attoCFM I for Surface Quality Inspection

Confocal microscopes work by scanning a tiny light spot on a sample and by measuring the scattered light in the illuminated volume. First, the resolution obtained is better in comparison with the microscope operated conventionally, since a pinhole removes the out-of-focus information. Second, by scanning many thin sections through a sample, one can build up a very clean three-dimensional image of the sample. Finally, the non-contact method prevents from destruction or degradation of the sample.

Because confocal microscopy is a three-dimensional, high-resolution, and non-destructive tool, it is ideal for high resolution defect analysis and topography profiles (examples are shown in the pictures on the right).

The highly modular and flexible attoCFMI features fully adjustable excitation and collection ports enabling easy handling and filtering of the excitation and collection signal for raman spectroscopy. The attoCFMIopens up new possibilities in quantitative surface characterization in the micron / sub-micron range.

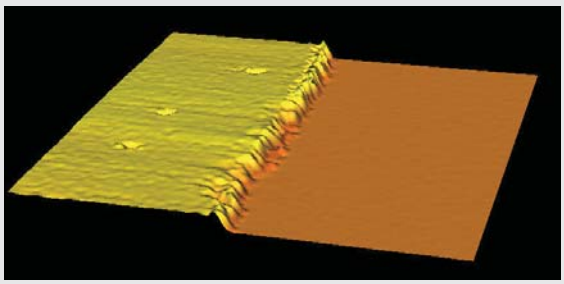

Fig. 1: *Confocal picture of GaAs-substrate: Inspection of a cleaved surface; the size of the image is 20 x 20 microns.*

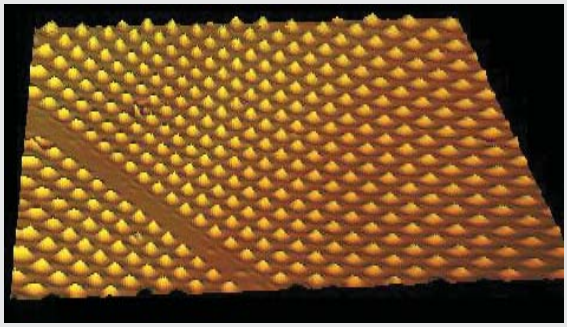

Fig. 2: *Confocal picture of a chess board grating (SiO_2 on Si) with a period of 2 microns, recorded in reflection mode. The sample has some defects on the surface structure.*

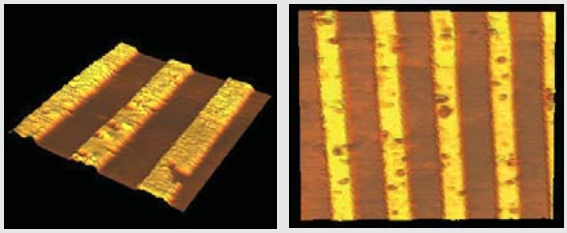

Fig. 3: *The aluminum on glass grating is damaged at certain locations. Left: size 30 x 30 microns; right: size 45 x 45 microns.*

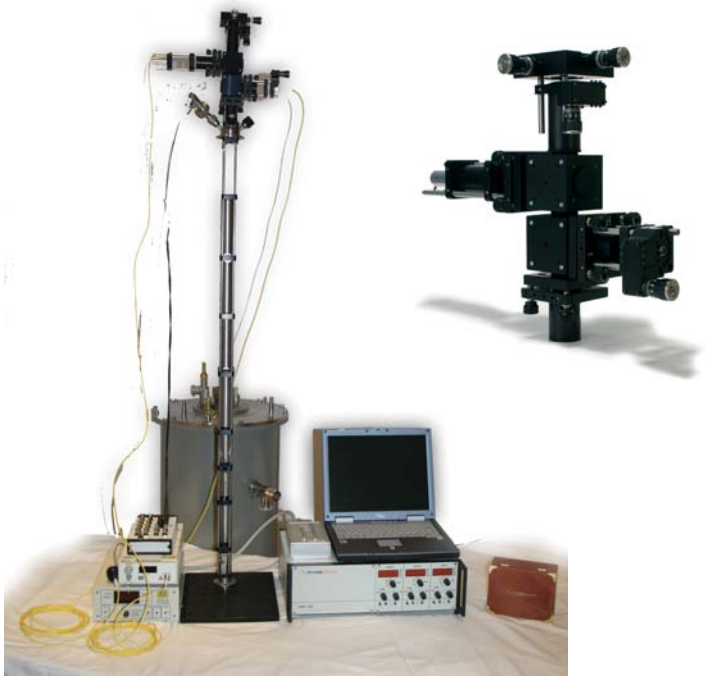

Fig. 4: *Complete attoCFM system and the confocal microscope head.*

RELATED PRODUCTS

attoCFM I	highly modular and flexible confocal microscope
ANPxyz100/LT	high precision, piezo electric, inertial positioner for big loads
ANSxy100	high precision piezoelectric scanner
ANC150/3	electronic controller
ANC200	electronic scan controller
attoSCAN	data acquisition software
attoVIEW	data viewing software

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3D - Imaging with attoCFM II

The confocal imaging system achieves out-of-focus rejection by two strategies:

- By illuminating a single point of the specimen with a focused beam, so that illumination intensity drops off rapidly above and below the plane of focus.

- By the use of a blocking pinhole in the conjugate plane of the previous plane of focus in order to eliminate the degrading out-of-focus information.

By scanning many thin sections through your sample, you can build up a very clean three-dimensional image of the sample. Confocal imaging can offer another advantage in favourable situations (small pinhole size, bright specimen): the resolution obtained is better than the resolution obtained with any microscope operated conventionally. In practice, the best horizontal resolution of a confocal microscope is (at λ=630 nm illumination) about 200 nm, and the best vertical resolution is less than 500 nm.

Fig. 3: *The attoCFM II microscope sensor head.*

Fig. 1: *Confocal picture of a chess board with 2 microns of period recorded in reflection mode.*

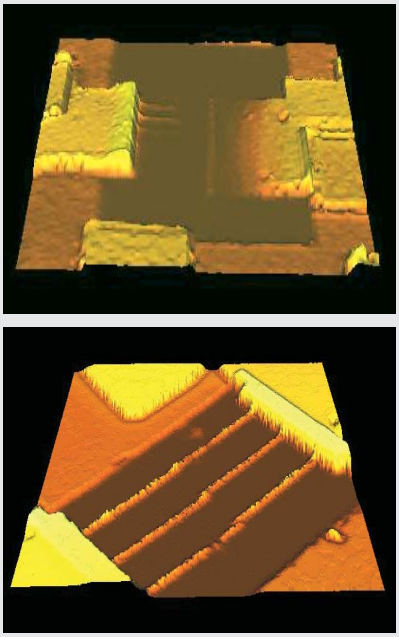

Fig. 2: *Confocal picture of a tweezers structure; the tweezers are freely suspended. The size of the image is 30x30 microns recorded in reflection mode. The 200 nm wide structures are resolved with an excitation laser source of 630 nm! (C. Meyer et al., IEEE Nano 2004).*

RELATED PRODUCTS	
attoCFM II	highly stable and compact confocal microscope
ANPxyz100/LT	high precision, piezo electric, inertial positioner for big loads
ANSxy100	high precision piezoelectric scanner
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ANC200	electronic scan controller
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Vibrations of the system

The vibrations of the complete system including the cryostat and the confocal microscope were recorded at different temperatures and with the cooler on and off. Figure 1 (top) illustrates the vibrations as a function of time recorded at 4 K with the cooler on. The corresponding vibration spectrum recorded under the same conditions is shown in Figure 1 (bottom). The vibrations corresponding to the operating frequency of the cooler were typically below 10 nm. Performing the same experiment at 300 K showed vibrations in the range of 25 - 30 nm (data not shown).

The vibrations as a function of the time recorded at 4 K with the cooler switched off are shown in Figure 2 (top). In this case, the vibrations corresponding to the operating frequency were determined to be below 5 nm. Figure 2 (bottom) illustrates the vibration spectrum recorded under the same conditions.

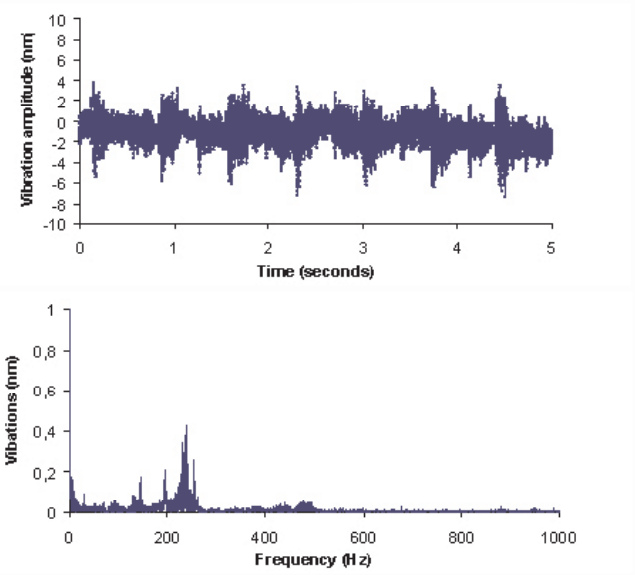

Figure 1: Vibrations (top) and vibration spectrum (bottom) of the complete system (confocal microscope inside the cryostat) recorded at 4 K with the cooler on.

Confocal imaging

The attoCFM II is an ultra-compact confocal microscope which is highly stable at low temperatures, high magnetic fields and in high vaccum. A laser beam is coupled into one arm of a 50/50 single mode optical fiber coupler. The fiber end of the second arm is placed in a ceramic ferrule, to guarantee an accurate position with respect to the objective and to minimize optical aberrations. This single mode fiber illuminates the sample and is used as the blocking pinhole aperture when collecting the scattered light from the sample. The mechanical parts are highly stable against thermal drift and the design is optimized to minimize light losses as well as to collect the maximum amount of light scattered by the illuminated point on the sample.

The images in Figure 3 were recorded with the attoCFMII in reflection mode. The illumination wavelength was chosen to be 1330 nm. As a sample, a SiO_2 on Si grating with a period of 4 μm and a chess board with a period of 2 μm was used.

The image on the left was recorded at 300 K with the cooler on. The sample features are clearly resolved despite the higher vibrations at this temperature. The other two images were recorded at low temperature (4 K) with the cooler running (middle) and switched off (right). Due to the low vibrations of the cryostat and the highly stable microscope, absolutely stable measurements over several hours were enabled. Furthermore, fast cycle times and easy, cryogen- free handling add to the simplicity of this complete low temperature confocal microscopy system.

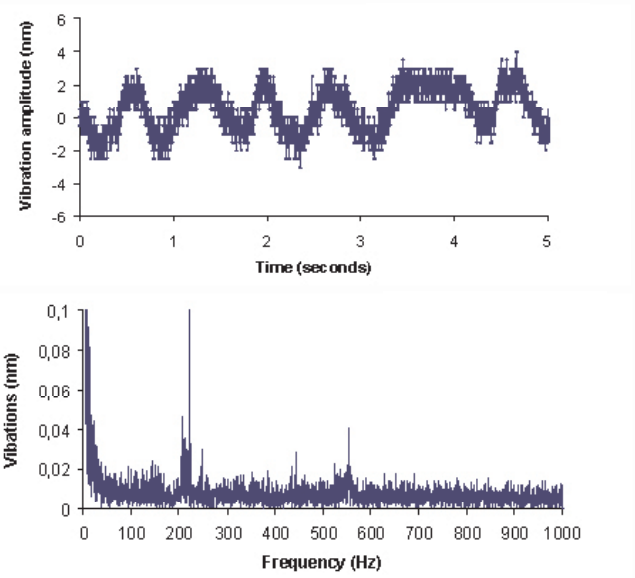

Figure 2: Vibrations (top) and vibration spectrum (bottom) of the complete system (confocal microscope inside the cryostat) recorded at 4 K with the cooler off.

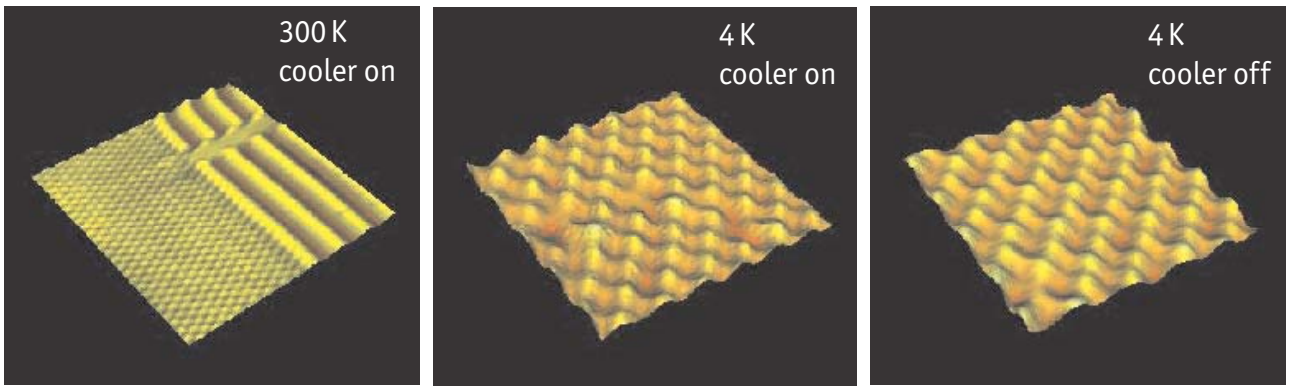

Figure 3: (left) CFM image of a SiO_2 on Si sample recorded at 300 K with the cooler on. The grating has a period of 4 μm and the chess board a period of 2 μm. The step scan range is 30 x 30 μm. (middle) CFM image of a SiO_2 on Si chess board sample recorded at 4 K with the cooler on. The chess board has a period of 2 μm. The step scan range is 10 x 10 μm. (right) CFM image of a SiO_2 on Si chess board sample recorded at 4 K with the cooler off. The chess board has a period of 2 μm. The step scan range is 10 x 10 μm.

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Confocal Microscopy in Combination with a Solid Immersion Lense for Enhanced Resolution

Confocal microscopy provides several advantages over conventional wide field optical microscopy including elimination of image degrading out-of-focus information and the ability to acquire serial optical images in successive thin sections from thick specimen. Confocal microscopy relies on wo strategies: a) Illumination of a single point of the specimen at a time with a focused beam so that the illumination intensity drops rapidly above and below the plane of focus and b) using a blocking pinhole aperture in a conjugate focal plane to the specimen eliminating degrading out-of-focus information. Solid immersion microscopy, where light is focused inside a high refractive-index lens close to a sample, offers a method for achieving resolution well below the diffraction limit in air. Combining these techniques, major improvement of resolution and light throughput are achieved in addition to offering a very simple experimental setup compared to other high resolution optical techniques, e.g. scanning near-field optical microscopy (SNOM).

In the confocal setup, the solid immersion lens is applied directly on the surface of the investigated sample, which was a SiO_2 on Si chess board with two microns in period. A schematic drawing of the experimental setup is shown in Figure 1. The confocal microscope attoCFM II was used first to acquire an image of a sample without the solid immersion lens, and second, to acquire an image with the solid immersion lens. The purpose is to determine the increase in the resolution. The wavelength used was 635 nm. The diffraction limited confocal objective had a numerical aperture of 0.55, thus leading to a lateral resolution of 700 nm. Figure 2 shows the image and a line cut recorded without the solid immersion lens. The micrometer sized structures are clearly resolved. Figure 3 shows the image acquired using the solid immersion lens. The measured resolution was about 160 nm. This ultra-high resolution is also attributed to the confocal setup using a pinhole that leads to an additional enhancement of the resolution.

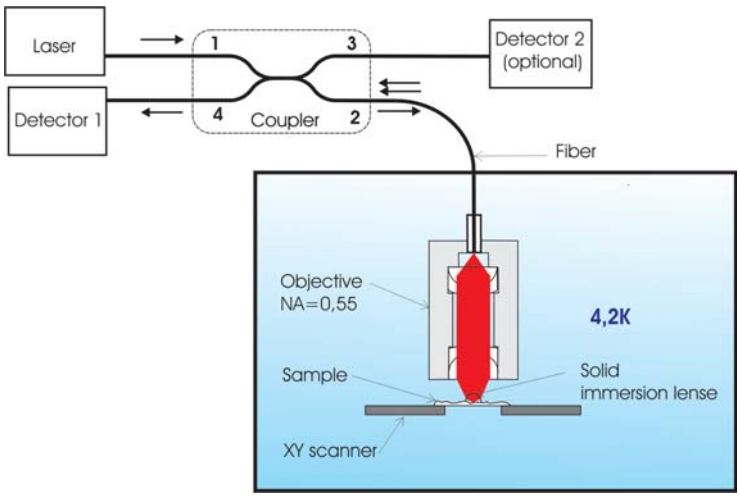

Figure 1: *Schematic drawing of the attoCFM II setup including the solid immersion lens.*

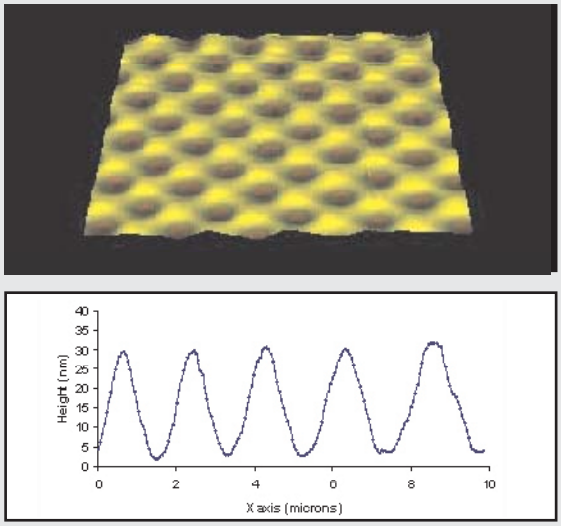

Figure 2: *3D-view and line cut of the image acquired with the attoCFM II confocal microscope. The sample is a chess board with 2 microns in period.*

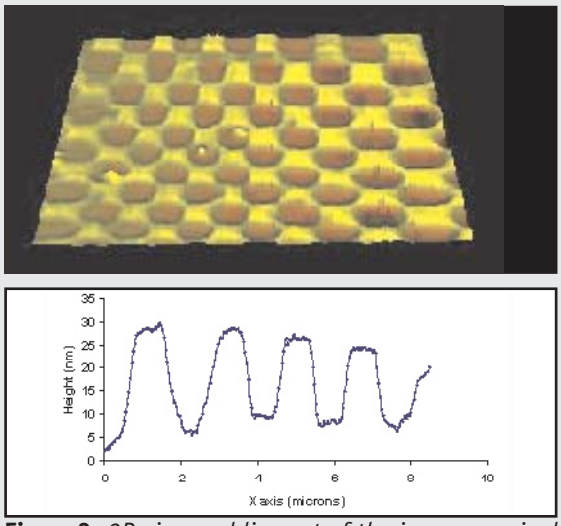

Figure 3: *3D-view and line cut of the image acquired with the attoCFM II in combination with the solid immersion lens.*

RELATED PRODUCTS

attoCFM II	highly stable confocal microscope
ANPxyz100	high precision, piezo electric, inertial positioner for big loadsAN-
ANSxy100	high precision piezoelectric scanner
ANC150/3	electronic controller
ANC200	electronic scan controller
attoScan	data acquisition software
attoView	data viewing and editing software

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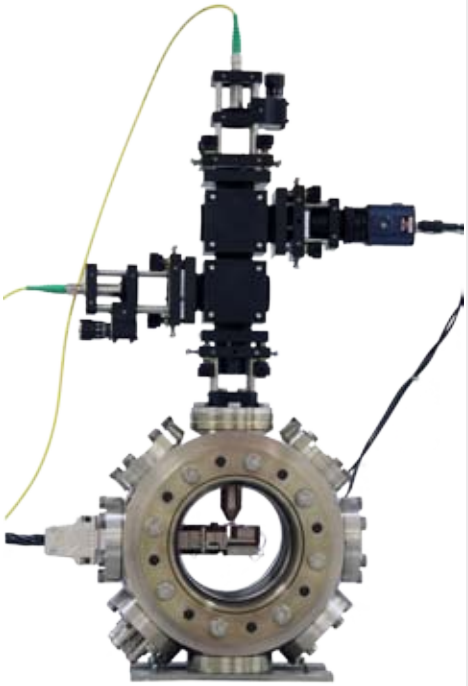
Compact confocal microscope integrated into the attoUHVchamber.

Based on the design of the atto**cube**'s low temperature compatible attoCFM I a confocal microscope setup has been integrated into the **atto***UHV***chamber**. The tests show superior performance of the optical microscope while enabling an easy optical access for sensitive applications such as Bose-Einstein Condensates, the detailed characterization of waveguides.

The measurements have been performed using a standard confocal head together with a special lens setup for the **atto***UHV***chamber**. The optical beam from the confocal setup was guided into the UHV chamber though an optical broadband window. A laser with a 635 nm wavelength and a UHV compatible objective with the following properties have been used: focal length of 1.56 mm and an NA of 0.68 which results in a theoretical spot size of ~600 nm and resolution of at best ~450 nm.



The confocal head and the objective were stationary, while the sample was mounted on an ANPxyz101 positioner set for coarse alignment in combination with an ANSxy100 scanner for scanning purposes. The sample was a standard chess board structure with ~60 nm high SiO_2 structures on Si substrate with 2 µm periodicity. The whole setup was at room temperature and UHV conditions, with the pressure less than 1E-9 mBar.

In Figure 1 the result of the measurement is shown. The image shows clearly the periodicity of the grating at good contrast. Additionally, the image shows that the circular spot size of the setup has no distortions or aberrations.

In summary, it has been shown that the attoUHV chamber can be easily combined with the confocal attoCFM I setup with no compromises on the quality of the measurement.

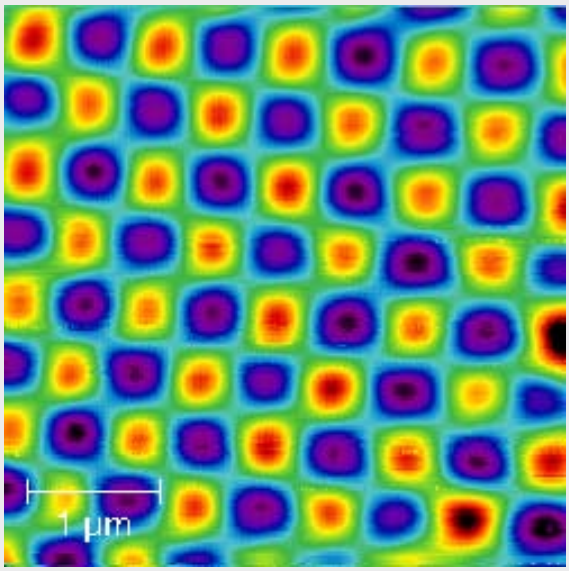


Fig. 1: *Image of the chess-board grating with 2 µm periodicity. Red corresponds to high, black to low intensity. From the graph, one can see that the spot is very good circular.*

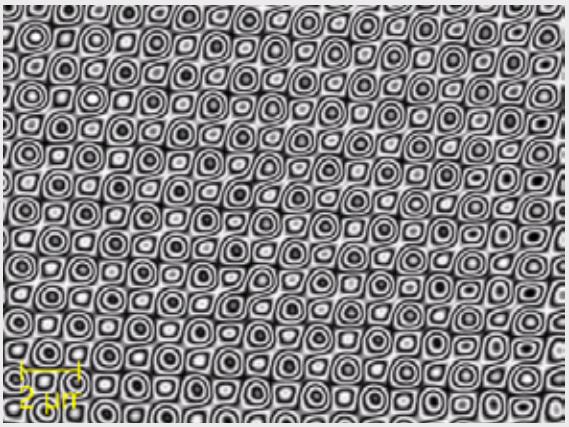


Fig. 2: *Image of the chess-board grating with 2 µm periodicity.*

RELATED PRODUCTS

atto*UHV***chamber**	miniaturized UHV chamber
attoCFM I	confocal microscope
ANPxyz101/UHV	high precision, piezo electric, inertial positioners
ANC150	electronic controller

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