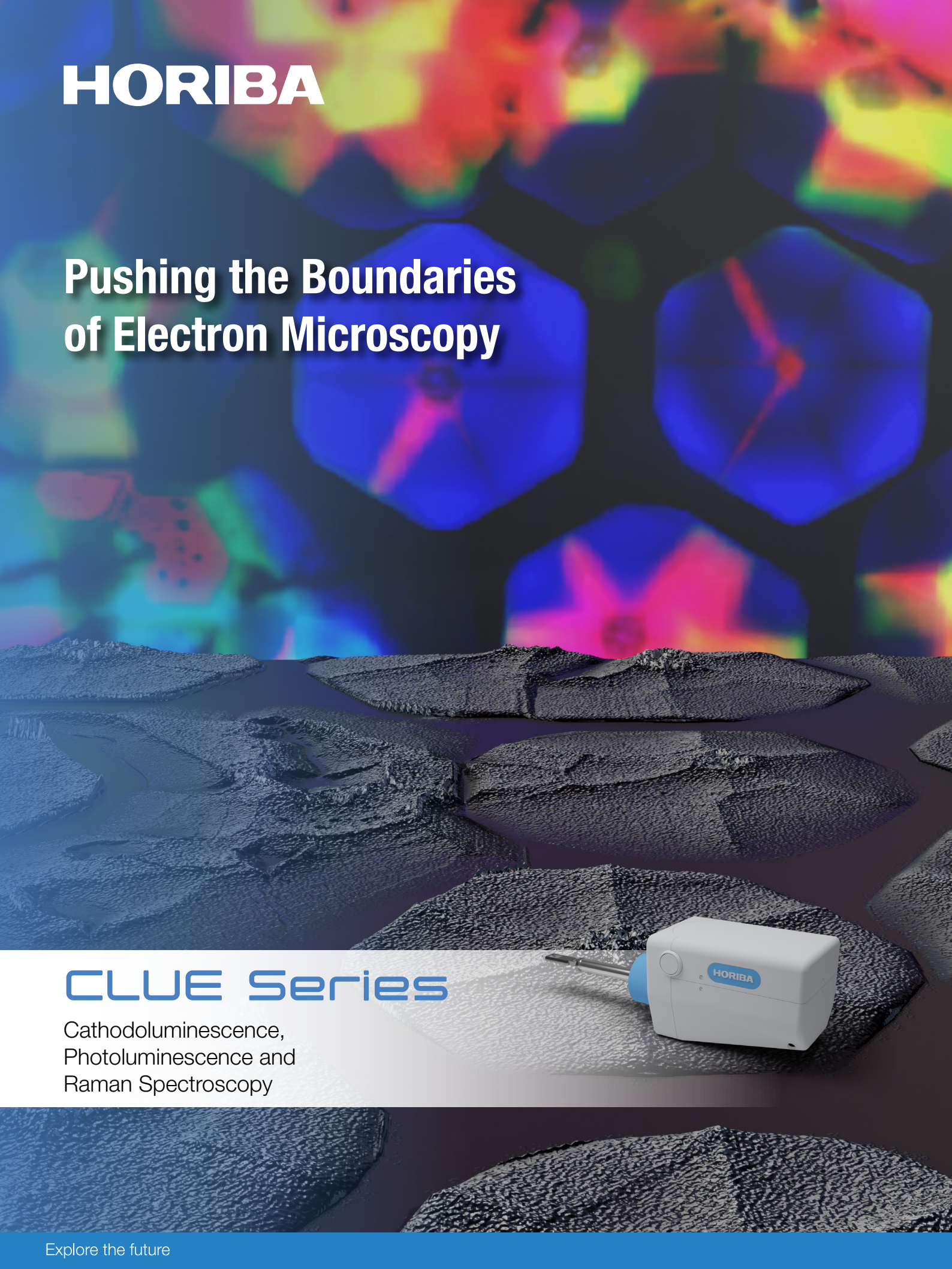
HORIBA

Pushing the Boundaries of Electron Microscopy



CLUE Series

Cathodoluminescence,
Photoluminescence and
Raman Spectroscopy

Cathodoluminescence: Advanced Spectral Imaging Technique

What is cathodoluminescence and what does it measure?

Cathodoluminescence (CL) is the light emitted when a material is struck by a high-energy electron beam. It reveals detailed information about a material's composition, crystal structure, band gap, impurities, and defects.

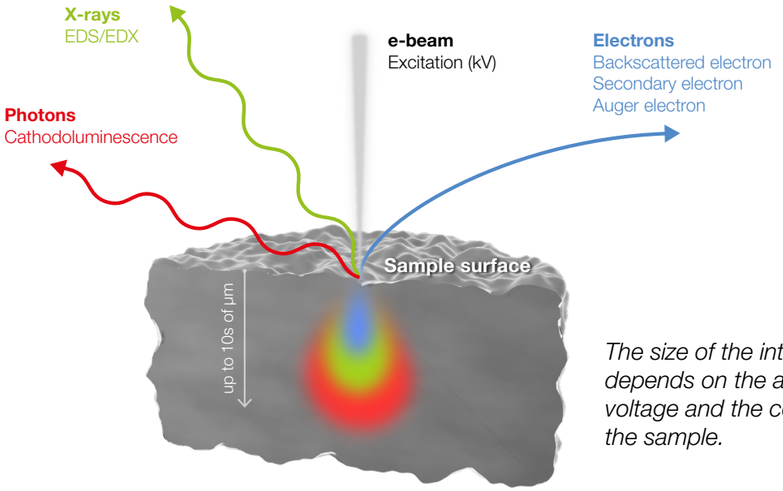
Application fields:

- Semiconductors
- Optoelectronics
- Geology
- Mineralogy
- And more.

Concept of cathodoluminescence

In combination with electron microscopy, cathodoluminescence (CL) is a powerful, non-destructive materials characterization technique to study optical and electronic properties from bulk samples to nanostructures.

CL, like the Photoluminescence (PL) technique, explores light emission phenomena, with the added advantage that excitation by a high-energy electron beam enables access to a broader range of electronic transitions, and allows emission from the Deep UV to the Near Infrared.

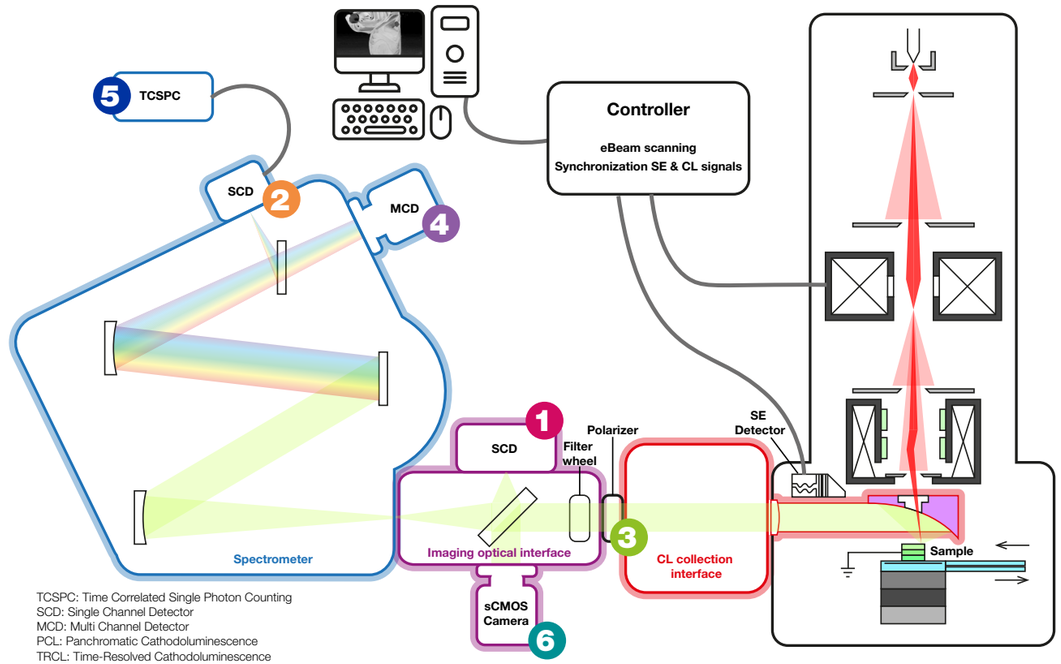


The size of the interaction volume depends on the acceleration voltage and the composition of the sample.

Cathodoluminescence (CL) can provide a wide energy excitation range with a single electron beam, making the technique highly versatile for **studying various materials** without needing multiple excitation sources.

It offers **high spatial resolution**, allowing for detailed imaging at the nanoscale, **high sensitivity** and **depth analysis** for revealing information about subsurface structures, and also excels in **multimodal colocalization**, as it can be combined with other electron microscopy techniques, enabling simultaneous analysis of multiple properties in the same region.

Add spectroscopy capabilities to your electron microscope

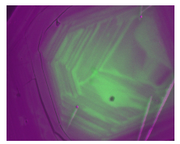


Cathodoluminescence System (CLUE) | **Scanning Electron Microscope**

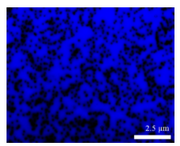
Information given by the various configurations:

1 2 **Panchromatic CL**
Fast visualization of emitted light with broad wavelength range and high spatial resolution.

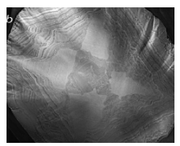
1 2 **RGB CL**
The true color imaging improves visualization of different emitted light compared to greyscale images.



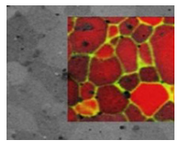
2 **Monochromatic CL**
Fast visualization with high sensitivity and contrast of emitted light at specific wavelength.



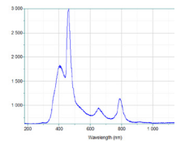
3 **Polarizer**
Analyzes the polarization state of emitted light.



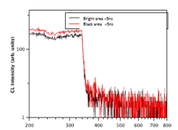
4 **Hyperspectral CL**
Simultaneously collects spectral information with imaging by capturing a full spectrum at each pixel within an image.



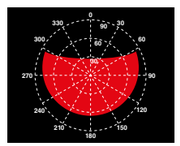
4 **Spectral CL**
Decomposition of the emitted luminescence into a spectrum to identify specific emission lines or bands.



5 **Time-Resolved CL**
Measurement of the temporal evolution of light emission from a material.



6 **Angular Resolved CL**
Analysis of directional emission of light from materials.



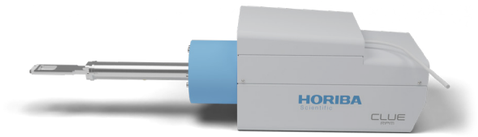
CLUE Series: One Solution for your Electron Microscope to Answer all Characterization Needs

Choose one HORIBA CLUE series collection interface to integrate with your existing electron microscope, then combine it with a detector and spectrometer for modular spectroscopy, or pair it with a Raman platform for multimodal, correlative microscopy.

HORIBA CLUE Series, dedicated collection interfaces

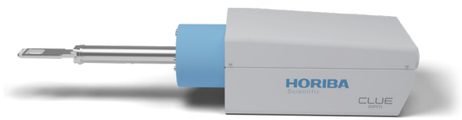
The HORIBA CLUE Series systems feature a compact design with a motorized, fully retractable mirror for easy integration in any SEM and FIB chambers.

F-CLUE



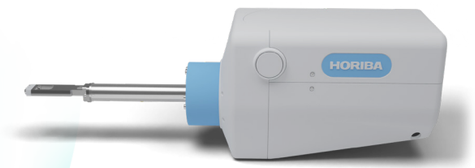
Space saving footprint, reliable

H-CLUE



Adaptable CL solutions with
unmatched sensitivity and modularity

R-CLUE



All-in-One
multimodal spectroscopy platform

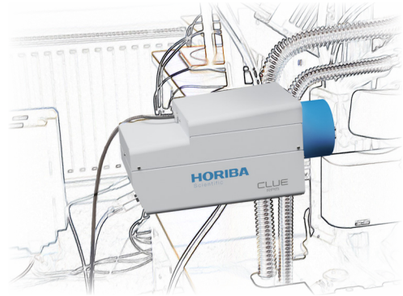
Find the interface that fits your needs

F–CLUE Compact and reliable CL

Optical fiber-coupled solution offering a reliable and flexible interface for Cathodoluminescence imaging and spectroscopy analysis.

Special features:

- Fibered optical coupling
- Compact, space-saving design
- Remote architecture for flexible configuration
- Mirror positioning assisted by built-in video camera



H–CLUE Versatile Hyperspectral CL

Direct coupled solution giving the ultimate performance for Cathodoluminescence imaging and spectroscopy analysis across a broad spectral range.

Special features:

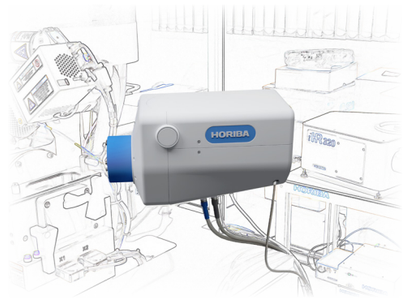
- Free-space optical coupling
- Only reflective optics from DUV to NIR
- Ultimate CL sensitivity based on imaging design
- Multimodal CL techniques (TRCL, ARCL, ...)
- Versatile detection options
- High-resolution imaging and spectroscopy

R–CLUE All-in-One Raman, CL & PL Platform

All-in-one fiber coupled solution allowing colocalized Raman, Photoluminescence and Cathodoluminescence imaging and spectroscopy analysis.

Special features:

- Fiber-coupled compact design
- Fully automated and user-friendly
- Multi-wavelength Raman lasers
- Co-localized laser and e-beam excitations
- Extended CL options (PCL, MCL)
- Advanced Raman & CL Software LabSpec 6

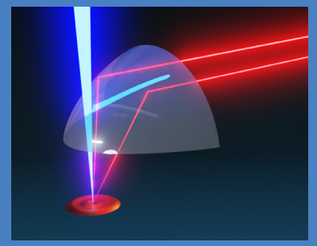


Enhanced Electron Microscopy by Spectroscopy

The CLUE series, collection interfaces for CL

All HORIBA CLUE system interfaces are compact, compatible with all SEM and FIB systems, require only **one horizontal port**, and feature a fully motorized, software-controlled parabolic mirror.

What makes the CLUE parabolic mirror special is its **high sensitivity**, thanks to a diamond-turned design with high numerical aperture for optimal light collection. Its **compact**, **fully retractable build** ensures easy integration into the microscope chamber without altering original conditions, with **multiple size options** to match various working distances.



Add modular spectroscopy by combining with a spectrometer or a detector

- **Spectrometers**

The iHR series features a unique asymmetric optical layout and toroidal mirrors that correct for astigmatism, allowing optimized resolution and imaging quality across the entire focal plane. This is critical for CL, where spatial and spectral precision are essential.

Modular and Customizable Design

Designed for flexibility, users can tailor entrance/exit ports, gratings, detectors, and accessories to meet diverse CL configurations across a broad spectral range.

iHR Series

- **Detectors**

Wide Detector Portfolio for Every Need

HORIBA offers a comprehensive range of detectors tailored for CL:

- Photomultipliers (ambient, cooled, photon-counting, time-resolved)
- CCDs for hyperspectral mapping
- InGaAs for extended NIR
- sCMOS for angular-resolved CL
- Hanbury–Brown and Twiss (HBT) setups for time-correlated measurements

Detectors in the CLUE series are modular and upgradeable, allowing labs to start with basic imaging and expand to full spectroscopy as needed.

CCD

Single channel detectors

Coupling with optical microscopy solutions

For enhanced chemical specificity and complementary analytical capabilities, CLUE and nanoGPS integration supports optional coupling with HORIBA's versatile Raman microscopy solutions controlled by the LabSpec 6 software suite.

Raman Microscope

- High-resolution and automated chemical imaging: Rapid chemical mapping, precise structural analysis, stress/strain characterization, and crystallinity measurements.
- High performance: Supports both routine analyses and advanced research applications with Raman and Photoluminescence.

LabRAM Soleil™ and XploRA Plus™
Raman Spectrometers

Modular Macroscopy Solutions (SMS)

- Advanced multimodal solution compatible with Raman, Photoluminescence, Reflectance, Transmittance and Time-Resolved Photoluminescence.
- Modular and flexible design for scalable and upgradable research applications with upright microscopes.

SMS
Standard Microscope
Spectroscopy Systems

HORIBA expertise

HORIBA is your partner in spectroscopy with unequalled experience in optics, vacuum and detectors designs.
Based on combined experience in Japan (MP series) and in France (CLUE series), HORIBA offers a variety of cathodoluminescence systems for process applications in semi-conductors, as well as research applications in Earth, Life and Material Sciences.
With a consistent worldwide installed base, and as a leader in diffraction gratings, Raman, PL and VUV spectroscopy, HORIBA is a global company with application and service support next to you.

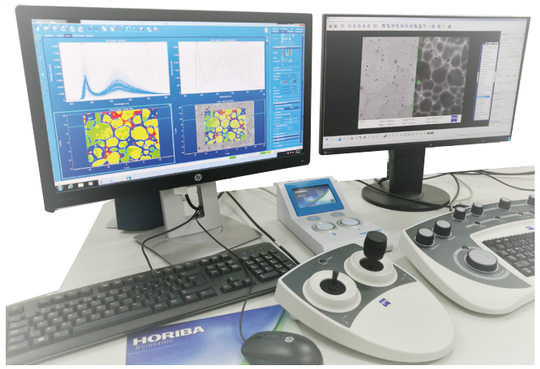
Software Suite That Empowers Your Workflow

Multimodal & multiscale characterization in one integrated workflow

LabSpec 6 (LS6) software suite is HORIBA's intuitive software suite for managing advanced spectroscopy workflows. It simplifies data acquisition, spectral mapping, and multimodal analysis through a unified, lab-friendly interface.

The **CLUE module** extends LabSpec 6 for correlative electron microscopy, offering precise control of calibration, sample positioning, and result visualization, essential for efficient, high-resolution, multimodal investigations.

- **Dedicated CL acquisition module:** Simplifies setup and captures high-quality spectral and imaging data directly from SEM sample.
- **Intuitive nanoGPS integration:** Instantly access and navigate to specific regions of interest using absolute XY coordinates.
- **Automated routines:** Saves time with customizable acquisition sequences, built for reproducibility and user efficiency.
- **Expandable for multimodal acquisitions** with Raman and Photoluminescence (PL) to grow with your analytical needs.



Additional LabSpec 6 software modules for extended streamlined operations

MVAPlus

Extract and visualize with multivariate spectral analysis.

ParticleFinder

Automatic particle detection.

IDFinder

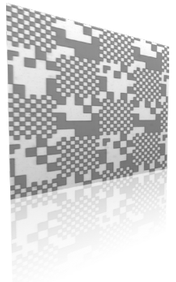
Identify Raman materials.

graphYX, powered by Mountains® Technology, is the correlative imaging hub for multimodal analysis, for multimodal image alignment and interactive visualization tool that enhances image clarity, contrast, and overlay settings to reveal what matters most in your data.

graphYX

Solve sample repositioning challenges with nanoGPS

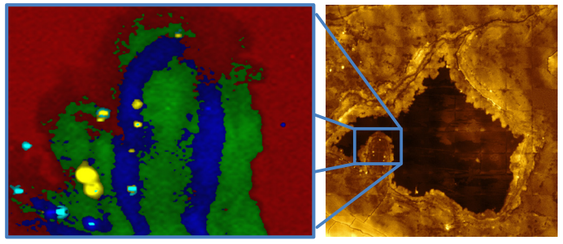
Correlative imaging often suffers from misalignment and inefficiencies. HORIBA's **nanoGPS** technology provides a robust, instrument-independent referencing solution that:



NanoGPS tag

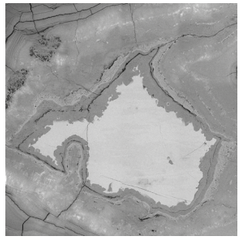
- **Accurately repositions regions of interest (ROIs)**
  Ensures the same sample area can be precisely revisited across multiple imaging and spectroscopy platforms.
- **Reduces time-consuming manual alignment**
  Automates cross-modality alignment, eliminating guesswork and repetitive adjustments.
- **Improves repeatability and data correlation**
  Maintains consistent ROI tracking across sessions, boosting confidence in comparative or time-lapse studies.

By embedding a compact XY tag directly on your sample, nanoGPS allows absolute positional referencing, enabling confident relocation between instruments. Combined with automated alignment in LabSpec 6 and GraphYX, your multimodal datasets are rapidly synchronized, accelerating insights for material science and nanotechnology.

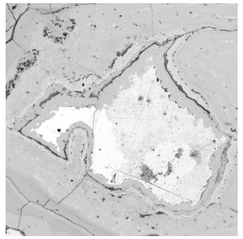


Hyperspectral CL

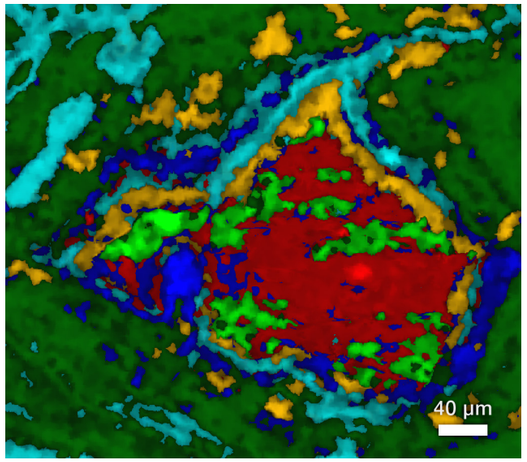
Panchromatic CL



Back Scattering Electron



Secondary Electron



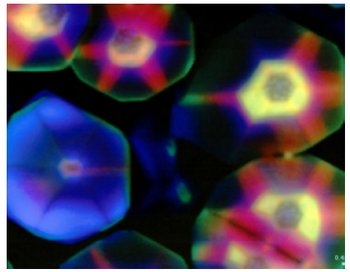
Goethite
Pyrite
Heulandite
Lepidocrocite
Carbon
Pyrite + Carbon

Analytical Needs Solved by CLUE

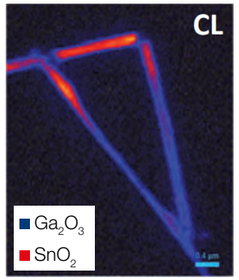
Semiconductors

When combined with an electron microscope, cathodoluminescence (CL) is a highly effective, non-destructive analytical method for examining the optical and structural properties of complex bulk semiconductor materials at the nanoscale.

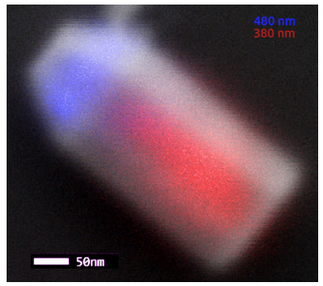
- Enables detailed mapping of strain, defects, doping, stress, grain boundaries, and dislocation, with exceptional spatial resolution and spectral sensitivity for comprehensive material characterization.
- Allows tunable electron beam energy for nanoscale analysis, from quantum dots and thin films to deep-layer heterostructures, across a broad spectral range.



Uniformity of GaN pyramids + InGaN well by MOCVD.



Growth of nanostructured tin oxide on gallium oxide nanowires leading to the formation of SnO_2/Ga_2O_3.

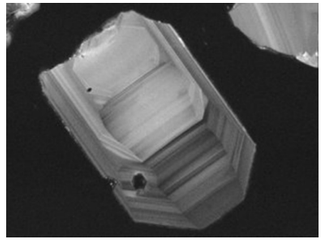


Courtesy of Prof. Victor J. Gomez.
CL enables the distinction of different In incorporation In InGaN shells due to the presence of different crystal planes 380 nm (red) 480 nm (blue).

Geology and Mineralogy

CL is a powerful tool for geologists and mineralogists to unravel the complex histories of rocks and minerals. By combining structural and spectral information, CL helps reconstruct geological processes and supports applications.

- Reveals growth zoning, deformation patterns, and diagenetic overprints that are often invisible under traditional light microscopy.
- Provides critical insights into mineral provenance, crystallization sequences, and the presence of trace elements or defects.

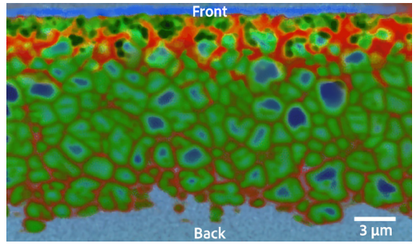


Courtesy of Dr Kristóf Fehér from Hungarian National Museum, Visualization of zircon crystal growth by PCL imaging (F-CLUE).

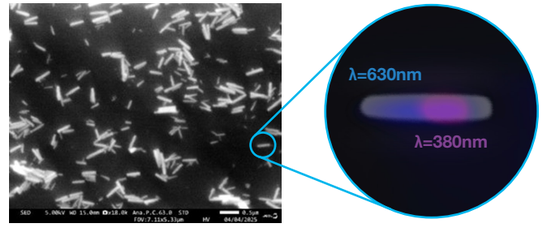
Photovoltaics and Optoelectronics

CL offers several distinct advantages in the fields of photovoltaics and optoelectronics, particularly for material characterization, crystal quality optimization, and failure analysis.

- Reveals dislocations and grain boundaries impacting solar cell efficiency, while offering insights into dopant activation, carrier recombination, and luminescence, crucial for photovoltaic optimization.
- Identifies active zones, defect quenching, strain, composition, and emission in quantum structures through CL mapping in LEDs and laser diodes, which is vital for tuning wavelength and efficiency.



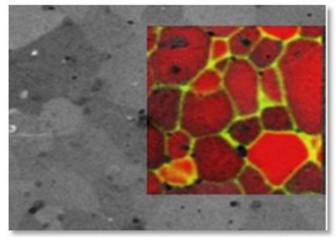
Polycrystalline film in-situ doped with As, capable of achieving high efficiency showing excitonic (blue), AsTe (green) and deeper defect (red) emission.



Courtesy of Dr.S.Boninelli, Dr. V. Strano from IMM-CNR, Catania, Italy.
Visualization of ZnO nanorods by hyperspectral CL map (F-CLUE), showing respectively near band gap (λ=380 nm) and deep level defect states (λ=630 nm).

Ceramics

Analyzes firing conditions, raw material sources, and technological choices of ancient and modern ceramic production, offering insights into crystalline phases, defects, and compositional zoning to support both quality control and archaeological interpretation.



Courtesy of Shanghai Institute of Ceramics.

Polycrystalline ceramic sample of Al-doped ZnO (AZO). Visualization of grain boundaries (yellow/green) by hyperspectral CL mapping (H-CLUE).

Forensics

Provides detailed analysis of trace materials such as glass fragments, minerals, or paints, linking evidence to sources by revealing luminescence at the micro- to nanoscale, beyond the reach of conventional methods.

Archeology

Identifies provenance, manufacturing techniques, and post-depositional changes in artifacts such as glass, stone, or pigments, revealing hidden structural details not visible with standard microscopy.

Biology

Reveals growth patterns, trace elements, and diagenetic alterations, aiding in studies of environmental conditions and biological processes over time.

Models	F-CLUE	H-CLUE	R-CLUE
Analysis Technique	CL imaging & Spectroscopy		Raman, CL, PL
Compatible SEM models	Various Scanning Electron Microscopes & Focus Ion Beam models from all major SEM suppliers		
Collection mirror	Diamond-turned Al-coated parabolic mirror, Enhanced in spectral range 185 -2,500 nm with collection efficiency >86% Optimized UV with surface roughness <10 nm Interchangeable mirror holder		
Collection Interface	Fully retractable and maintains original SEM performance Motorized mirror mount controlled by software Compatible large specimen chamber x, y stepper motors with accuracy < 1 µm Automated insertion positioning Ultra-precise adjustments with real-time video and spectral visualization.		
Interface coupling	Fiber coupling	Free space coupling with only reflective optics	Fiber coupling
Compatible spectrometers	microHR iHR series	iHR series	iHR series Raman spectrometers
Panchromatic CL imaging	•	•	Optional
Monochromatic CL imaging	250-900 nm	185-980 nm	Optional (250-900 nm)
Hyperspectral CL mapping	250-1,050 nm	185-1,050 nm	450-1,050 nm optional (250-1,050 nm)
Hyperspectral Raman mapping	-	-	•
SWIFT™ CL mapping	•	•	•
Wavelength resolution	See spectrometer specification sheet		
Field of view (CL)	Up to 10,000 µm²	Up to 10,000 µm²	100 µm² standard up to 10,000 µm² with enhanced CL extension
Laser excitation	-	-	Up to 3 lasers 532 nm in standard Others available on request
Software	Spectroscopy and imaging Windows® 11, 64 bit powered by LabSpec 6™ Data acquisition, processing, mosaic mode, drift correction, image overlay …		
Options			
Ultraflat parabolic mirror Short working distance <10 mm	•	•	-
Enhanced MCL sensitivity	Cooled photomultiplier detection with photon counting mode		
NIR-MCL imaging extension	Up to 2,100 nm with cooled IGA single channel detection		
NIR hyperspectral CL mapping	Up to 2,100 nm with cooled IGA array detector instead of MCL detection		
Enhanced NIR sensitivity with 2nd spectrometer	-	Up to 4 detectors and 6 gratings	-
Panchromatic CL detection to SEM	250-900 nm	185-900 nm Direct coupling	280-900 nm
RGB CL imaging	•	•	•
Polarizer	-	•	-
Time-resolved CL	•	•	•
Angle-resolved mode	-	•	-
Correlative microscopy NavYX	•	•	•

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