SPARC

delmic

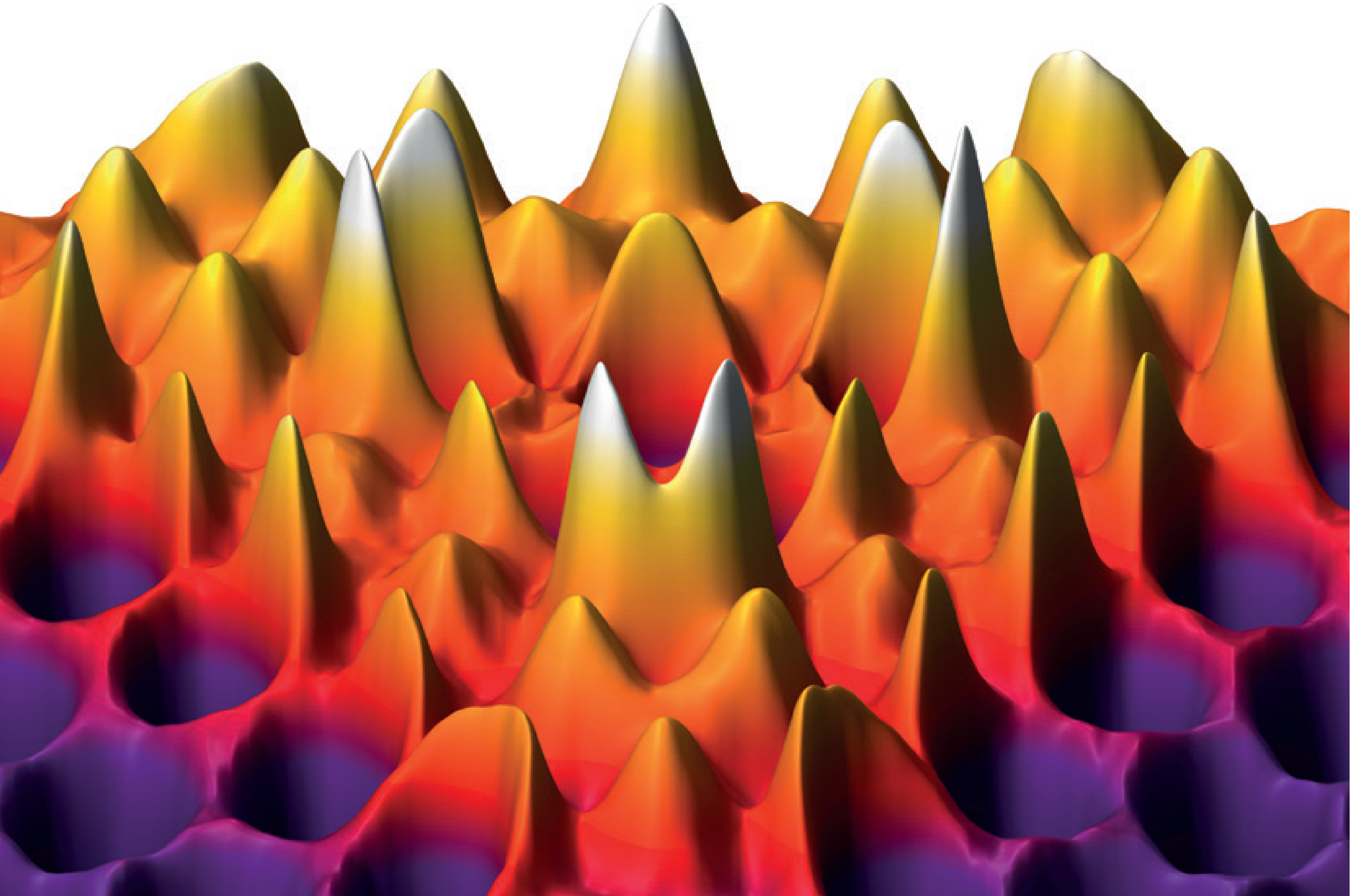


TABLE OF
contents

What is cathodoluminescence? *3*

The SPARC platform at a glance *4*

High-performance cathodoluminescence *5*

Application areas *7*

Example geology *8*

Example nanophotonics *9*

Key features *11*

Imaging modes *13*

Additional features *14*

ODEMIS - integrated software *15*

Specifications *17*

Cathodoluminescence excitation map showing an optical cavity mode of a triangular defect cavity in a 2D silicon nitride photonic crystal membrane.

(R. Sapienza et al., Nat. Mater. 11, 781 (2012))

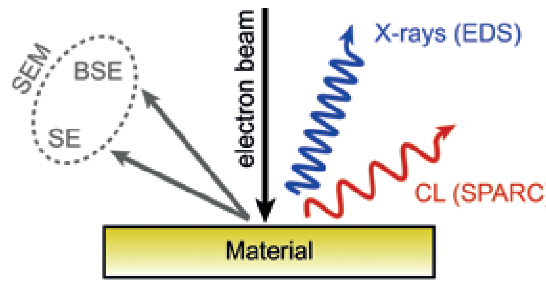
Image courtesy of T. Coenen, FOM institute AMOLF

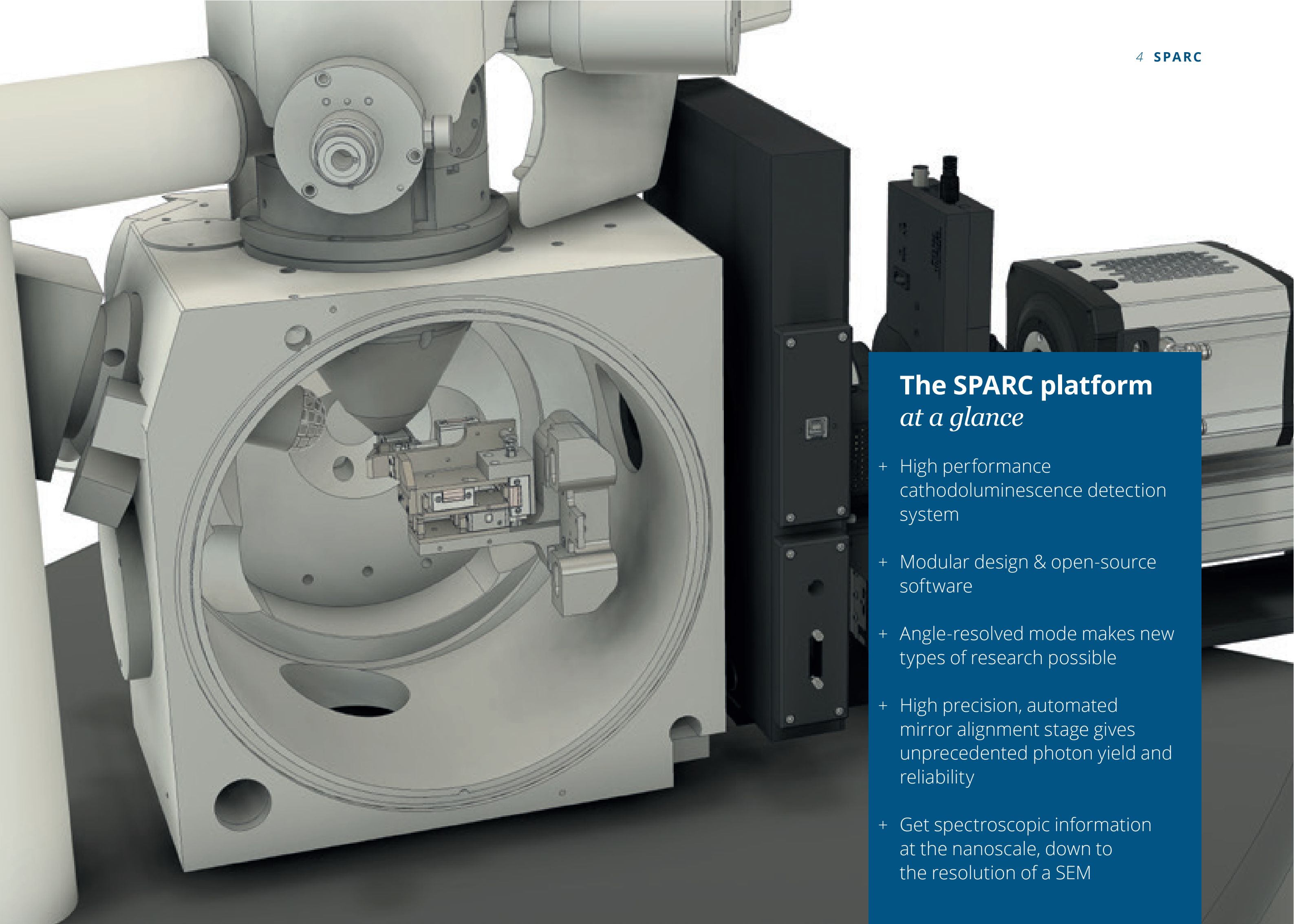
What is cathodoluminescence?

Cathodoluminescence is light generated by irradiation of a material with an electron beam.

The control of light at the nanoscale is becoming more and more important as a result of the increasing use of optoelectronic devices and materials. It also opens up technological opportunities, such as highly sensitive chemical sensing and identification, improving performance of photodetectors or light emitting devices, and increasing the efficiency of solar cells.

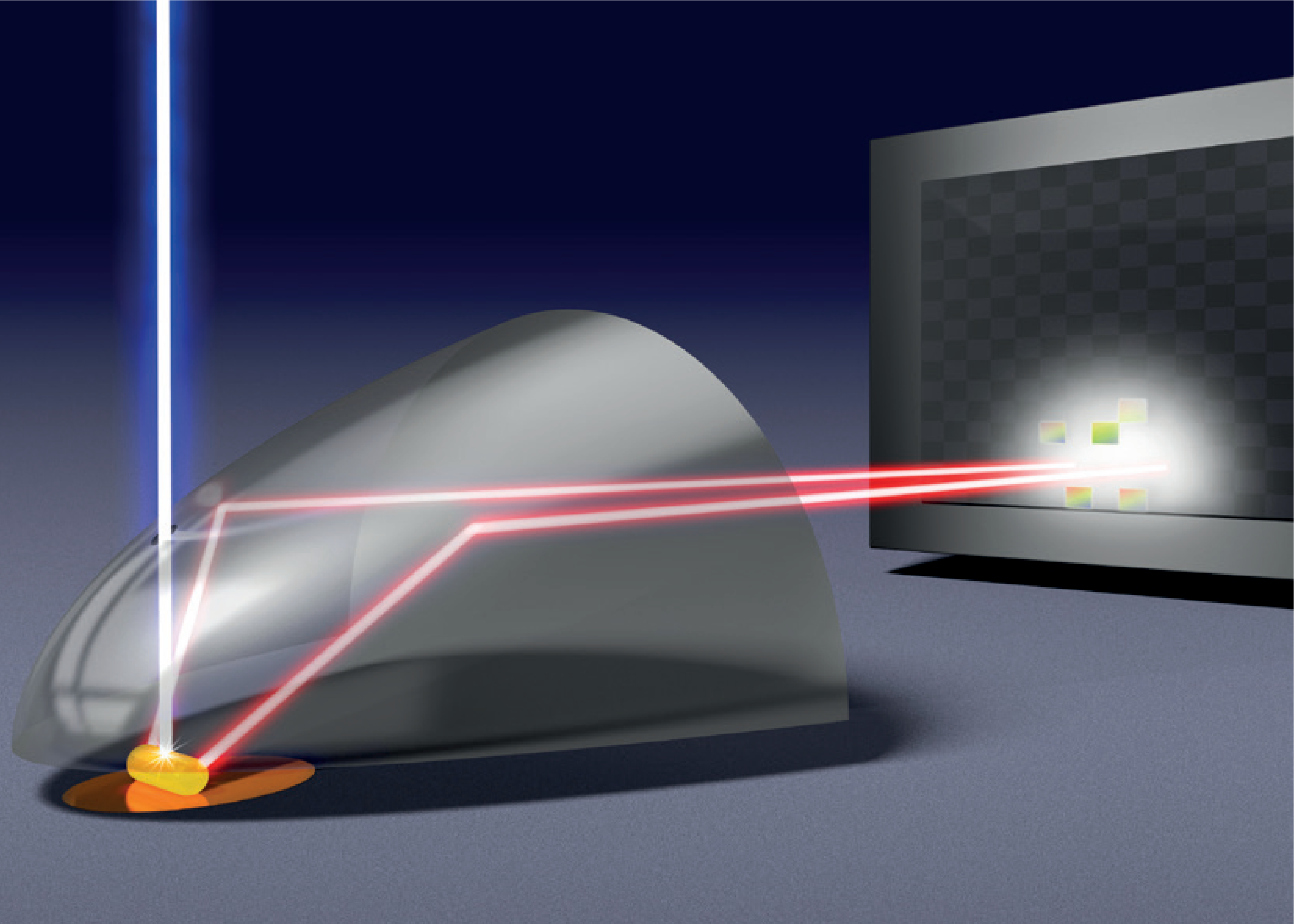
The characterization of optical properties at the nanoscale is a challenge due to the diffraction limit which is inherent in optical techniques. As a result, cathodoluminescence is an increasingly popular technology with a wide range of applications for the development and characterization of materials and systems.

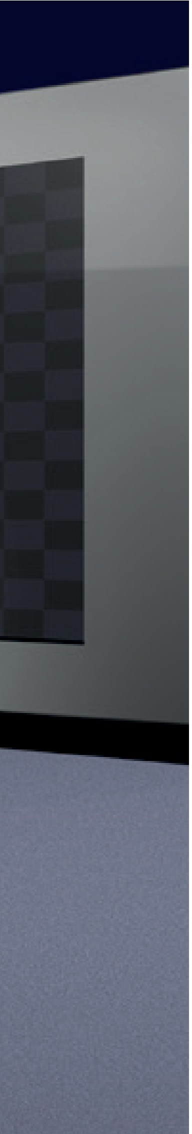




The SPARC platform *at a glance*

- High performance cathodoluminescence detection system
- Modular design & open-source software
- Angle-resolved mode makes new types of research possible
- High precision, automated mirror alignment stage gives unprecedented photon yield and reliability
- Get spectroscopic information at the nanoscale, down to the resolution of a SEM





SPARC

High-performance cathodoluminescence

The SPARC is a cathodoluminescence system that offers ultimate resolution and reliability. A large, ultraflat parabolic mirror is mounted on a high precision stage. All optics are free-space coupled, ensuring maximum photon yield. The system is modular and open, allowing for the addition of multiple optical components and a wide range of detectors. The open source software – written in Python – makes it possible to easily add functionality.

While the system is open and modular, DELMIC's commitment to ease-of-use and high performance ensures that your system is turn-key ready.

The system is closely integrated with the scanning electron microscope. This is seen in both the hardware and the software. The mounting of the hardware is done on a vacuum port in such a way that it is minimally invasive for the SEM. It takes less than five minutes to bring the SEM from CL mode back to its full original configuration.

APPLICATION AREAS

Cathodoluminescence

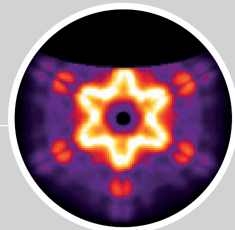
1 The SPARC opens up new avenues of research such as **electron beam induced nanophotonics**, but its sensitivity and ease of use also make it possible to breathe life into more ‘traditional’ applications of cathodoluminescence

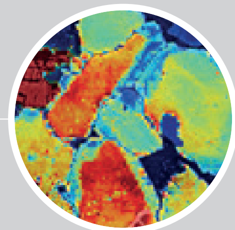
2 The SPARC offers users advanced understanding of **semiconductor and optoelectronic devices**. The high collection efficiency even allows the investigation of poor emitters of light, such as silicon-based materials.

3 Cathodoluminescence gives an additional contrast mechanism for **materials inspection**, failure analysis, geology, and petrology applications. CL imaging is an ideal tool, because it is fast and it provides information, not easily available by other techniques.

4 For both the **pharmaceutical** as well as the **life sciences** industry, CL can be used to screen active pharmaceutical ingredients and offers spectral fingerprinting.

1


2


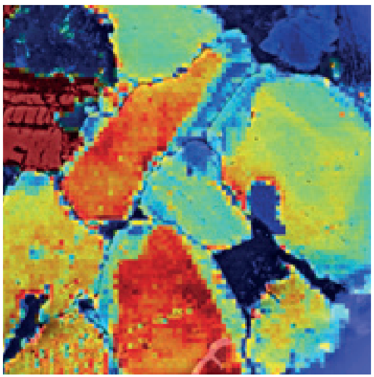
3


4

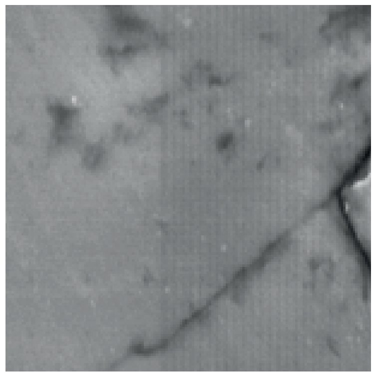

EXAMPLE

Geology

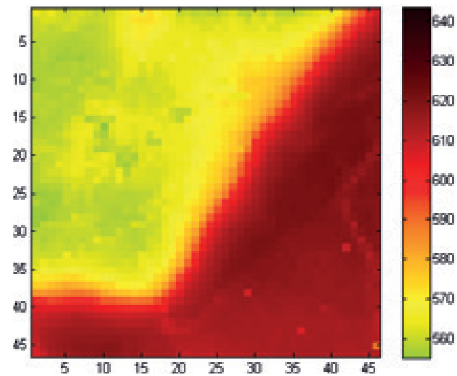
Cathodoluminescence imaging is particularly useful for providing mineralogical information. The color and intensity of the emitted light gives insight into processes as crystal growth, replacement, deformation, provenance, and defect structures and can be used to fingerprint minerals down to the resolution of a scanning electron microscope.



Overlay of intensity image with SEM image. NB: field of view is 500μm



SEM image



CL image (Color indicates wavelength in nm)
Samples courtesy of J. Jahre, Oslo University

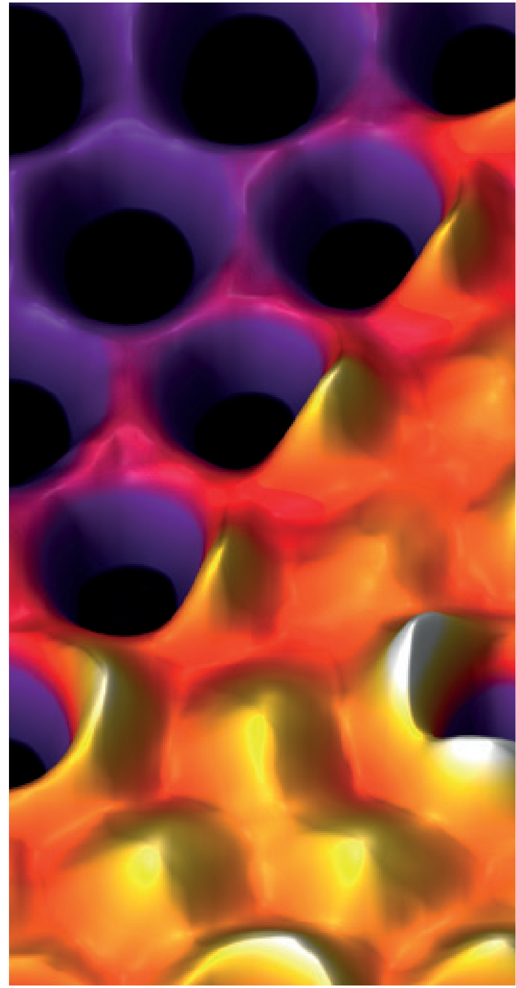
EXAMPLE

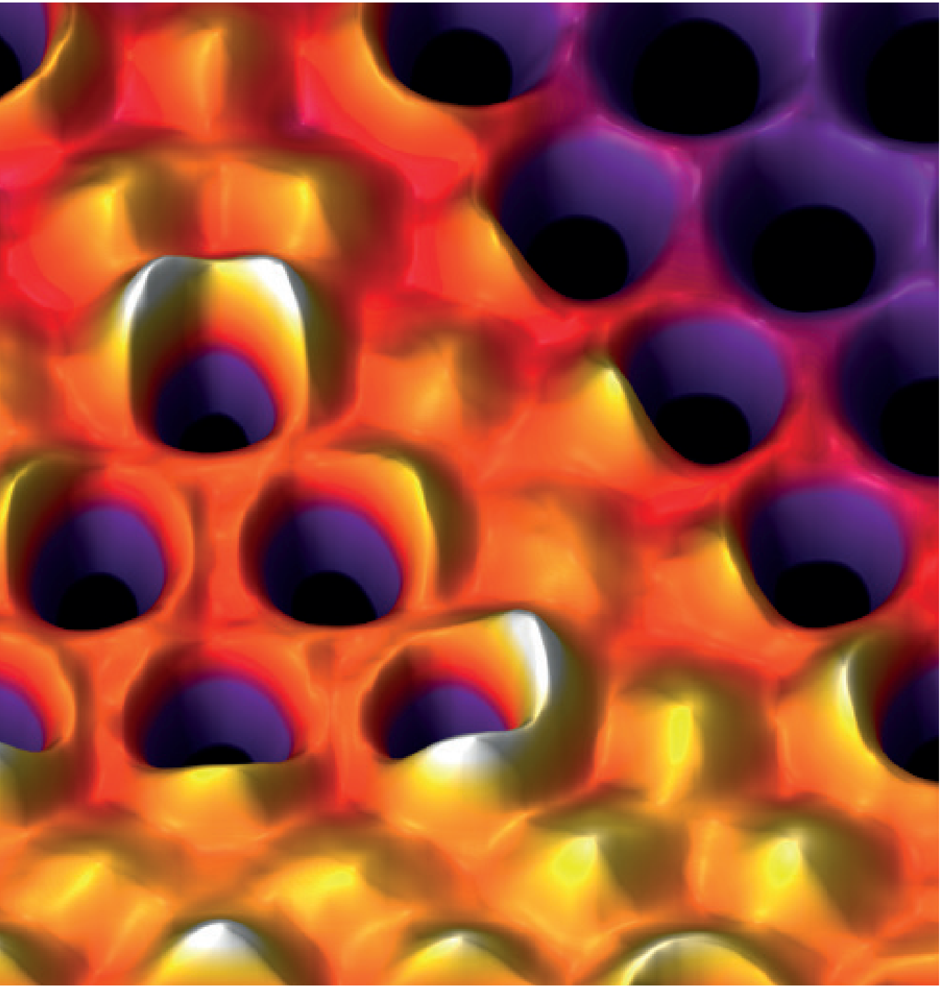
Nanophotonics

The SPARC offers a very powerful method to study optical phenomena at the nanoscale and to understand how light couples to matter in a fundamental way. It is also a useful tool for improving the performance of optoelectronic devices, because the light-emission maps created with the technique reflect the local density of electromagnetic states, a quantity that determines how well light couples to matter and vice versa [1].

The SPARC enables the study of nanostructures with deep-subwavelength resolution. The electron beam is used to excite nanostructures and the cathodoluminescence detector is subsequently used to detect the generated light. The higher detection efficiency not only leads to better results, but also makes it possible to do a whole new type of nanophotonics research; angle resolved measurements. With this new detection method, the direction in which the light is emitted from an excited structure can be mapped as a function of the excitation position.

[1] *Electron beams set nanostructures aglow, Nature 493, 143 (10 January 2013) doi:10.1038/493143a*





Cathodoluminescence excitation map showing an optical cavity mode of a triangular defect cavity in a 2D silicon nitride photonic crystal membrane.

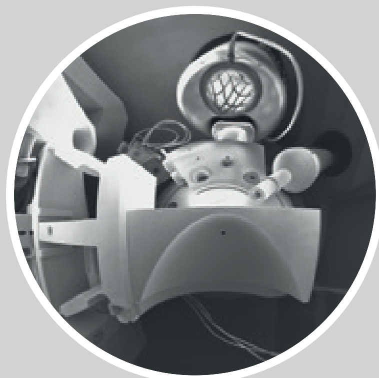
(R. Sapienza et al., Nat. Mater. 11, 781 (2012))

Image courtesy of T. Coenen, FOM institute AMOLF

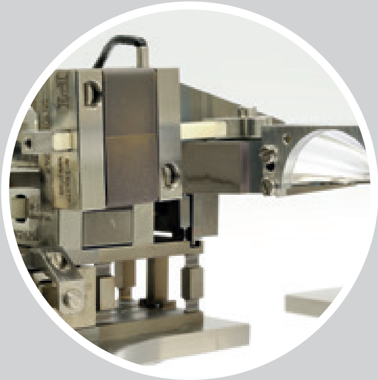
Key features

Modularity
The SPARC has an open design. This makes it possible to tune the system to your exact needs.

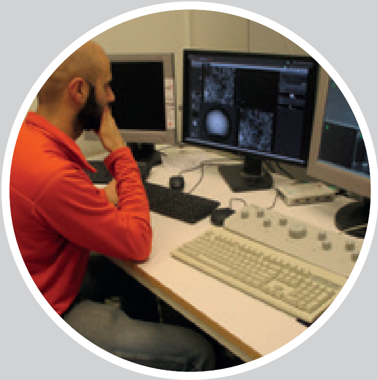
Unsurpassed sensitivity
The mirror is made of a unique type of aluminium: its tiny grain size ensures maximum flatness of the mirror, enhancing reflectivity, decreasing measurement time and reducing artifacts.



Reproducibility
The mirror's precision stage ensures proper alignment between experiments. This makes it possible to do reproducible and quantitatively comparable measurements between different samples.

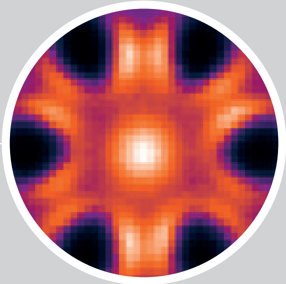


Ease-of-use
The operating software is straightforward to use and allows for easy alignment, acquisition and analysis of the results. The software can control the electron beam to allow for acquisition of electron images and to properly trigger the optical acquisition. With no adjustments in your sample preparations, you can take advantage of the high spectral resolution and extra contrast provided by electron microscopy.

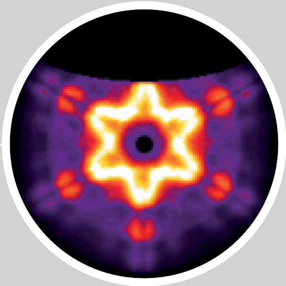


Imaging modes

Spectral mode
When the SPARC system is used in spectral mode, the light from the mirror is focused on a grating, as part of a Czerny-Turner spectrograph. A silicon detector is connected to the spectrograph resulting in optimized detection over the range of 400-900 nm. By scanning the e-beam across the sample, a hyperspectral image is made.



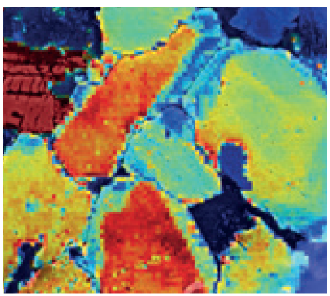
Angular mode
The SPARC provides the unique option to acquire angle-resolved images. Instead of focusing the light signal on a grating, an image of the mirror is projected onto an imaging camera. This allows for the detection of the directionality of the emitted light; also known as momentum spectroscopy. In this mode a filter wheel is used to spectrally distinguish the different emission wavelengths.



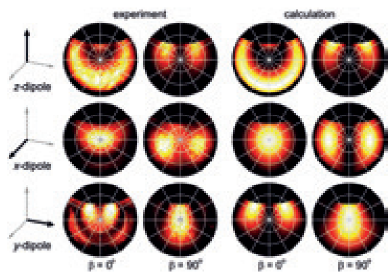
Additional features

The SPARC's modular design in combination with the open source software makes it possible to tune the system to your exact needs. This design in combination with these features also ensure that the system is future proof, as additional measurement methodologies can be added for future applications.

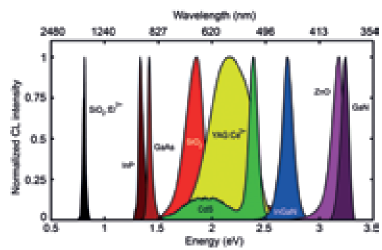
Cathodoluminescence color imaging
Adding a PMT to your setup allows you to do easy and fast acquisition of photons and further reducing the measurement time to acquire CL colour images. By adding a monochromator this can be either done for all photons, or for individual wavelengths. This will also enhance the field of view.



Polarization mode
Using a polarizer in the angle-resolved image allows for the detection of separate multipole orientations for nanophotonic applications, and the separation of polarization directions in a more general sense.



Enhanced spectral performance
The modular design allows easy extension towards ultra violet and infra red wavelengths, enhancing sensitivity and allowing analysis below 400 nm or above 900 nm.



ODEMIS

Integrated software

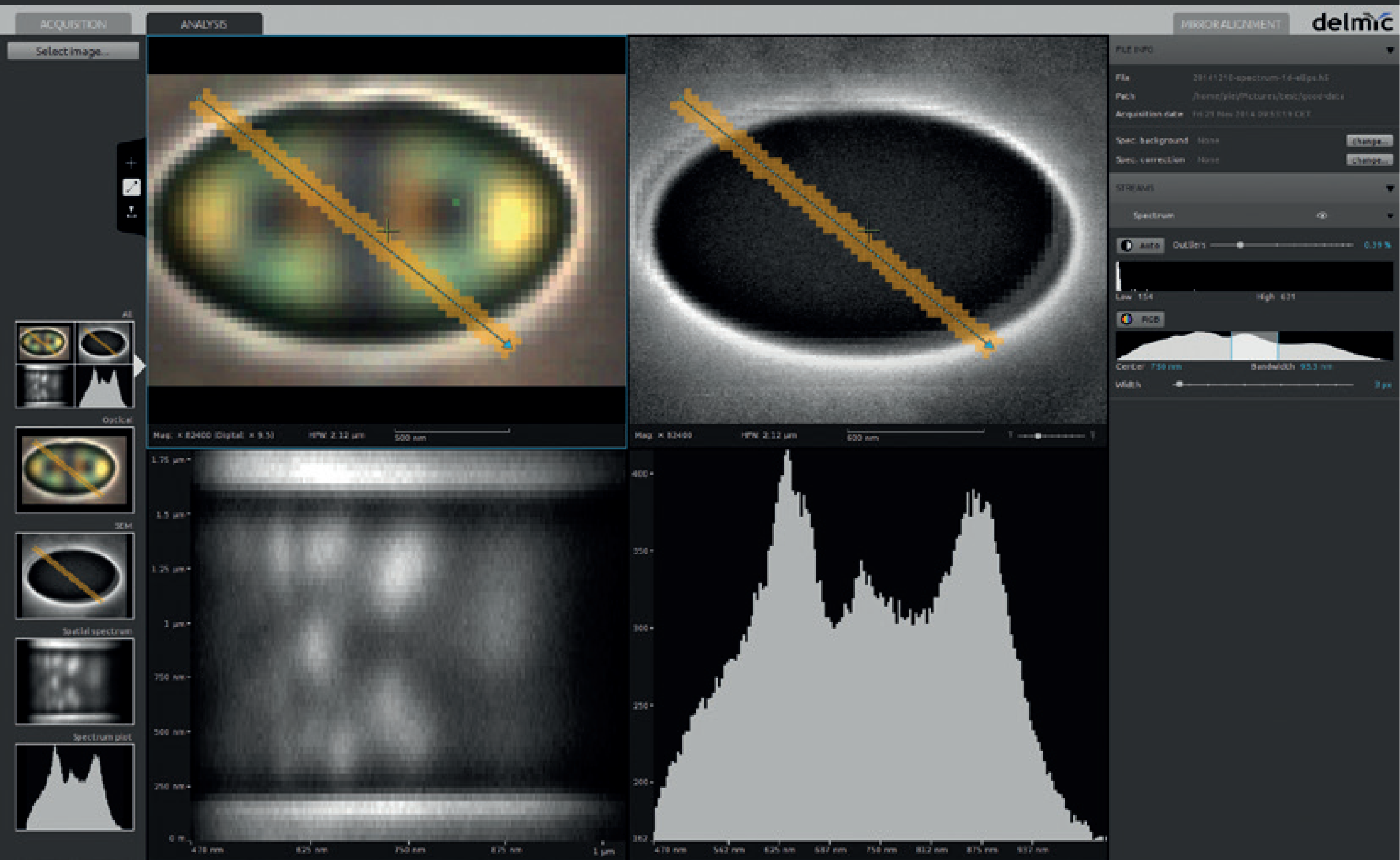
ODEMIS allows for easy acquisition and analysis of the data. The software controls the scanning of the electron beam acquiring both secondary electron images and the triggering for the acquisition of spectral and angular resolved images. Spectral response data can immediately be subtracted from the datasets, showing the 'clean' spectrum at a glance. ODEMIS is open-source and makes use of the open file formats OME-TIFF and HDF5.

In particular, the software has the following features for acquisitions:

+ DRIFT CORRECTION
+ SIMULTANEOUS ACQUISITION of the secondary electron and spectral or angle-resolved images
+ Easily obtain images over an ARBITRARILY SIZED GRID with an arbitrary number of pixels
+ Easily obtain a large number of ANGLE-RESOLVED images

In analysis

+ Easily visualize 3D CL data as a 2D MAP or pixel by pixel graph
+ Immediate POLAR PLOTTING of angle-resolved images
+ Use CORRECTION FILES (such as the system response function) to obtain a corrected spectrum in one go
+ For detailed analysis easily transfer files to for example MATLAB
+ Advanced 2D slicer through 3D dataset with adjustable integration limits
+ Overlay of SEM and spectral images


ACQUISITION
ANALYSIS
MIRROR ALIGNMENT
Select image...
Optical
SEM
Spatial spectrum
Spectrum plot
Mag: × 82400 (Digital × 9.5)
HFW: 2.12 µm
500 nm
Mag: × 82400
HFW: 2.12 µm
500 nm
FILE INFO
STREAMS
Spectrum

Specifications

At a glance

- Modular detection system for high precision and sensitive CL measurements.
  Standard specifications:
  - < 2 nm spectral resolution
  - < 10 mrad angular resolution

- Czerny-Turner optical spectrometer
- sCMOS camera for angle-resolved imaging
  - Filterwheel is used for spectral differentiation

- Ultraflat, parabolic mirror, enhancing reflectivity, decreasing measurement time and reducing artifacts
  - 87% collection efficiency from a Lambertian source

- Advanced open-source software for data acquisition and in-depth analysis
  - Drift correction
  - Easily export to for example MATLAB

- Additional detector packages possible

Entry level

- Sample size 26 x 46 mm
- Application field a.o. geology, semi-conductor research
- Additional: enhanced sensitivity, enlarged field of view, fast intensity mapping

Plus

- Sample size 26 x 46 mm
- Angle-resolved mode
- Application field a.o. photonics, plasmonics
- Additional: all options above, extra gratings, enhanced spectral performance, photon counting mode, fiber coupled spectrometer

Ultimate

- Fully retractable, automated mirror alignment
- Unrestricted sample size
- Easily integrated in FIB/SEM for slice-and-view applications

- All options available

delmic

Integration without compromise

Thijsseweg 11 2629 JA Delft The Netherlands
tel. +31 15 7440158 info@delmic.com www.delmic.com