Raman Microscopy with High Spatial Resolution for Semiconductor Applications

Sol instruments Ltd., 58-10 Nezavisimosti ave.,
Minsk, Belarus

sales@solinstruments.com

SOL instruments

SOL instruments Ltd. (SOLAR TII) was founded in 1994.

SOL instruments Ltd. is an innovation-focused manufacturer of technologically advanced instruments for

- Analysis
- Spectroscopy
- Lasers

SOL instruments Ltd. continually expands its presence on the world market of high-end products.
The products are currently exported to over 30 countries.

Confotec
family

Confotec® MR150

Confotec® MR350

Confotec® MR520

Confotec® NR500

Confotec® CARS

www.solinstruments.com

3D Raman Microscopy System Confotec® NR500

Features

- 3D Raman Confocal Measurements
- Laser Reflection Measurements (1000x1000 pixels per 3 sec)
- Fully automated control
- Completely motorized laser change (up to 3 / 5 lasers)
- High spatial resolution (lateral: up to 200 nm; axial: up to 500 nm)
- High spectral resolution (up to 0.006 nm)
- Wide spectral range
- High temporal and temperature stability

Applications

Advantage of Raman Spectroscopy

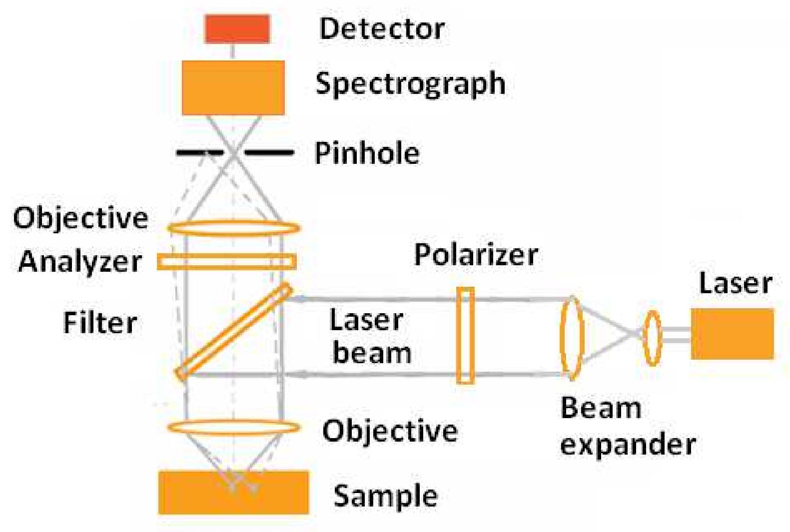
- Qualitative and Structural material analysis
- No special requirements for sample preparations
- Nondestructive, non contact method
- Very small sample can be measured
- Depth analysis

Application field

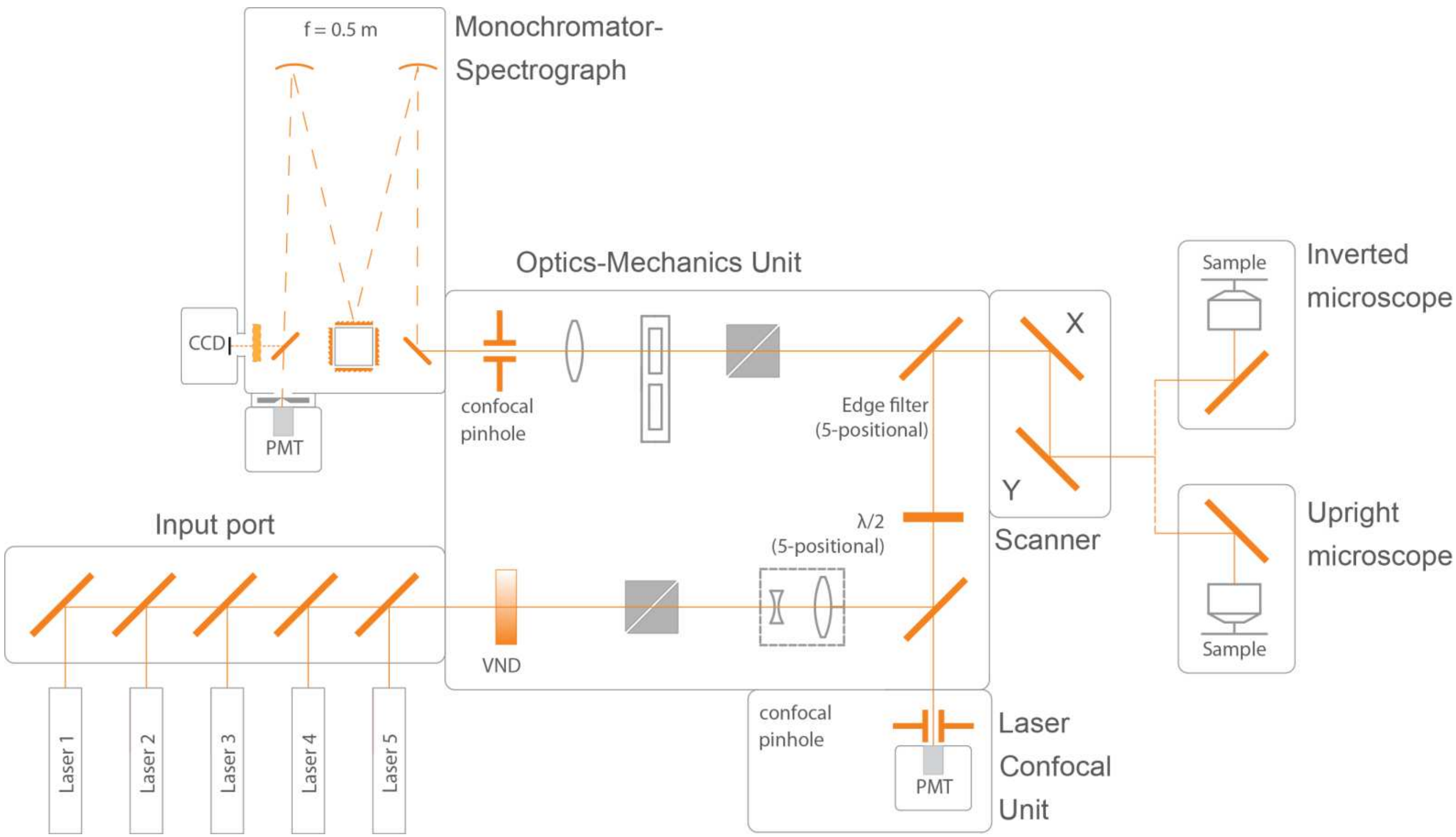
- Pharmaceutical
- Material science
- Biosciense
- Geological
- Heritage and Art
- Organic and Polymer chemistry
- Forensic science, etc.

Confocal Raman Microscopy. Principles.

A pinhole blocks the scattered light which is coming from the out-of- focus points.



Confotec® NR500 Optical Setup



High sensitivity for Raman spectra detection

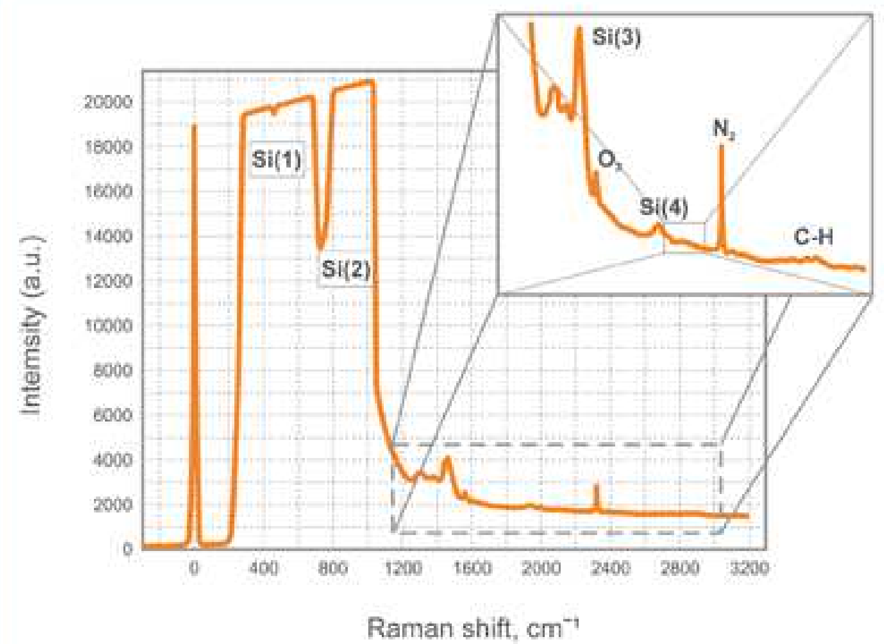
Raman spectrum of Si wafer.

Si (4) peak is clearly detected.

Si (1) and Si (2) are in deep saturation.

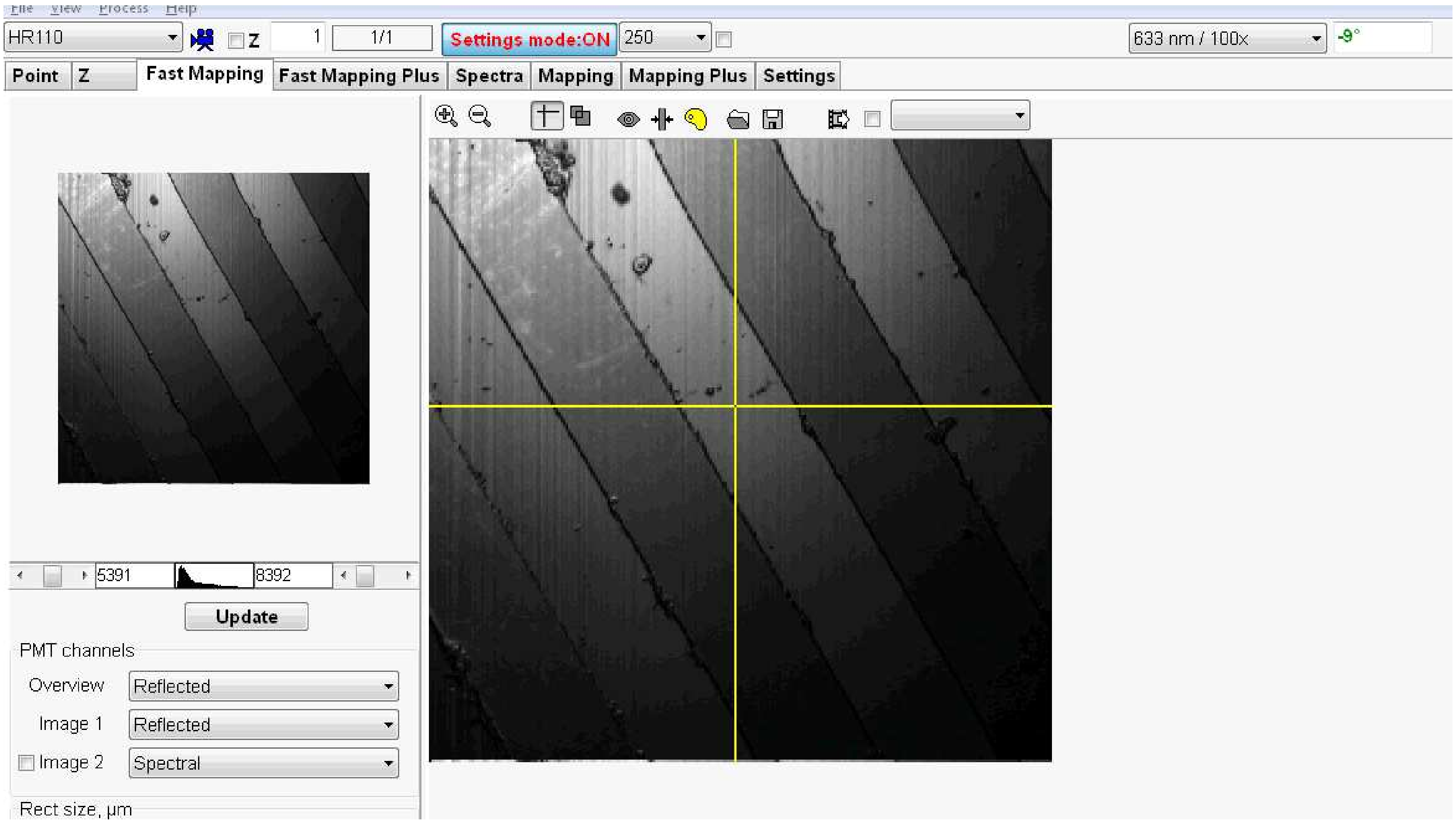
Accumulation time - 60 seconds.

488 nm laser, 5 mW power

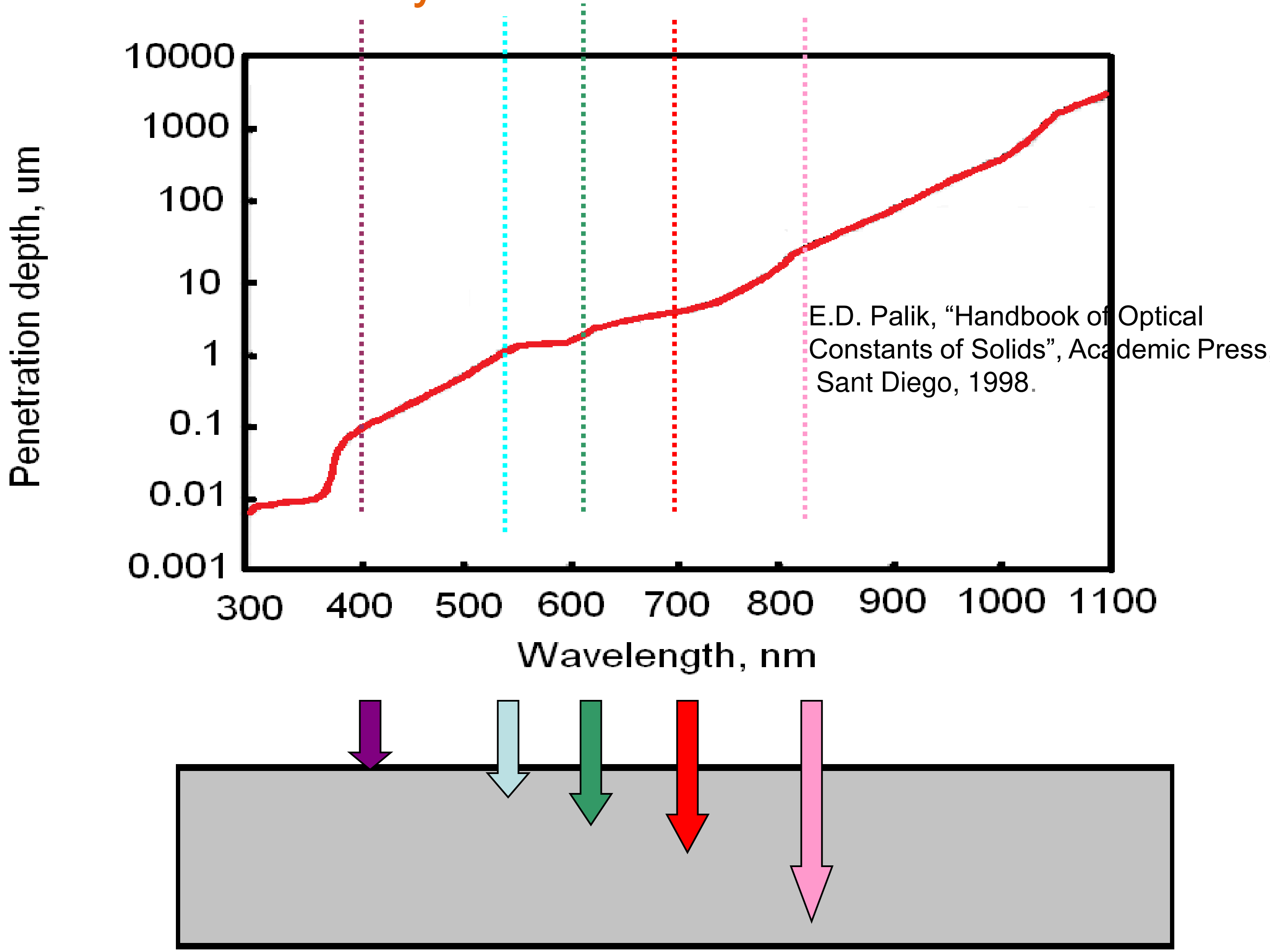


www.solinstruments.com

High speed Raman imaging with Confotec®



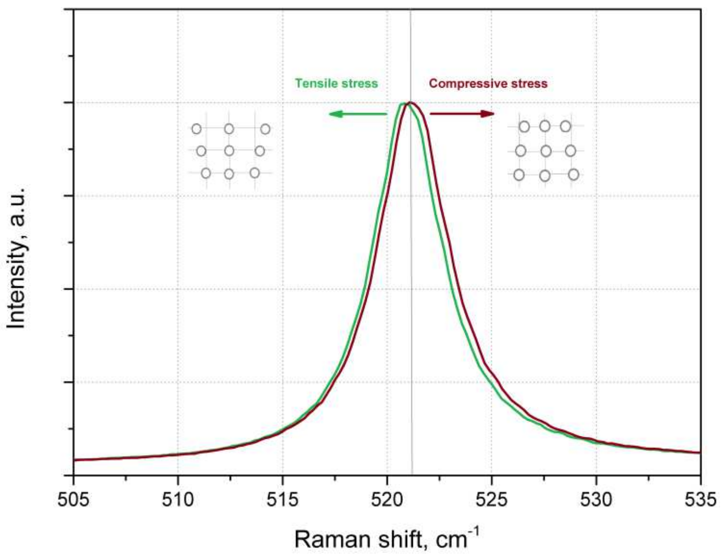
Many lasers can be installed

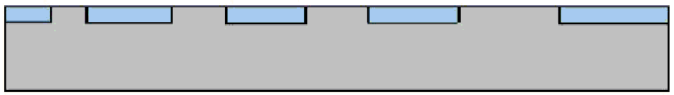


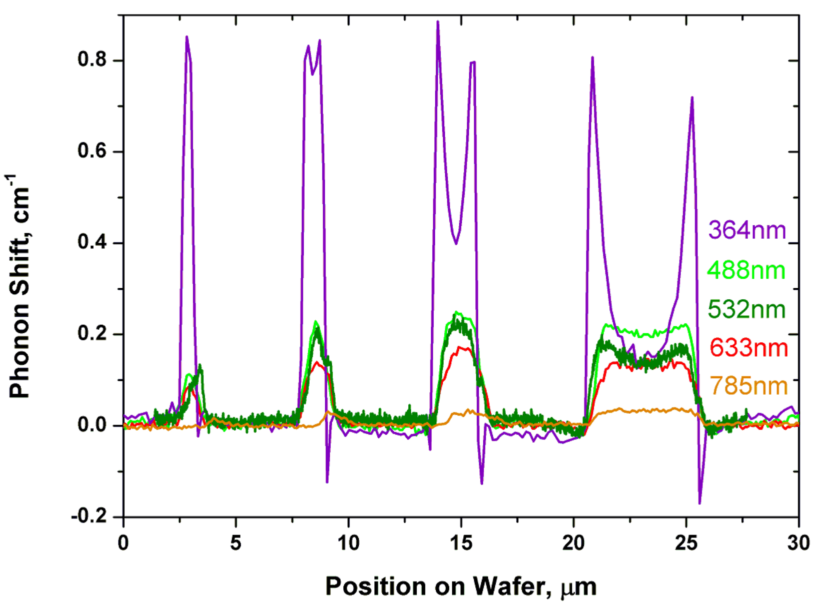
The next equation can be applied to the Si stress monitoring:

$$\sigma(MPa) = -435 \cdot (\omega - \omega_0)\ (cm^{-1}),$$

where σ is the stress value, $\omega_0 = 520.5\ cm^{-1}$ is the peak position of the stress-free state, ω is the Si peak position at the stressed state.

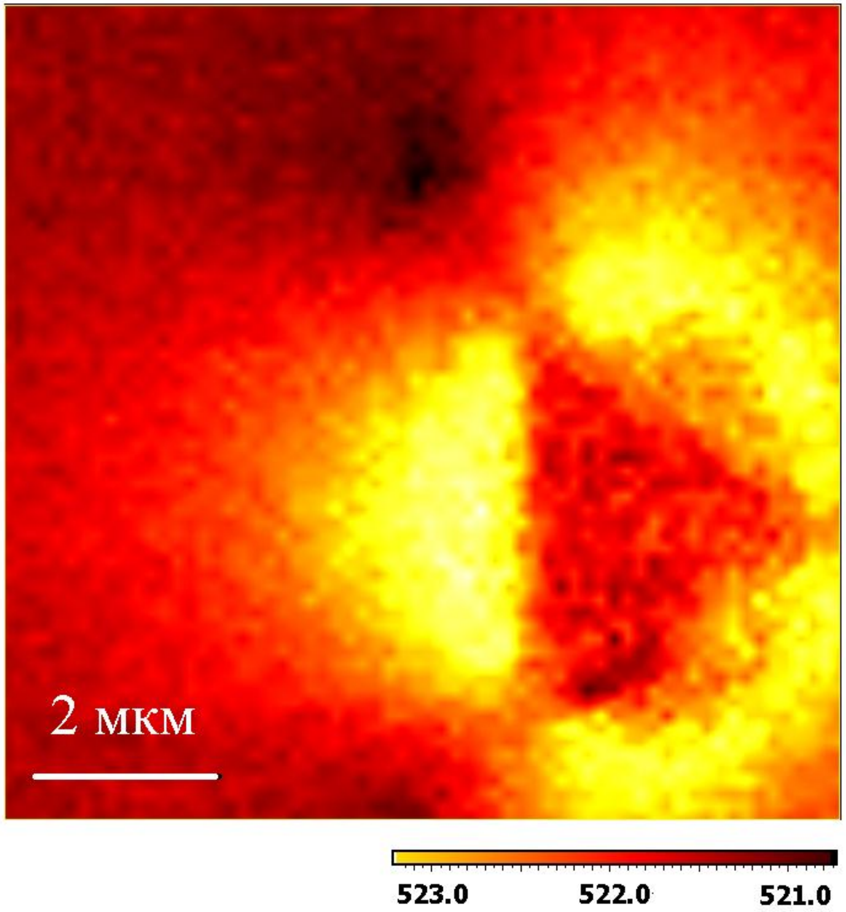






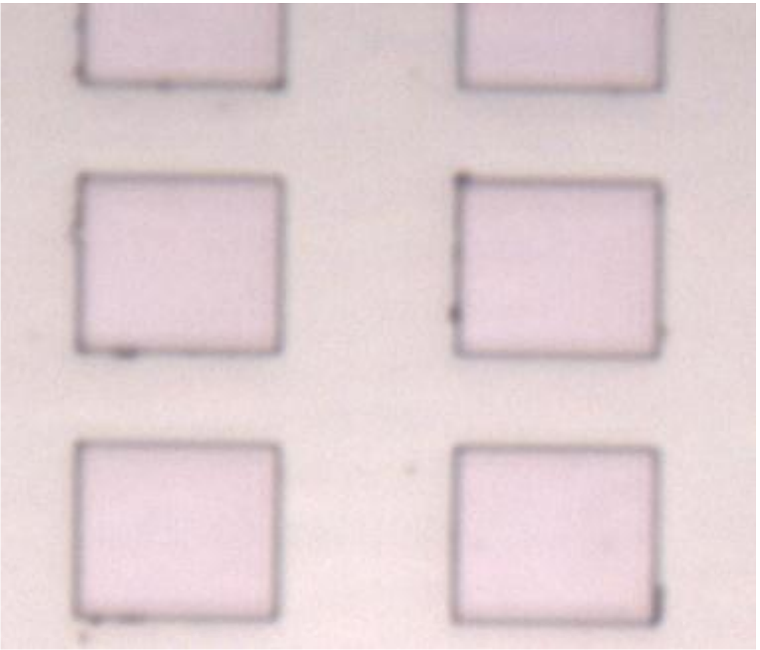
The sample consists 1, 1.5, 2 and 4 μm wide Si stripes separated by 4 um shallow trenches.

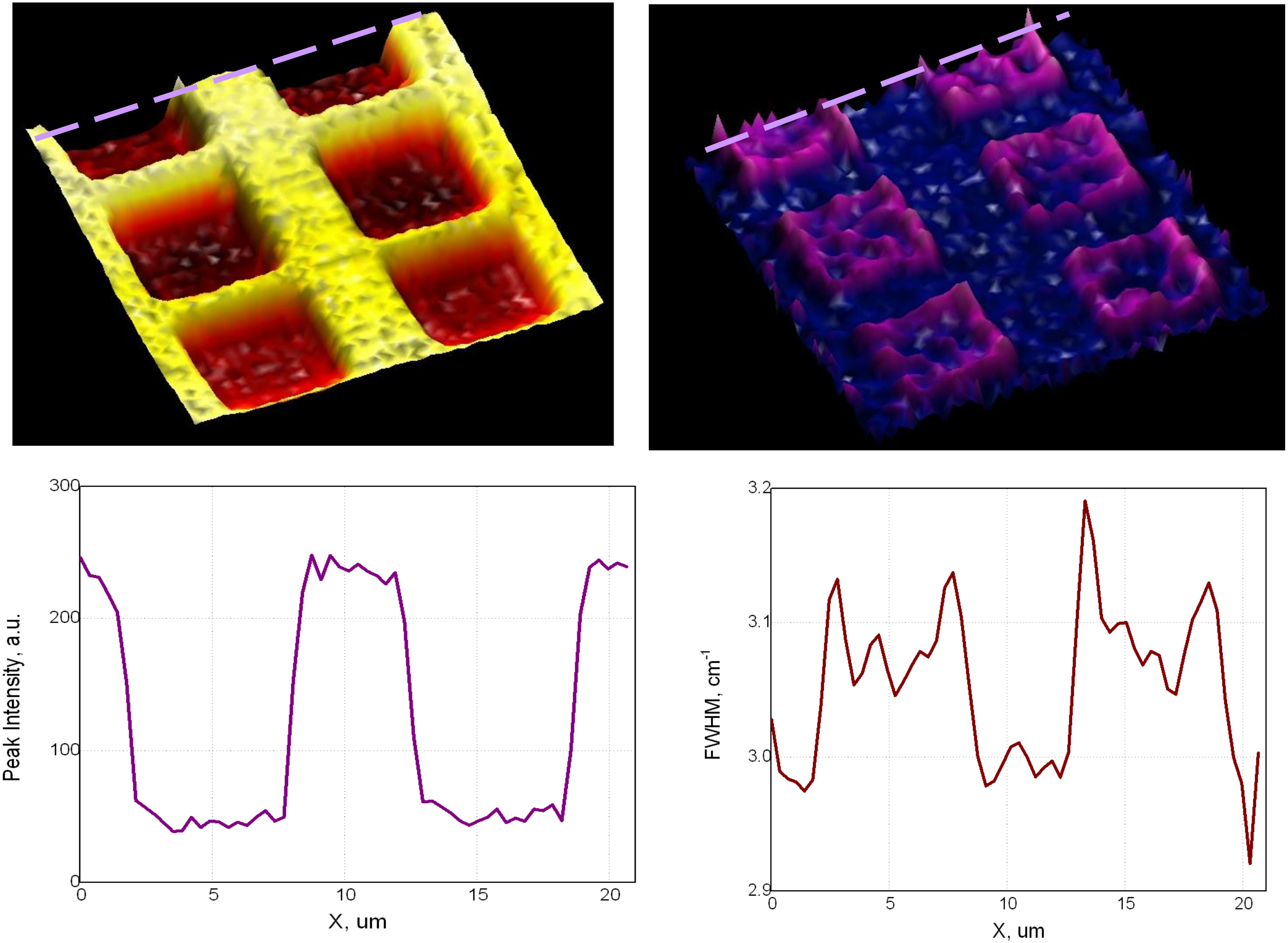
Raman image (peak position)



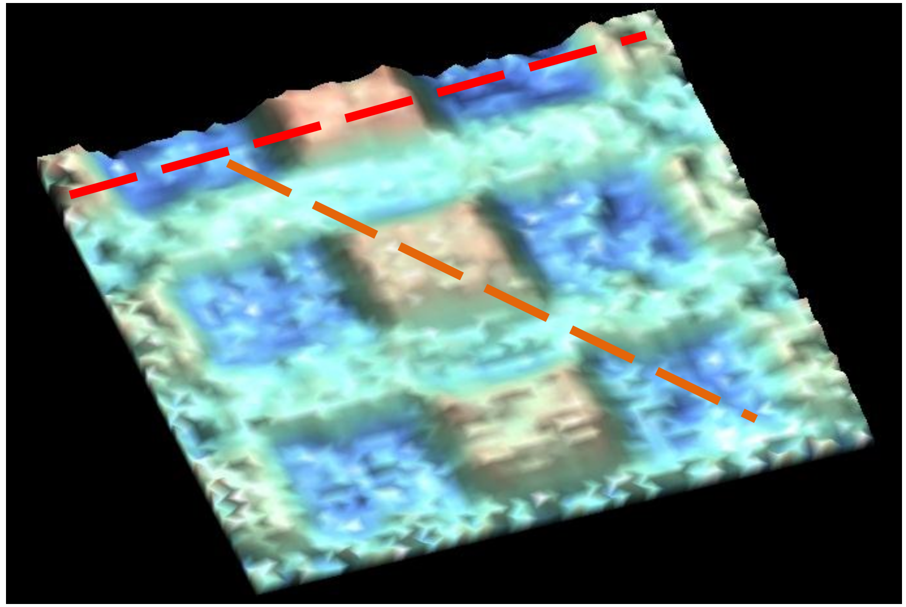
Optical image

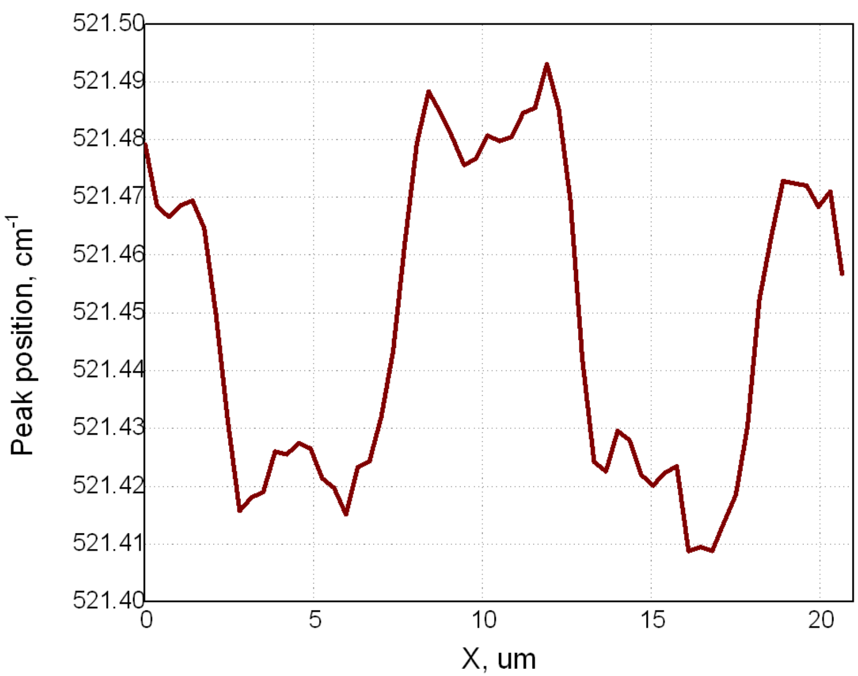
Structured Si sample. Optical image (100x)

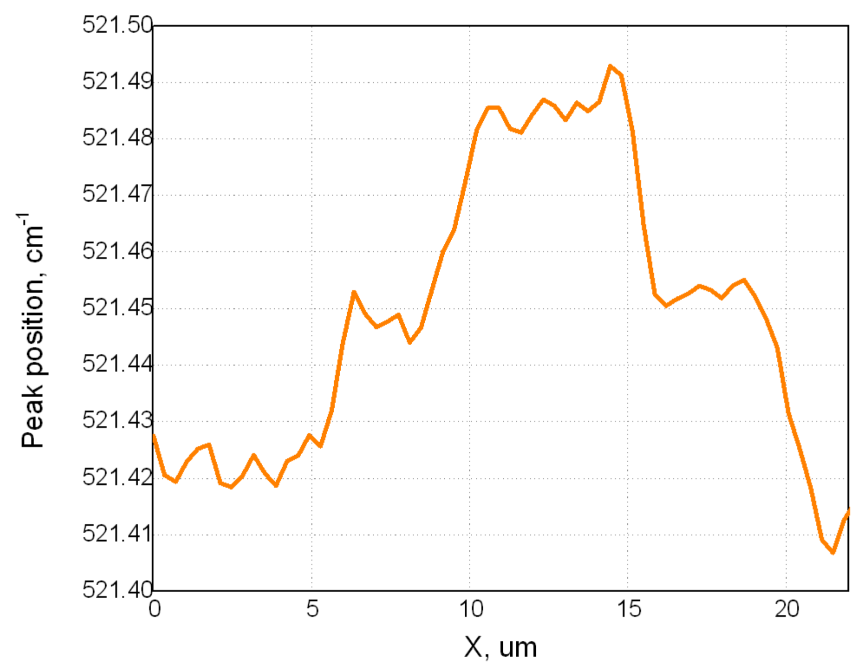


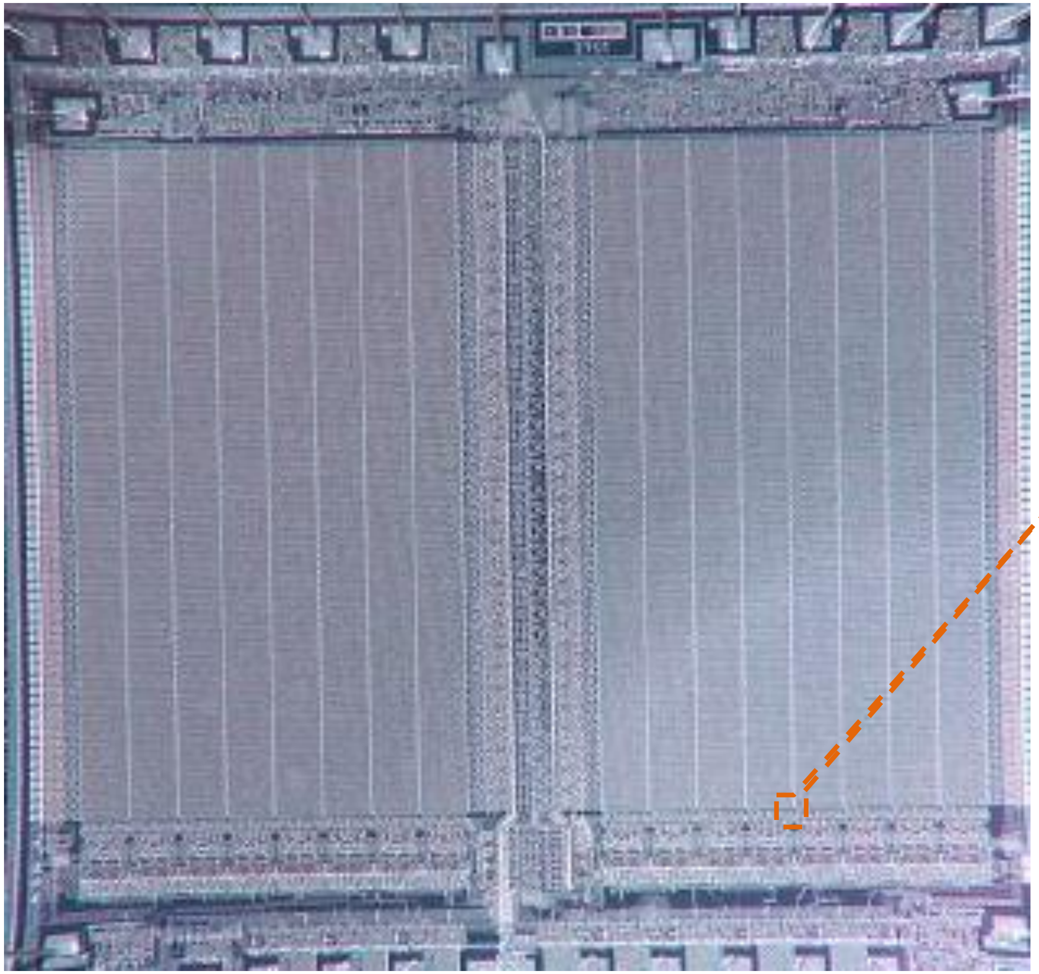


300
200
100
0
Peak Intensity, a.u.
0
5
10
15
20
X, um
3.2
3.1
3.0
2.9
FWHM, cm^{-1}
0
5
10
15
20
X, um

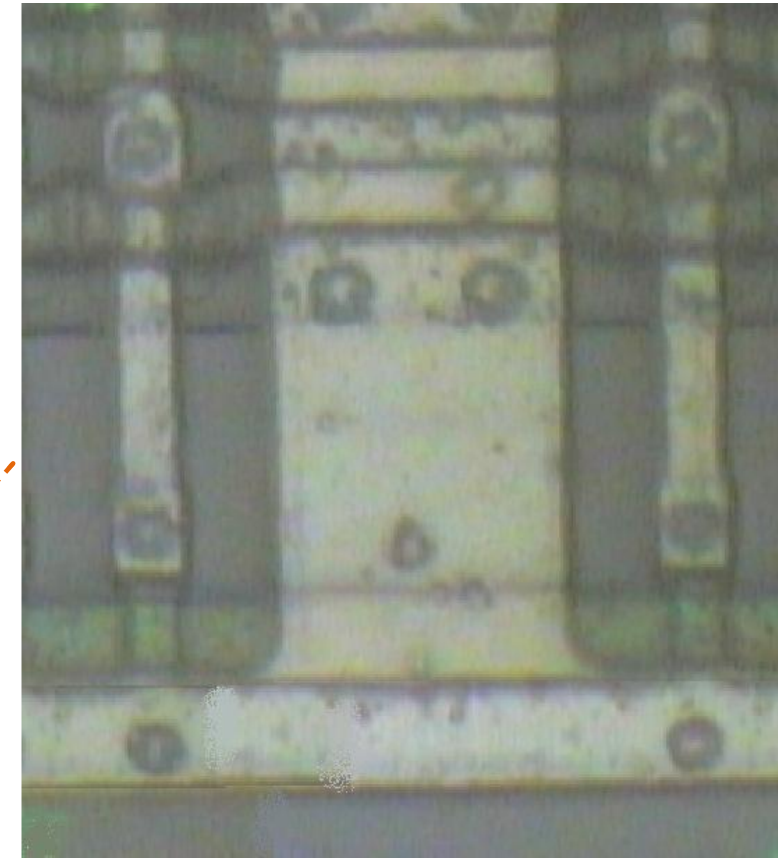



Peak position, cm^{-1}
521.50
521.49
521.48
521.47
521.46
521.45
521.44
521.43
521.42
521.41
521.40
0
5
10
15
20
X, um


Peak position, cm^{-1}
521.50
521.49
521.48
521.47
521.46
521.45
521.44
521.43
521.42
521.41
521.40
0
5
10
15
20
X, um

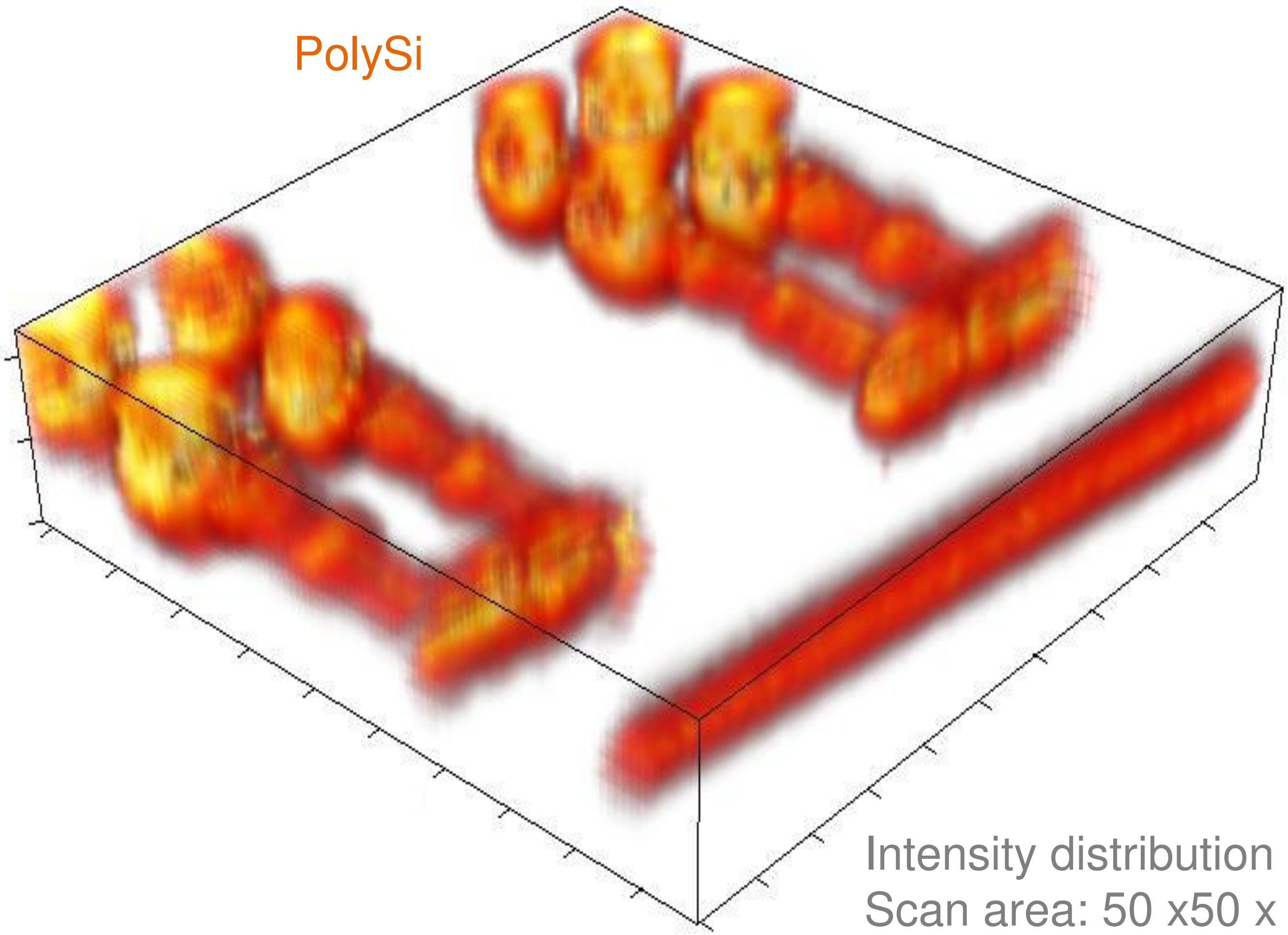


5x



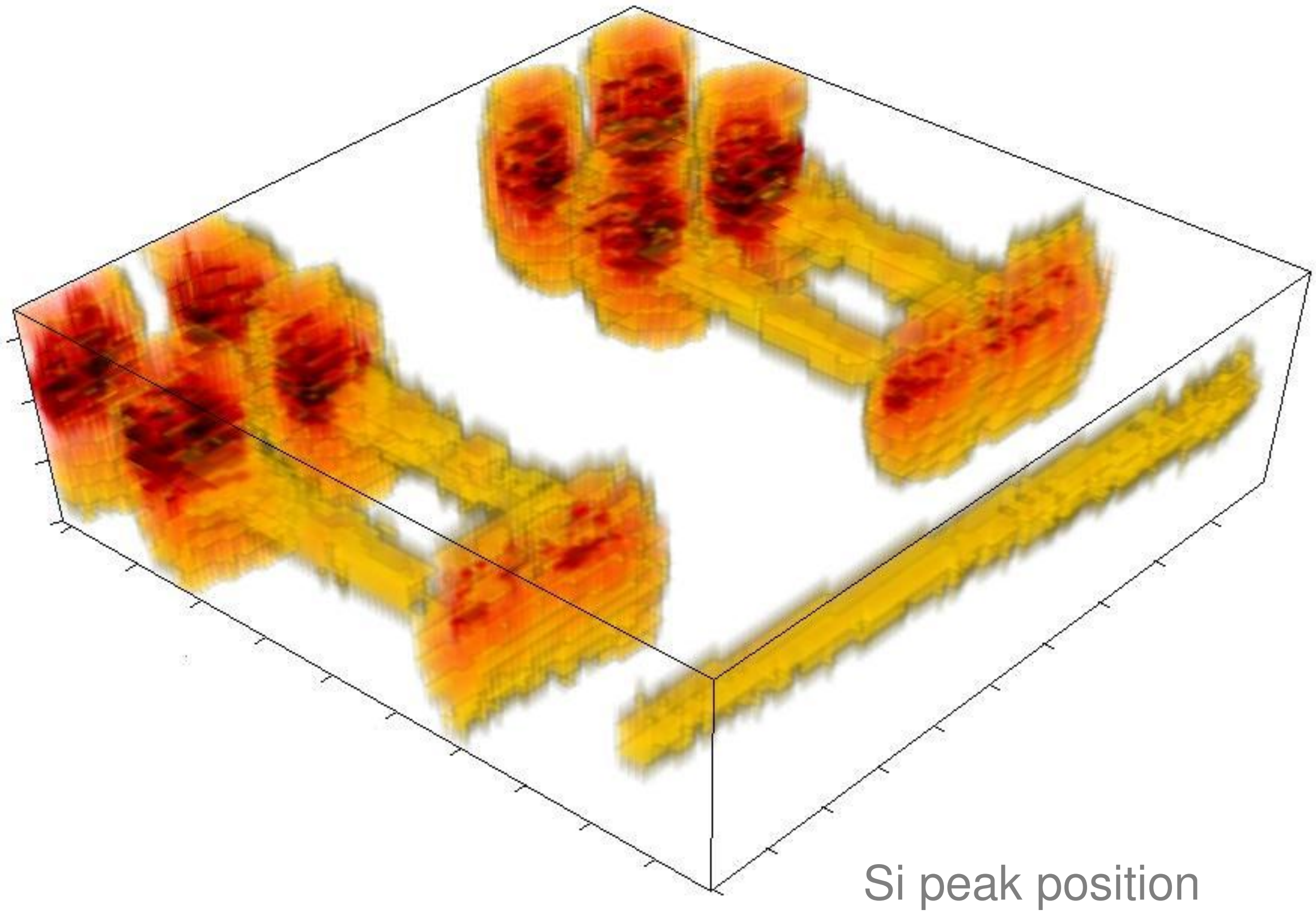
100x

PolySi



Intensity distribution (Si peak)
Scan area: 50 x50 x 7 um
Points: 100 x 100 x 10
Time per point: 0.1sec

www.solinstruments.com



Si peak position
Scan area: 50 x50 x 7 um
Points: 100 x 100 x 10
Time per point: 0.1sec

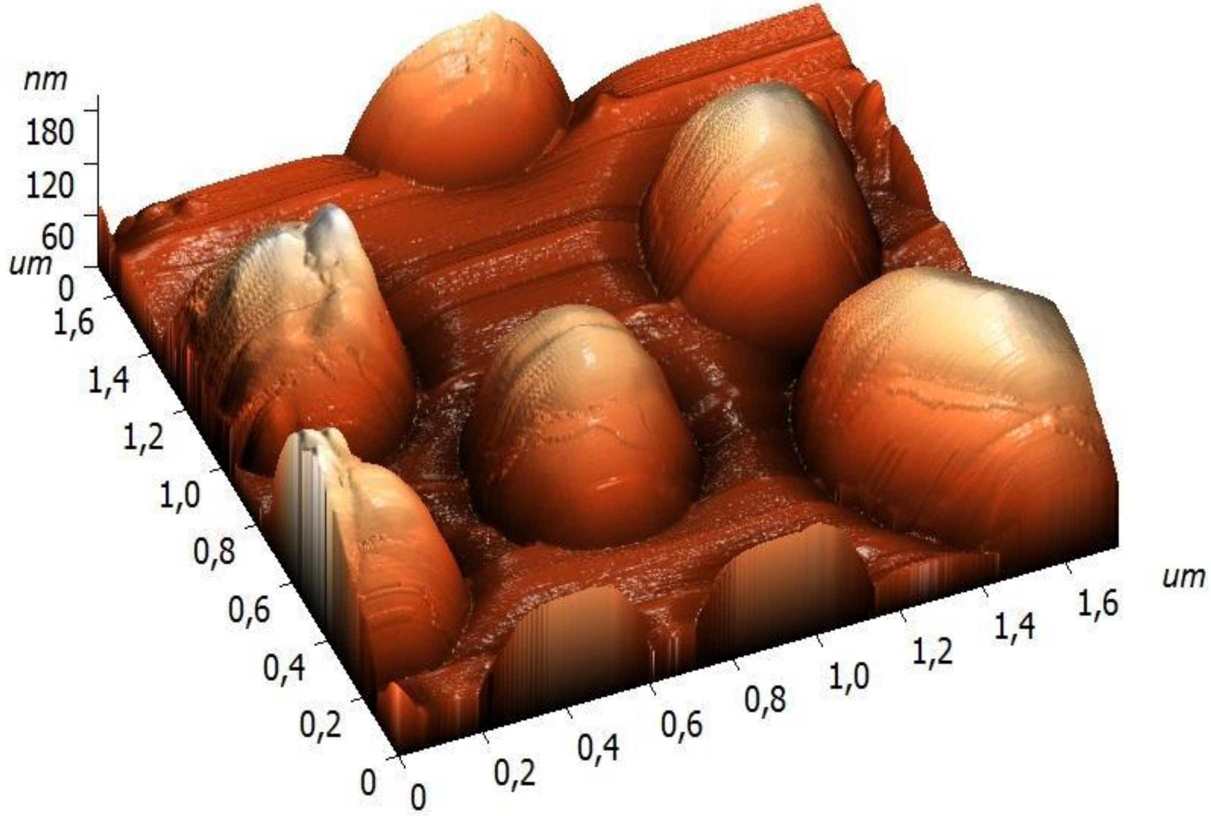
Ge QD on a Silicon substrate

Self-assembled Ge dots grown on Si substrates are attracting attention because they have a potential to be simply integrated with the existing Si-based technology.
The electronic properties of the Ge dots depend on many parameters, including shape, size and distribution of strain.

Raman scattering spectroscopy is absolutely necessary method for the characterization of QDs.

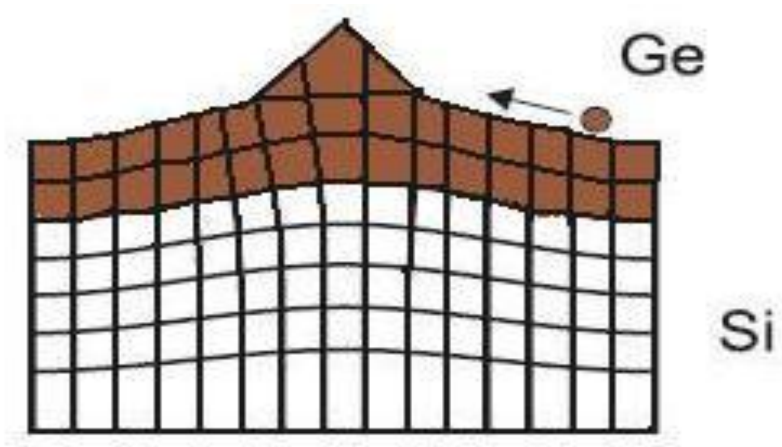
Raman spectroscopy allows to obtain information on the composition, strain in the structures, distribution of dots on the surfaces.

AFM Topography



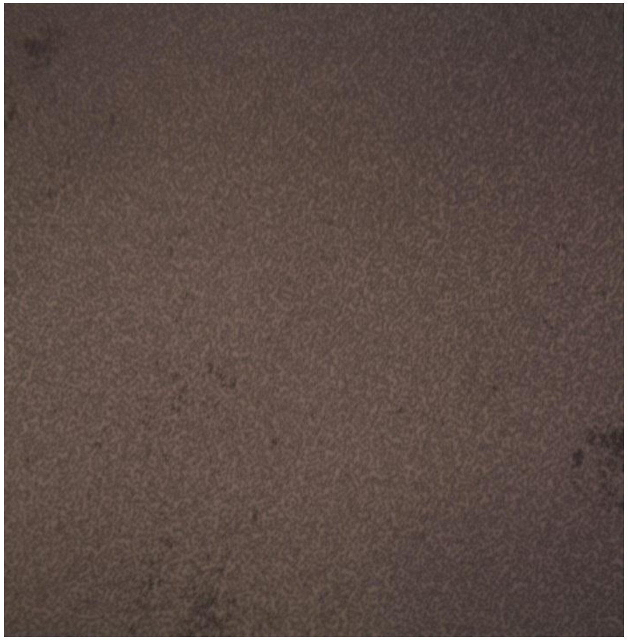
Ge QD on a Silicon Substrate

Forming of three-dimensional Ge islands on Si substrate is illustrated below.

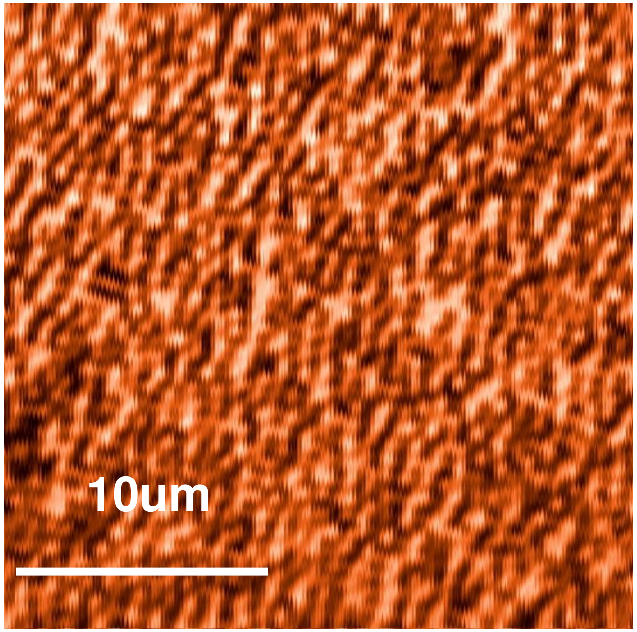


Growing of Ge dots on Si substrate (schematic diagram)

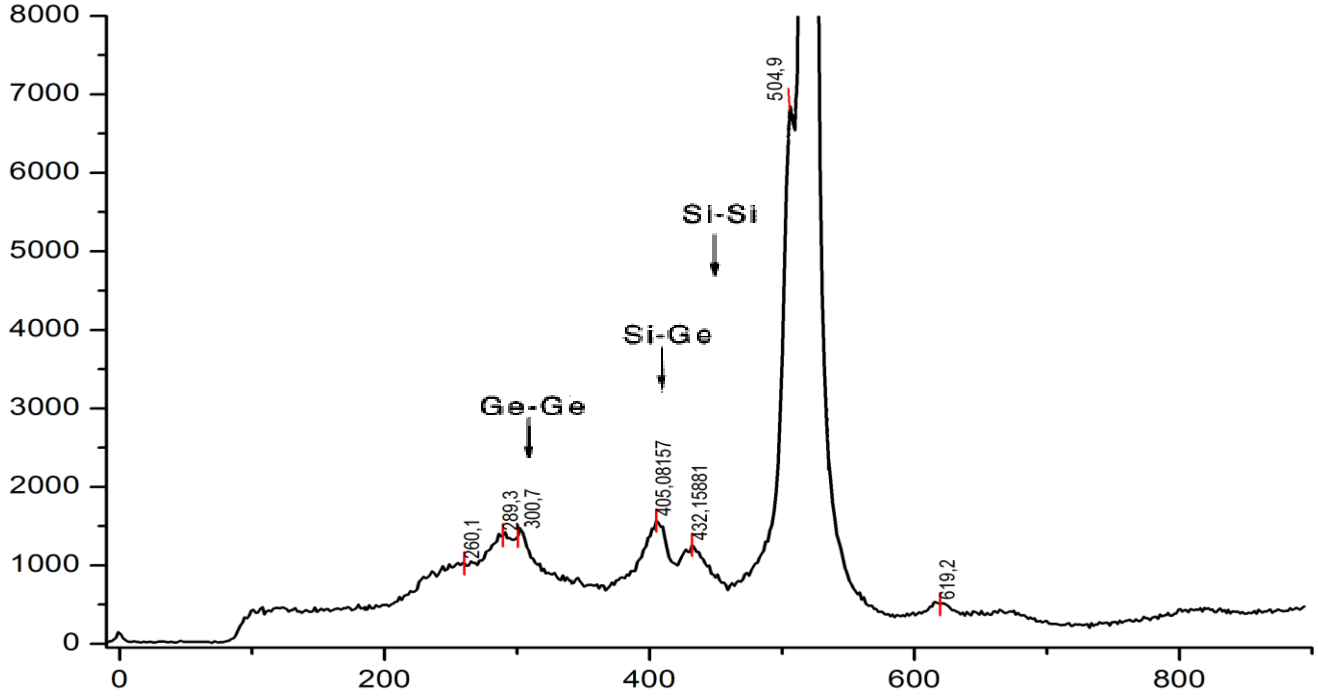
Optical image, 100x objective



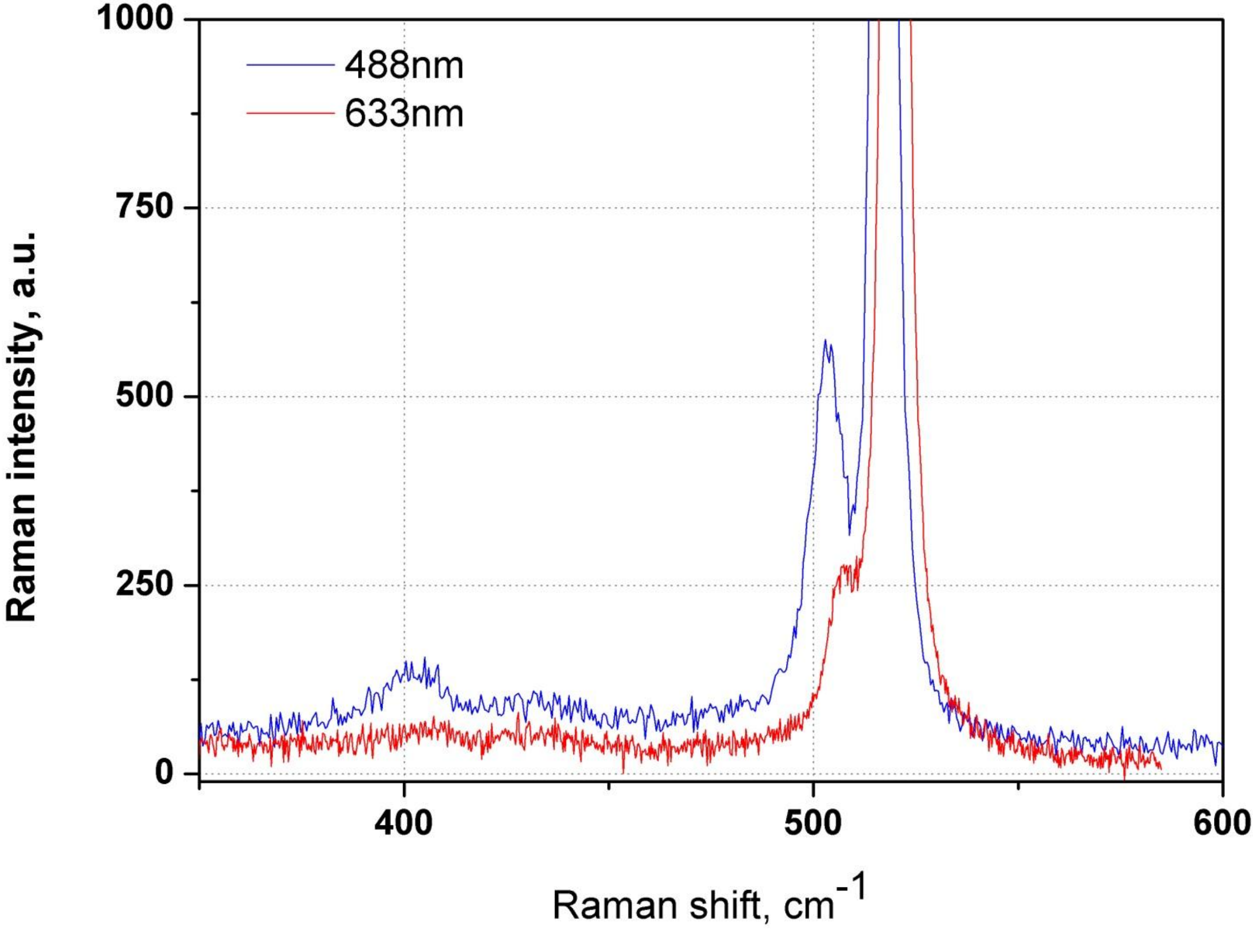
Rayleigh scattering, 21x21um, 488 nm



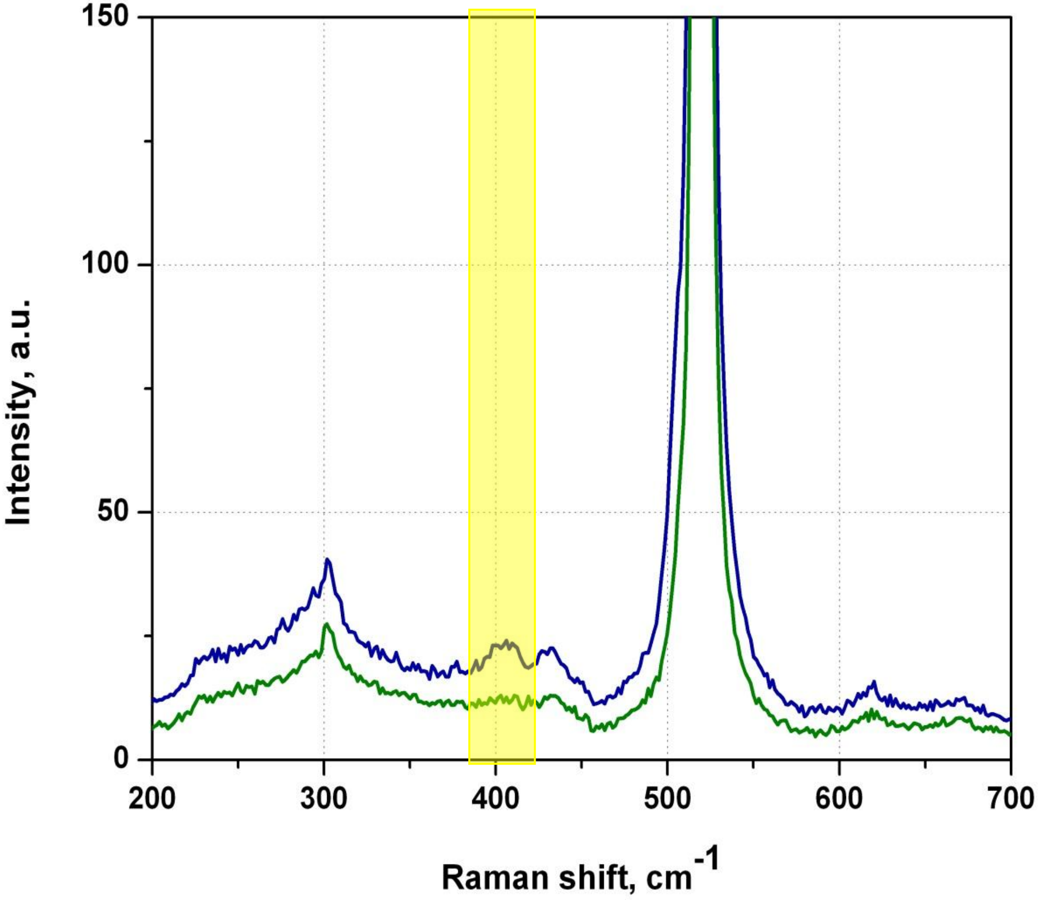
Raman Spectrum of Ge dots on Si



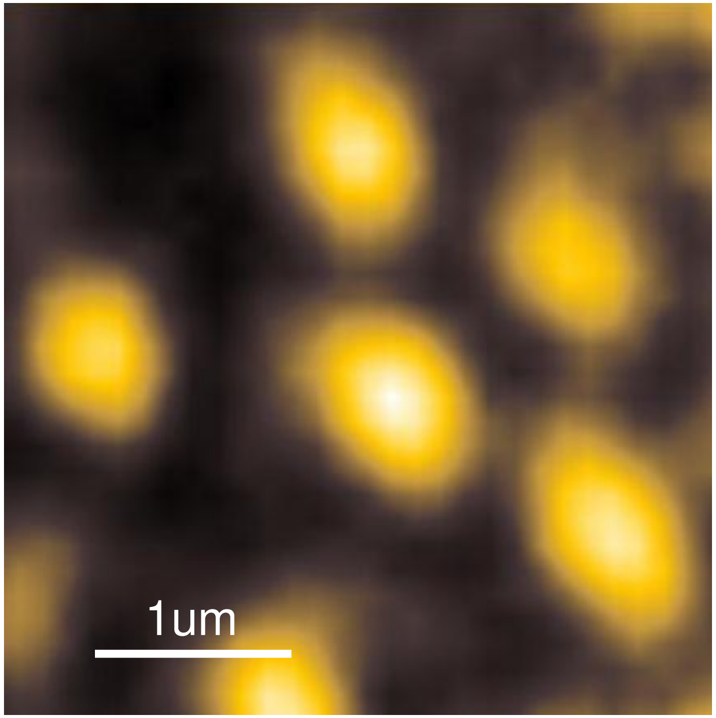
Samples exhibit two strong bands at 504.9 cm^{-1} and 521 cm^{-1}, and many weak features. Ge–Ge, Si–Ge and Si–Si optical modes can be found at around 290, 405 and 432 cm^{-1}, respectively.

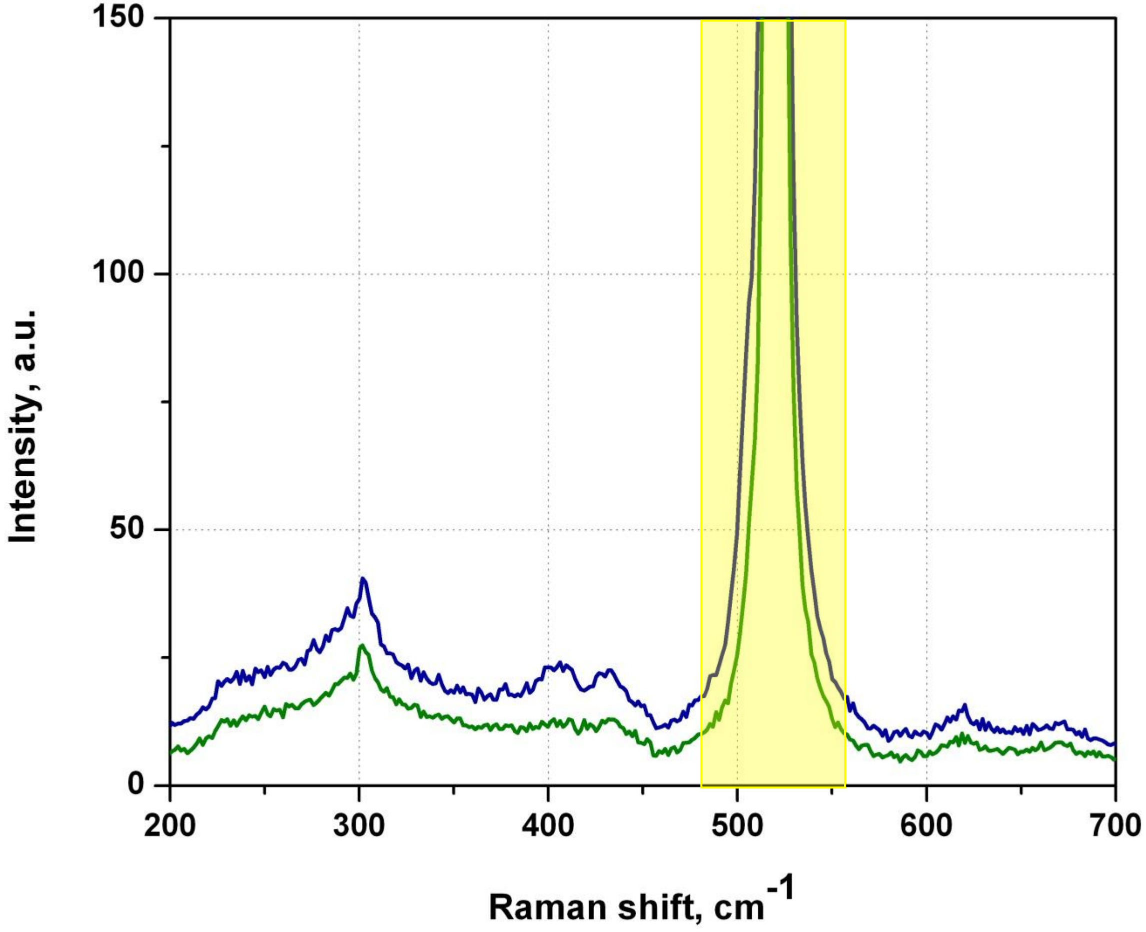


488nm
633nm
1000
750
500
250
0
400
500
600
Raman intensity, a.u.
Raman shift, cm-1

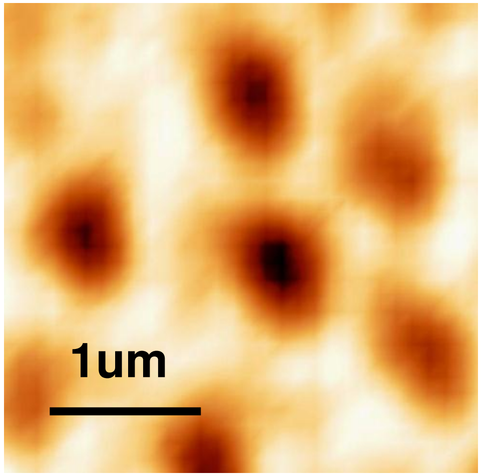


Peak intensity

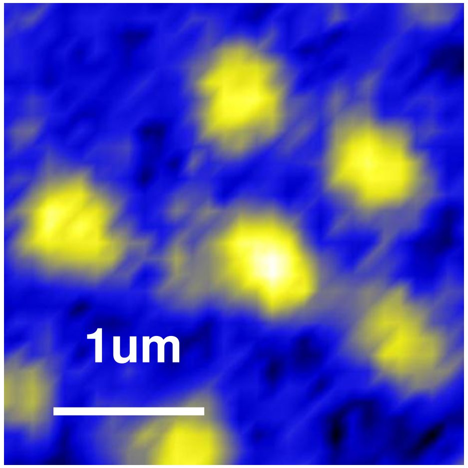




Peak position



Peak FWHM



www.solinstruments.com

Chen et al, Physical review B, Volume 65, 233303

$$\omega_{SiGe} = 400.5+14.2x-575\varepsilon$$

$$\omega_{GeGe} = 282.5+16x-385\varepsilon$$

$405.08\ cm^{-1}$

$289.3\ cm^{-1}$

ε Удельная деформация в структуре

x содержание Ge

SiC analysis

SiC has become important in the semiconductor industry because of its properties:

- High thermal conductivity
- High electric field breakdown strength
- High maximum current density

Raman Scattering of Different SiC Polytypes

SOL instruments

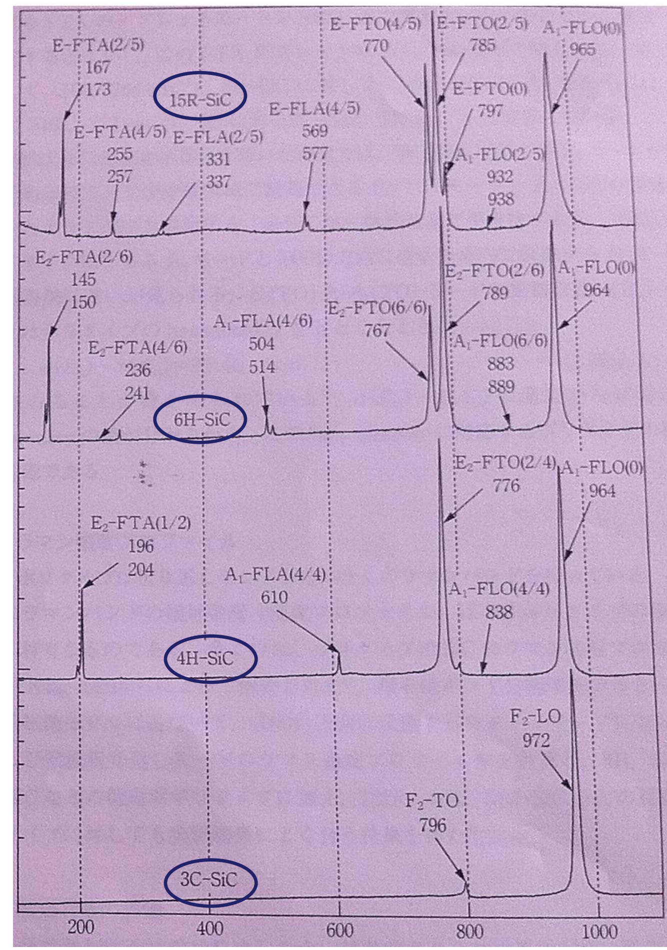
Main Raman Bands

Polytype

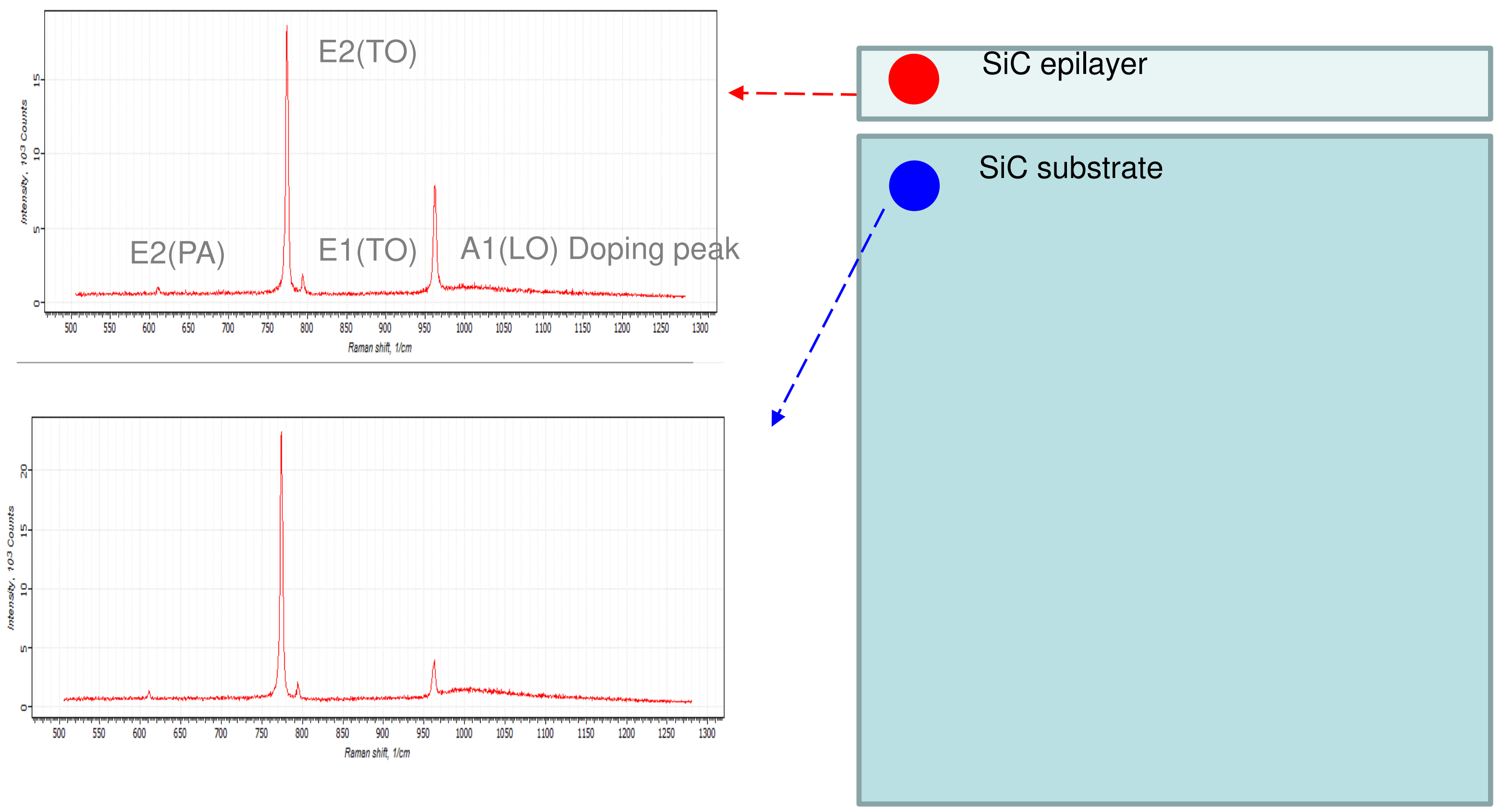
		FTA : cm^{-1}	FTO : cm^{-1}	FLA : cm^{-1}	FLO : cm^{-1}
3C	T_d^2	-	796 (F_2)	-	972 (F_2)
2H	C_{6v}^4	264 (E_2)	799 (E_1) 764 (E_2)	-	968 (A_1) -
4H	C_{6v}^4	196, 204 (E_2) 266 (E_1)	796 (E_1) 776 (E_2)	610 (A_1)	968 (A_1) 838 (A_1)
6H	C_{6v}^4	145, 150 (E_2) 236, 241 (E_1) 266 (E_1)	797 (E_1) 789 (E_2) 767 (E_2)	504, 514 (A_1) -	965 (A_1) 889 (A_1) -

*FTA - Folded Transversal Acoustical mode , FTO - Folded Transversal Optical mode, FLA – Folded Longitudinal Acoustical mode, FLO – Folded Longitudinal Optical mode

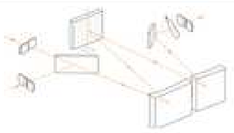
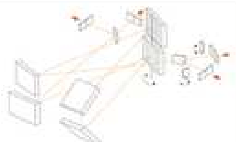
Raman Spectra of Different Polytypes



Silicon Carbide (4H-SiC)

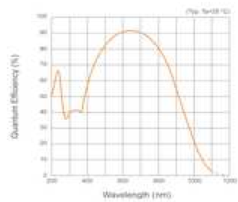
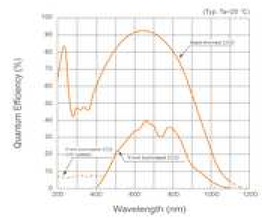
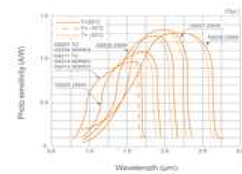


SOL instruments® Spectographs

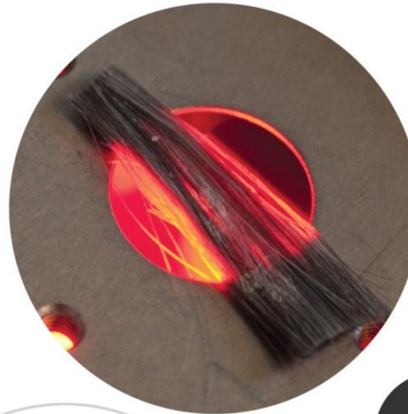
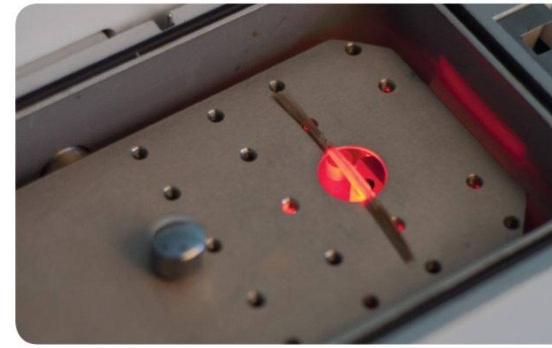
Series	**MS200** monochromator-spectrograph	**MS350** monochromator-spectrograph	**MS520** monochromator-spectrograph	**MS750** monochromator-spectrograph	**MSDD1000** monochromator-spectrograph
Photo of device:					
Optical scheme:	 Cherny–Turner	 Cherny–Turner	 Cherny–Turner	 Cherny–Turner	 Cherny–Turner
Ports:	1 input, 2 output	1 input, 2 output	1 input, 2 output	1 input, 2 output	2 input, 2 output
Wavelength range:	185 nm – 60 µm	185 nm – 60 µm	185 nm – 60 µm	185 nm – 60 µm	185 nm – 60 µm
F/number (entrance):	1/3.6	1/3.8	1/5.4	1/8.9	1/5.9
Focal length (output):	200 mm	350 mm	520 mm	750 mm	1000 mm (2 x 500)
Size of diffraction gratings:	40 x 40 x 6 mm	70 x 70 x 10 mm	80 x 70 x 10 mm	80 x 70 x 10 mm	80 x 70 x 10 mm
Stray light (20nm from laser line 632.8nm):	3×10^{-5}	1×10^{-5}	1×10^{-6}	5.5×10^{-7}	1×10^{-8}

SOL instruments® Spectral Cameras

SOL instruments

Model	**HS 103H** CCD area image sensor	**HS 101H (HR), HS 101H** CCD area image sensor		**HLS 190IR** Linear InGaAs detector
Photo of the device				
Spectral sensitivity				
Technical characteristics	**HS 103H**	**HS 101H (HR)**	**HS 101H**	**HLS 190IR**
Wavelength range:	from 200 to 1100 nm	from 200 to 1100 nm	from 200 to 1100 nm	from 0.9 to 2.55 мкм
Max. readout speed:	up to 500 kHz	up to 500 kHz	up to 1 MHz	up to 416 kHz
Sensor type:	CCD Back-Thinned	CCD Back-Thinned or Front-Illuminated	CCD Back-Thinned or Front-Illuminated	linear InGaAs
Number of pixels:	2048 x 64	from 2048 x 122 to 2048 x 506	from 1024 x 58 to 1024 x1024	256 or 512
Pixel size (H) x (V):	14 x 14 µm	12 x 12 µm	24 x 24 µm	from 25 x 250 µm to 50 x 500 µm
Nominal value of the distance from a forward plane of the camera up to photosensitive field of the sensor:	10 mm	10 mm	10 mm	10 mm
Exposure time:	from 10 µs to 7.5 h	from 10 µs to 7.5 h	from 10 µs to 7.5 h	from 1 µs to 7.5 h
Analog-digital converter (ADC) of the cameras:	16 bit	16 bit	16 bit	16 bit

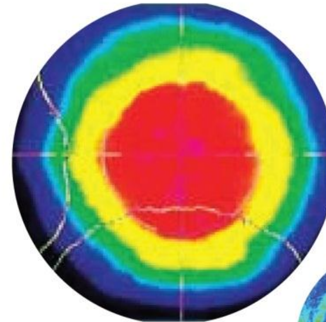

LASER ELEMENTAL ANALYZER
LEA-S500

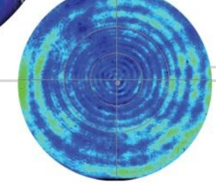
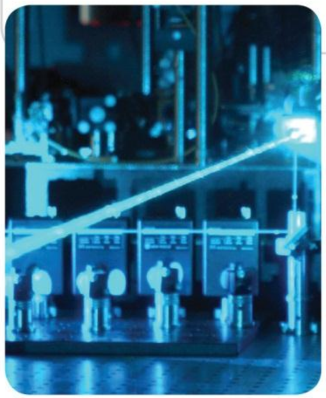
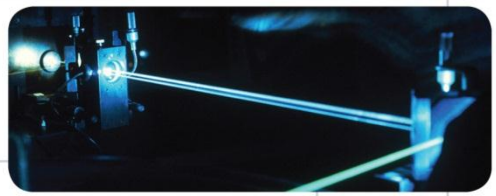




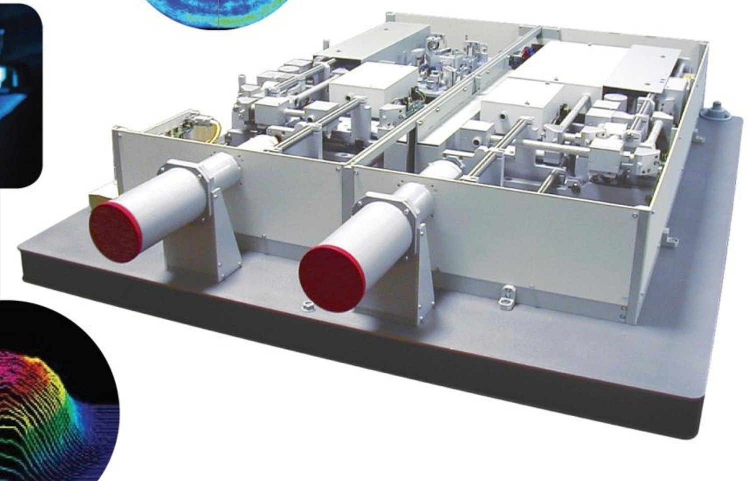


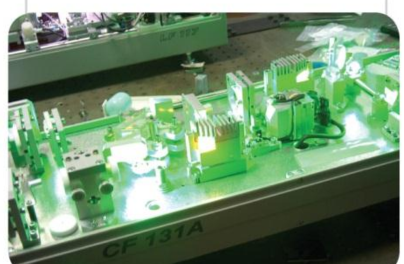

STAND BY
POWER
HV
LOCK
FAULT
POWER
OFF
ON
LASER POWER SUPPLY LPS 251

SOL
instruments
LASER ELEMENTAL ANALYZER
LEA-S500


CF 131A
SOL
instruments


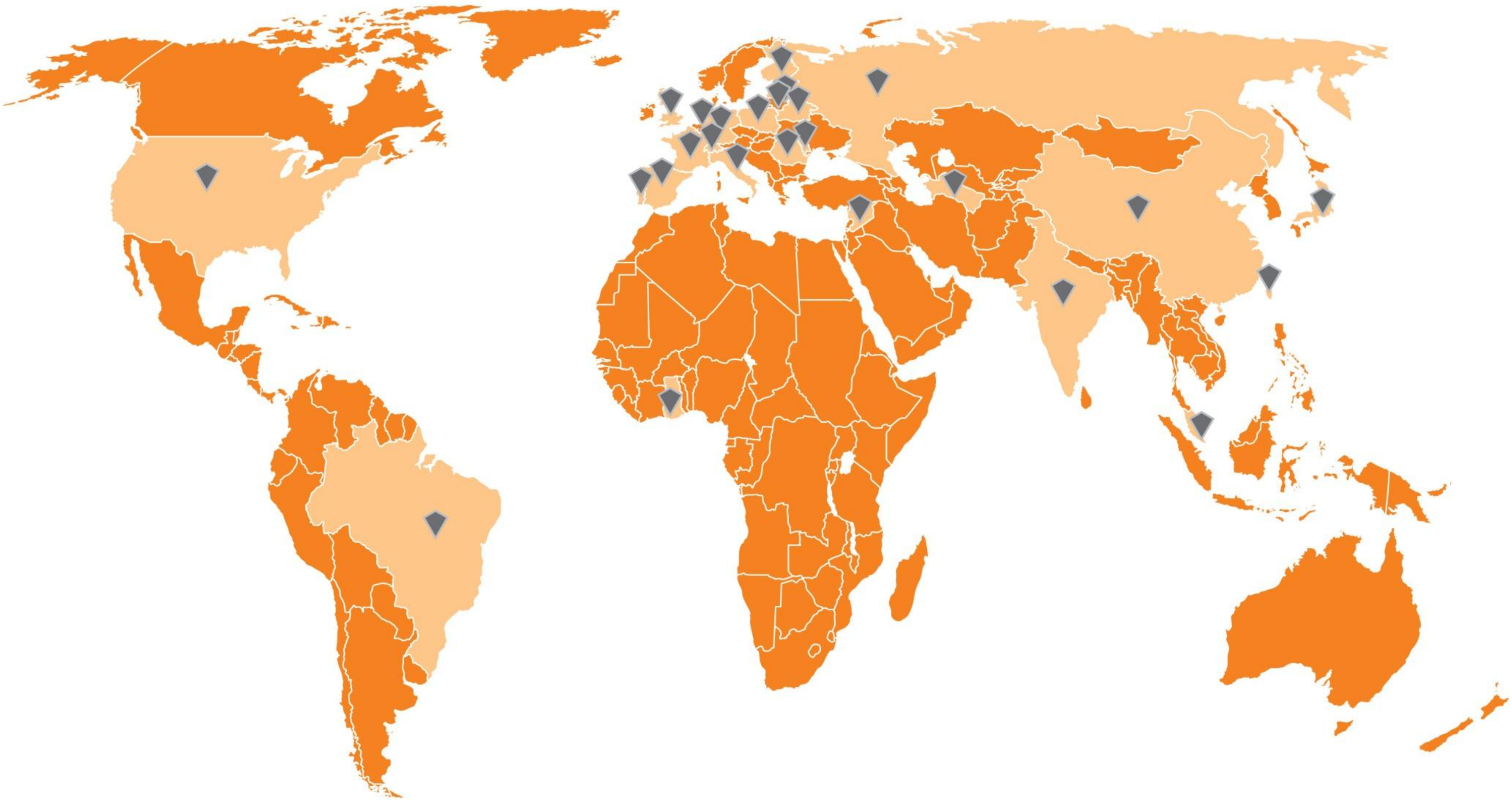
SOL
instruments
DF152




SOL
POWER
FAULT
ETHERNET



COPO 2200A
SOL
instruments

CF 131A

LF 117
SOL
instruments

SOL instruments



Thank you very much for your attention!