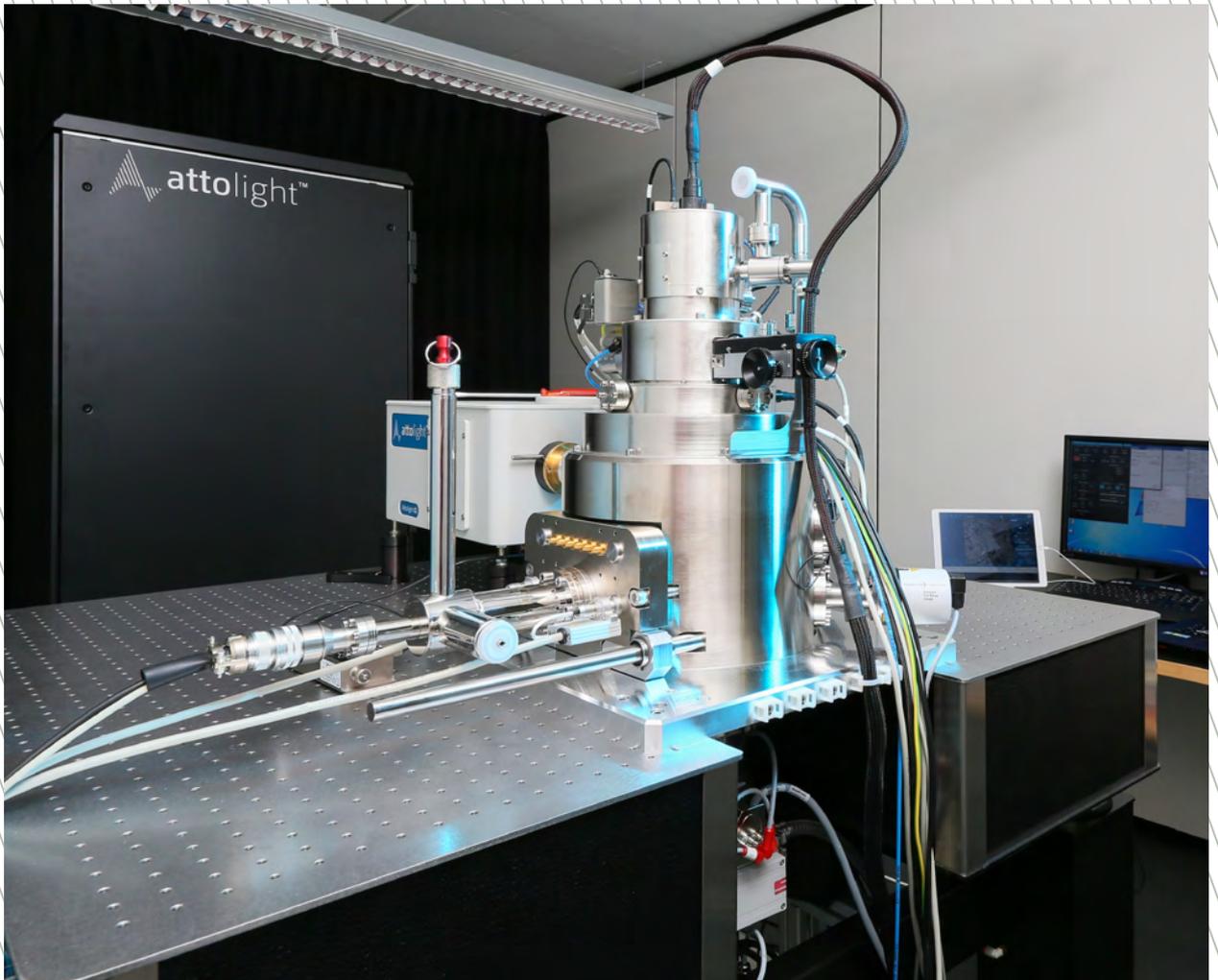


Allalin

Blazing fast quantitative CL



Overview

The **Allalin** is a nanometer resolution spectroscopy instrument, based on a disruptive technology known as quantitative cathodoluminescence that integrates a light microscope and a scanning electron microscope (SEM) into one tool. The **Allalin** allows for “No Compromise” large field/fast scanning simultaneous SEM imaging with hyperspectral or panchromatic CL maps. The system was constructed from the ground up to attain the best cathodoluminescence performance without sacrificing the SEM performance: the light microscope and the objective lens of the SEM are carefully integrated so that their focal planes match each other; the light microscope is machined with sub-micrometer precision so as to an achromatic, high numerical aperture (N.A. 0.71) detection with superior photon collection efficiency over a large field of view — up to 300 μm — compared with traditional CL technologies. As a result, quantitative cathodoluminescence, where instrument related artifact can intrinsically be ruled out as an explanation for a spectral feature or a contrast, becomes conceivable for the first time. →

The **Allalin** is built for those who need to follow a tight technology roadmap and quickly access very precise spectroscopic information that has been out of reach for traditional methods.

In semiconductor Failure Analysis, Development & Research, the **Allalin's** spectroscopic measurement capabilities offer an unparalleled solution for fast and reliable defect detection and localization. Proven use cases include measurement of dislocation density, material composition fluctuations, strain, dopant type and concentration; and a wide range of other applications.

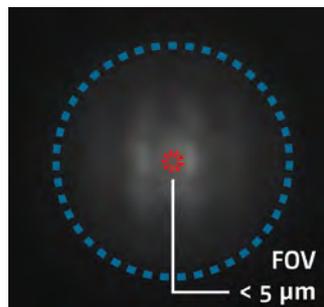
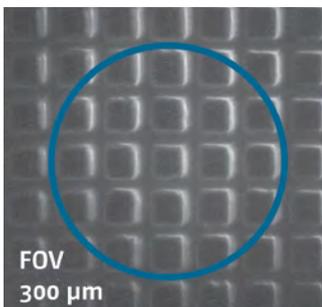
In scientific research, the **Allalin's** ability to create spectroscopic maps with nanometer resolution makes it the ultimate tool to acquire a deep understanding into the physics of nanoscale objects.

The **Allalin** features a comprehensive set of options to optimize the tool's performance for your application: various choices of detectors to cover the UV-IR wavelength range, an stable low temperature stage, and a high sensitivity EBIC (Electron Beam Induced Current) detection solution.

Key benefits

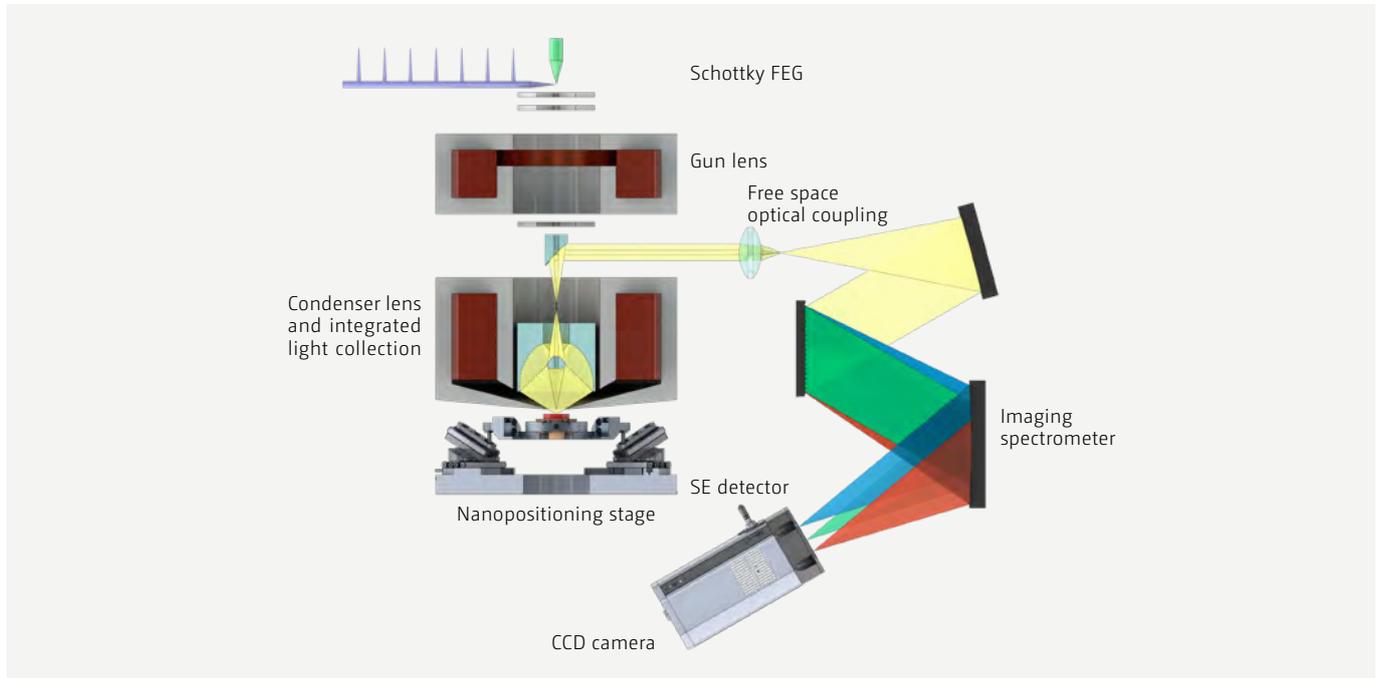
Designed from the ground up as an integrated CL-SEM system

- Puts optical collection within the electron column
- Requires ZERO optical alignment for CL
- Highest collection efficiency over a field of view (FOV) of 300 μm
- Ensures CL uniformity and reproducibility, making the system quantitative as well as qualitative. Quantitative: the photon collection efficiency is constant ($\pm 1\%$) over a large FOV of 300 μm (no vignetting); a 300 μm map is performed without any displacement of the specimen: cathodoluminescence results are reproducible and comparable
- Uses lower beam dosages, reducing the possibility for beam damage to sensitive samples
- Fast! Single hyperspectral CL map measurement time ranges from 18s to 30 min compared to the competition's 30 min – multiple hours
- Simultaneous generation of a SEM image and a hyperspectral CL image with no degradation of the electron probe size
- Schottky FEG for high current densities from: 30 pA to 300 nA
- Highest resolution SEM in CL mode: down to 3 nm
- Intuitive User Interface and specialized software
- Touch screen control with easy to navigate context based GUI that does not require an expert to operate the tool
- Dedicated Attomap hyperspectral analysis software (see separate brochure)
- High precision nanopositioning stage with low temperature option (10K to room temperature)
- Highly versatile: Optical hub for integration of the Attolight CL instrument in a larger spectroscopic system or complement its functionality



Attolight optical microscope features constant resolution and photon collection efficiency over a field of view of 300 μm (left). Quantitative cathodoluminescence, i.e. comparison of emission intensities between various points is now possible. The traditional parabolic mirror approach is plagued by blur and vignetting (right).

System Configurations



Schematic setup of an Allalin system showing the main components.

UV-Vis hyperspectral detection in the spectral range 200 nm–1100 nm

Fast hyperspectral mapping allows to fully characterize a region of interest with speeds as fast as 1 ms per spectrum, a good quality hyperspectral map (128×128 pixel) can be obtained in under 18 s. This detector covers the emission range of most commonly used semiconducting materials such as gallium nitride, gallium arsenide, diamond, gallium oxide and compounds.

NIR hyperspectral detection in the spectral range 900 nm–1700 nm

Fast hyperspectral mapping extension to detect emission in the near infrared domain. This extension is especially useful for CL applications on Silicon and Silicon related compound materials.

Panchromatic detection in the spectral range 200 nm–900 nm

Panchromatic detection allows for ultrafast mapping of the CL intensity within a specified wavelength range (bandpass). Measurement times per pixel can be as low as 100 ns which means that a 4 k map can be registered in under one second. Attolight provides detectors and bandpasses that are adapted to the user application. Panchromatic detection is particularly useful to determine defect densities in different materials such as GaN, SiC, or GaAs.

Ultrastable Helium cryostage system

The helium cryostat system is compatible with the nanopositioning stage and allows to carry out measurements at precise temperatures (± 0.1 K) between 10 K and room temperature. A copper braid between the cold head of the cryostat and the sampleholder allows to limit vibrations enough to guarantee the best imaging resolution at low temperatures. The cryostat's versatile design allows it to be used with liquid helium and liquid nitrogen. The cryostat option is extremely useful to separate thermal contribution to the emission spectrum or to study spectral variations depending on thermal activation.

Electron beam induced current (EBIC) and electron beam absorbed current (EBAC)

EBIC and EBAC measure the electrical currents induced in the structure under test. EBIC and EBAC are complementary to CL since they measure non radiative effects, whereas CL looks mostly at radiative effects. EBIC/EBAC signals and CL can be measured simultaneously, even at low temperature.

Pico-second time-resolved CL (TRCL)

TRCL allows to measure CL decay times with resolutions below 10 ps. Please refer to the Attolight Chronos brochure for a detailed description of TRCL options. Attolight can add up to two spectrometers per CL system, this allows for a total of four detectors connected to the CL setup. Switching between the detectors is computer controlled and does not need any hardware re-configuration.

Specifications

Electron Optics

- Schottky thermal field emission gun
- Beam energy 1 keV–10 keV
- Smallest electron spotsize: 3 nm at 10 kV
- Optimal working distance 3 mm
- High sensitivity SE detector
- Field-upgradable to picosecond pulsed photoelectron gun (see Chronos specifications for more information)
- Electron probe current: 30 pA to 300 nA

Light Optics

- Field of view up to 300 μ m
- Integrated light collection: 30% of the photons emitted by a lambertian emitter exit the microscope (constant over the whole field of view)
- Achromatic reflective objective from 180 nm to 1.6 μ m
- Numerical aperture: NA 0.71 (f/0.5)

Light Detection

- Dispersive spectrometer with two imaging exits (320 mm focal length) and a 3-grating turret (Attolight provides a large collection of diffractions gratings to optimally fit your application), motorized entrance and exit slits
- High speed CCD camera for UV-Visible (200 nm–1100 nm) detection, highest speed > 900 spectra per second
- InGaAs camera for near infra-red (600 nm–1700 nm) detection, highest speed > 180 spectra per second
- Panchromatic detection in the range 200 nm–1700 nm using different detectors, highest speed > 50 ns per pixel

Electron beam induced current (EBIC)

- Low noise EBIC electronic board
- Current measurement limit of 100 fA
- Gain 10^4 to 10^{15} V/A
- Bandwidth up to 100 kHz

Chamber and Vacuum System

- Oil-free pumping system: Ion getter pumps for electron gun and electron column and turbo molecular pump for the specimen chamber
- Typical specimen exchange time: 20 min
- Electrical feedthroughs on vacuum door

Nano-Positioning Stage

- 6 degrees of freedom for arbitrary movements (compatible with the cryostat)
- Travel range: 25 mm (X and Y), 3 mm (Z), 3° tilt (X and Y), 10° rotation (Z)
- Smallest increment: 1 nm
- Repeatability of 100 nm over full travel range
- Coordinate system for easy and precise navigation

Low Temperature Cryostat

- Temperature range from 10 K – room temperature with 0.1 K precision
- Advanced digital temperature controller
- Less than 300 nm drift per hour at a temperature of 10 K

System Control and measurement modes

- simultaneous CL (hyperspectral or panchromatic mapping), SEM, and EBIC mapping
- capability for semi-automated operation
- Intuitive touch screen based graphical user interface (GUI) for quick sample navigation & realtime data illustration to check measurement status
- Maximum image resolution of 4 k, maximum resolution of a hyperspectral map 512 \times 512 pixel, minimum electron beam dwell time of 50 ns per pixel

Data analysis

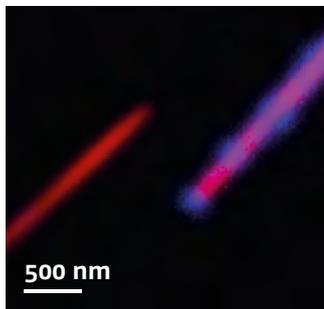
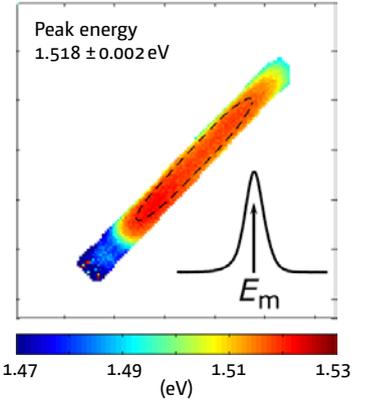
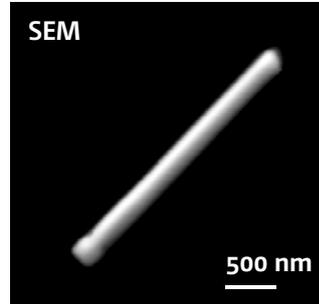
- Attolight provides Attomap a powerful analysis and reporting solution. Please refer to the separate Attomap brochure for more information.
- Tool configuration and CL data is saved simultaneously for easy reproduction of the tool configuration
- Easy password protected user access to measurement data over the network
- Export to open data format to give maximum flexibility to users to choose their preferred data analysis software

System lay-out

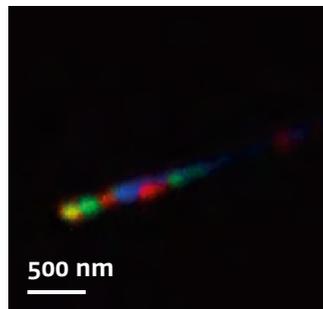
- Footprint: (length) 1219 mm \times 1039 mm (width)
- Recommended service area: (length) 2017 mm \times 2426 mm (width)
- Tool weight: ~1110 kg

Applications and examples

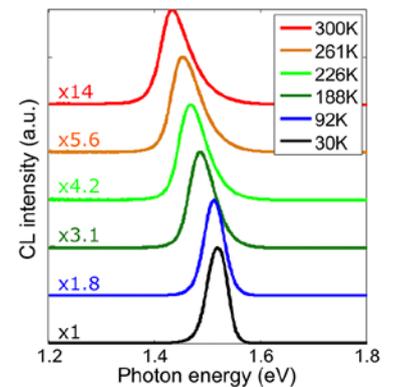
- Optical properties of semiconducting nanostructures
- Crystallographic defect detection and localization (Threading dislocations, stacking faults, inclusions, etc.)
- Determination of nanometer scale compositional fluctuations
- Doping metrology
- Failure analysis
- Nanophotonics



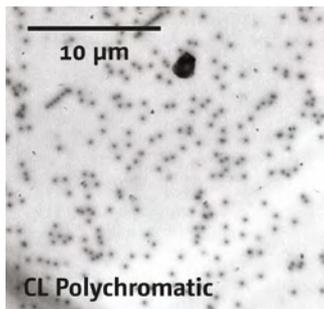
Close-up of two NWs tip. Red now represent emission from the GaAs core (820 nm) of the wire, when blue regions mark the QDs emission (670 nm). Dots at less than 500 nm can be easily resolved. (Specimen temperature: 10 K)



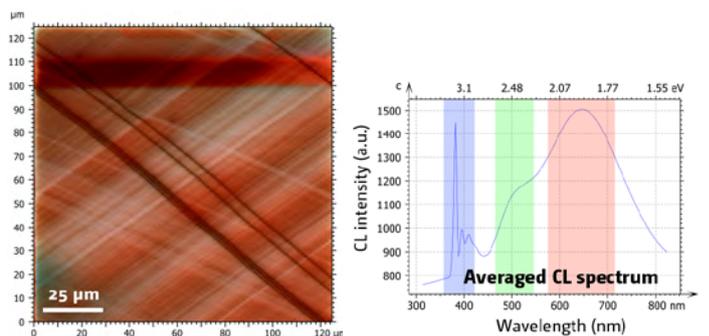
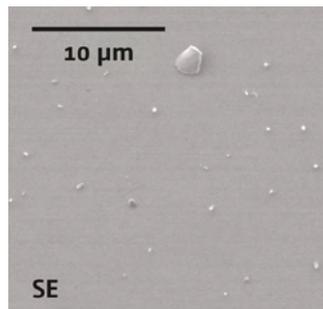
Mapping of the QDs location with respect to the emitted wavelength. Blue, green and red correspond to 3 wavelengths between 650 and 700 nm. Some dots emit at several wavelength, resulting in composite colors (e.g. yellow).



High resolution SEM and CL map of GaAs nanowire. The GaAs spectra from structures with varying n-type doping allow to precisely determine the doping level in the nanowires (*Nanoletters*, 17 (11), pp. 6667-6675 (2017)).



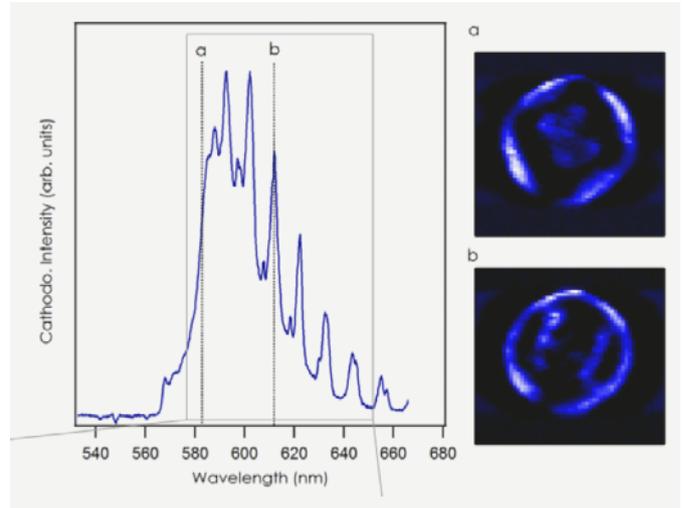
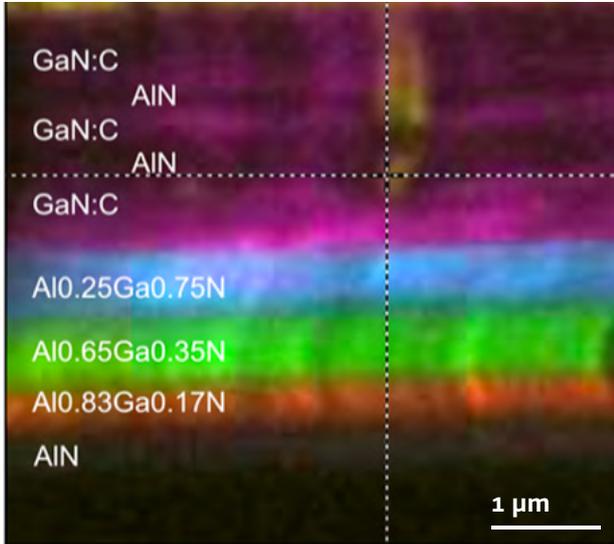
Cathodoluminescence is the ideal tool to measure threading dislocations density in GaN (left); they appear as dark spots because of non radiative recombination in their vicinity. A secondary electron scan of the same region cannot identify any threading dislocation (right).



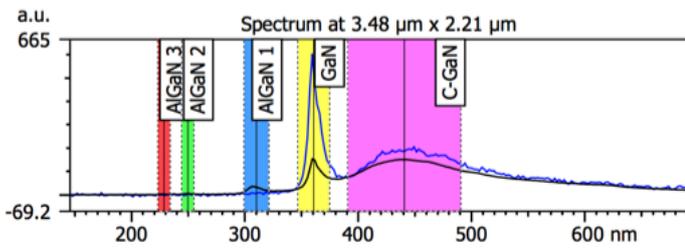
Hyperspectral map of SiC and corresponding point spectrum. The green band shows 3C-SiC inclusions in 4H-SiC, the blue band stems from point defects, the red band shows basal plane dislocation sheets. Dark lines correspond to stacking faults and dark spots indicate dislocations.

Other applications

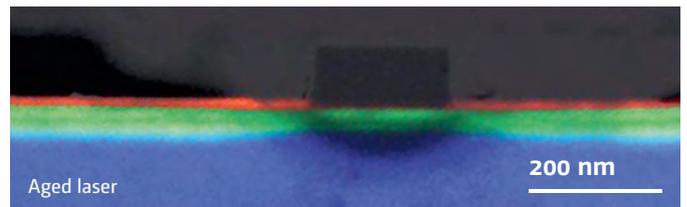
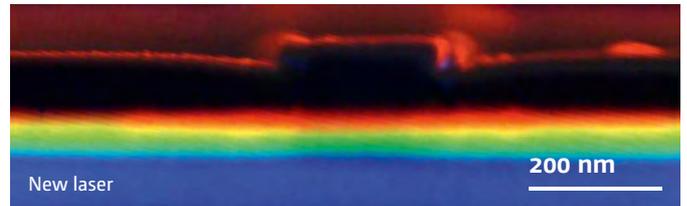
Refer to the Attolight Chronos brochure for more applications on dynamic pico-second time-resolved CL. Please refer to the publication list on our website for more applications and in-depth analysis of CL measurement.



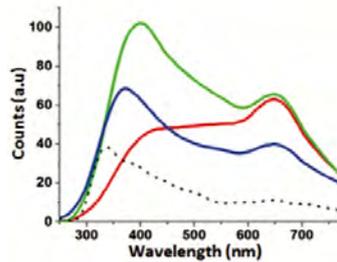
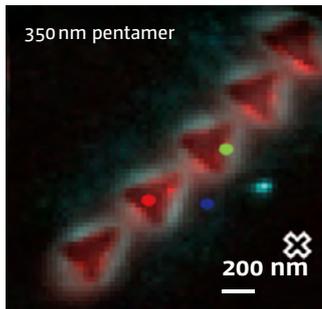
Whispering gallery modes in a GaP microdisk with GaPN quantum wells (*Optics Letters*, 43 (8), pp. 1766-1769 (2018)).



Hyperspectral CL map of GaN high electron mobility transistor and corresponding average spectra over the shown field of view. Each alloy has a distinct spectral signature and can be easily distinguished. A punch-through growth defect in the GaN:C layer is also shown.



Hyperspectral CL maps of a new and an aged laser. The CL signature shows degradation in the active zone of the laser (*IEEE Transactions on Nanotechnology* 15, 274 (2016)).



CL map of plasmonic modes in metallic nanostructures and corresponding point spectra (*Nanoscale*, 2016, 8, 15296).