application note

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WITec
focus innovations

Scanning Near-field Optical Microscopy - VCSEL's

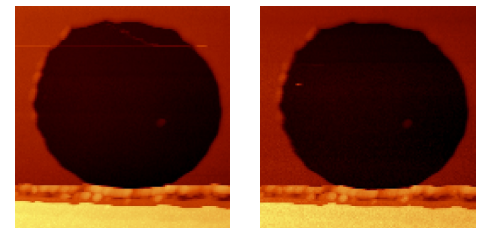
Vertical cavity surface emitting lasers (VCSELs) are being intensively developed for years. Two-dimensional laser matrices of high packing density can be produced. Coupling into optical fibers is possible without any additional optics. Data transfer rates exceeding 40 Gbit/s have been demonstrated.

Because of the very short cavity, the light emission of these lasers is from a single longitudinal mode, although multiple transverse modes with slightly different wavelengths are supported due to the lateral cavity diameter dimension of several microns. The threshold current is very low because of the high conversion efficiency.

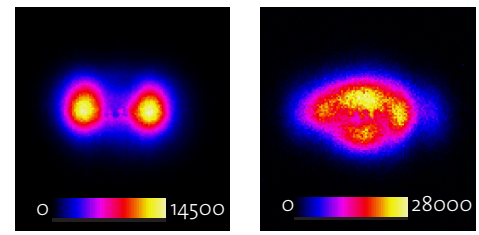
For use of the VCSEL's in optical communication technology, it is essential to know the transverse mode structure and polarization.

Scanning Near-field Optical Microscopy (SNOM) is a perfect tool to study these properties with highest possible resolution. A near-field sensor with a 100 nm aperture was scanned across the VCSEL and the collected laser light was coupled into a spectrometer. At each pixel, a high-resolution spectrum was obtained from which the different transverse modes could be extracted. This was done for different polarizations to detect local polarization variations.

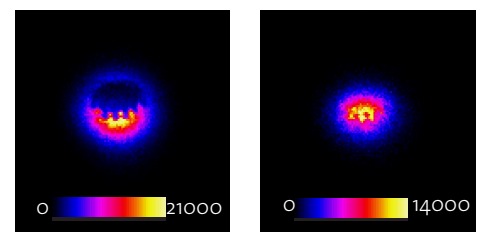
VCSEL at an injection current of 9.5 mA (threshold: 1.5 mA). Top row images show topography. Image size 15 µm.



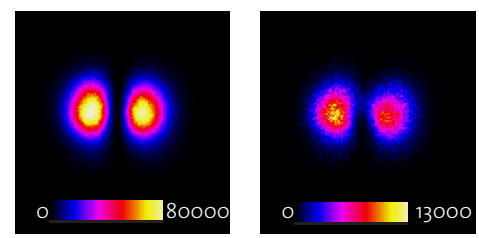
Overall intensity at an injection current of 9.5 mA. Left column polarization 0°, right column polarization 90°.



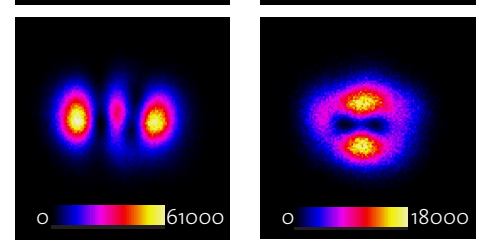
The fundamental mode (832.41 nm) is highly degenerated. The laser emission is strongly influenced by local inhomogeneities in the active layer or bragg reflectors, probably due to stress.



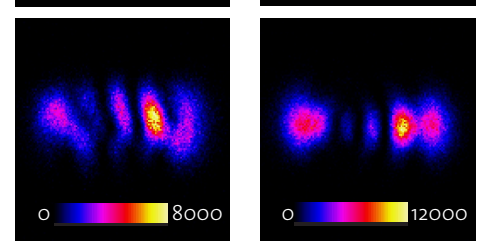
The other transverse modes are not influenced. Transverse mode at 832.00 nm.



Transverse mode at 831.53 nm.



Transverse mode at 830.96 nm.



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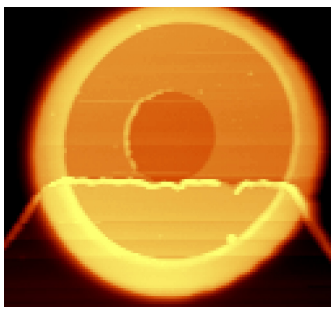
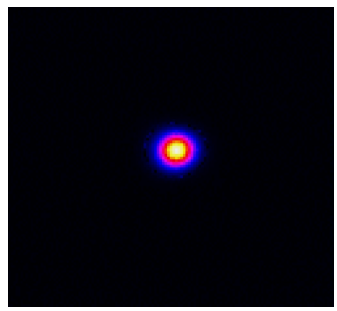
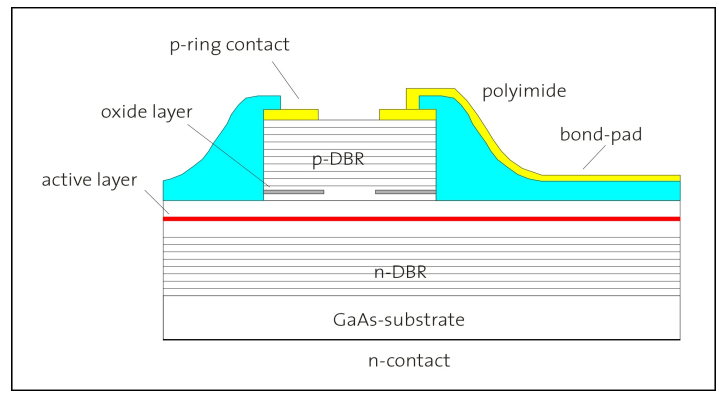
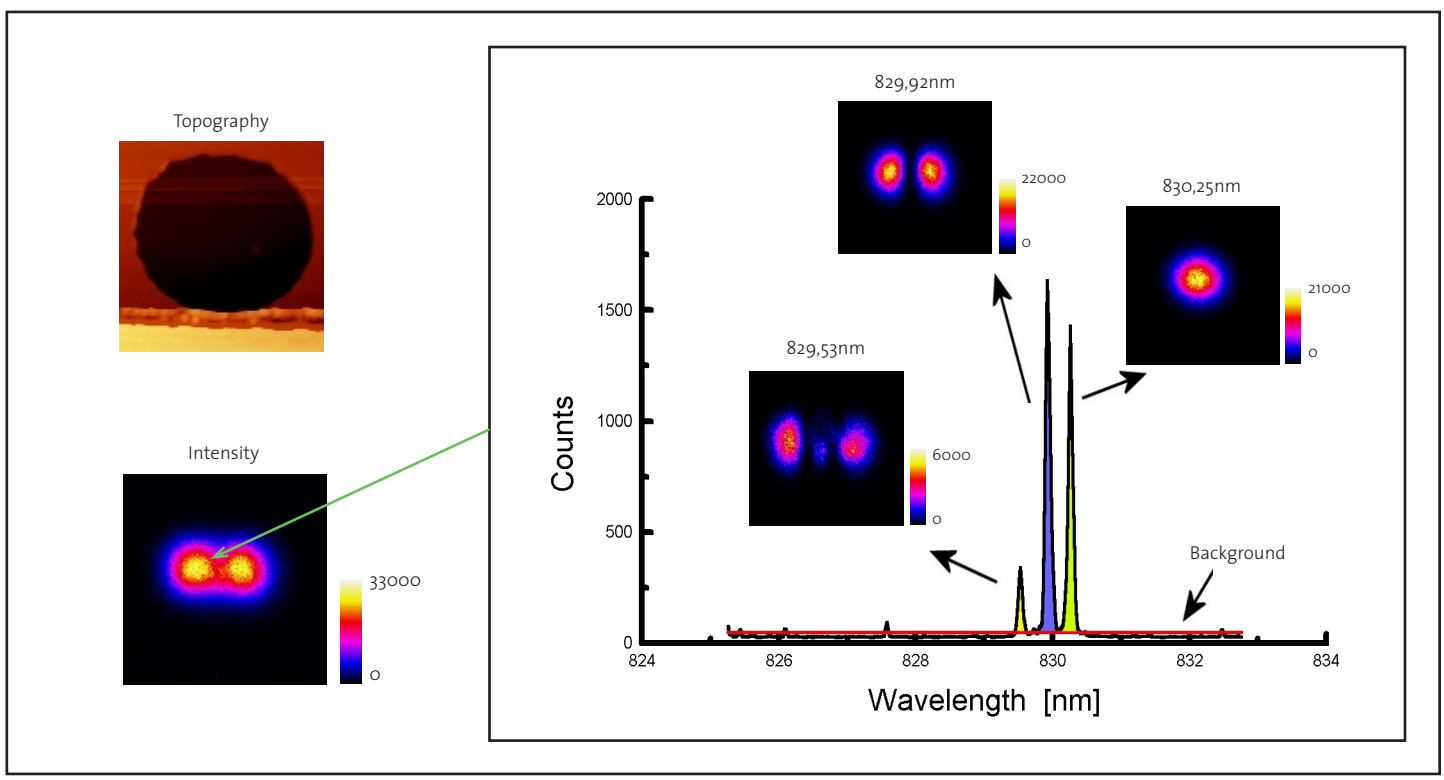




Sample
n-DBR (distributed Bragg reflectors):
38 pairs of λ/4 $Al_{0.2}Ga_{0.8}$ As and $Al_{0.9}Ga_{0.1}$ As layers doped with silicon
active layer: three 8 nm GaAs-quantumlayers 30 nm AlAsO oxidelayer
p-DBR: 23 pairs of $Al_{0.2}Ga_{0.8}$As und $Al_{0.9}Ga_{0.1}$As doped with carbon
ring contact: layers of titanium, platinum and gold
polymide: Probimide 7510
bond-pad: layers of titanium, gold, nickel, gold.



Simultaneously obtained topography (left) and overall intensity (right) image of a VCSEL with an active region of about 3 µm diameter at an injection current of 3 mA (image size 40 µm).



Topography and intensity are measured at the same time. A full spectrum is taken at each pixel. This gives full information about the spectral andspatial distribution of the emitted light. As each mode has a slightly different wave-length, the modes can be separated. The images of the modes represent the area under the different peaks in the spectra.

Samples courtesy of Christian Jung and Prof. Dr. K.J. Ebeling,
Abteilung Optoelektronik, Universität Ulm.