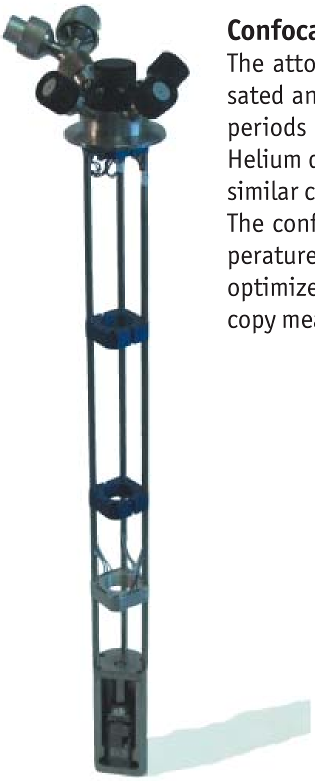
# First 4 K Closed Cycle Cryostat Combined with Confocal Microscopy

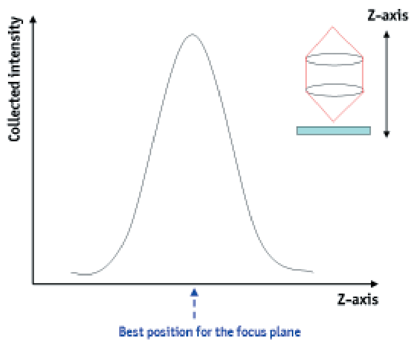
The use of cryogen-free cryostats is desired for many applications e.g. where liquid Helium is not available or not desired. For use in conjunction with high-resolution low-temperature microscopy, one requirement is performance with low vibration. Ideally, the cryostat should also provide short cool-down times and easy handling. Such a system has been developed and tested successfully in a collaboration of atto**cube** systems and VeriCold Technologies. The confocal microscope attoCFM II was used in conjunction with the low-vibration pulse tube cryostat from VeriCold to determine the system vibrations at the one hand, and perform confocal microscopy at 4 K, at the other hand (see page 2).



**Confocal Microscope** (atto**cube** systems)
The attoCFM II confocal microscope is thermally compensated and guarantees stability for spectroscopy over long periods of time. Ultra compact versions for 1" bore liquid Helium dewars and larger versions for 2" bore cryostats or similar chambers are available.
The confocal objectives, specially developed for low-temperature and high-vacuum use, are diffraction limited and optimized for high-resolution imaging and/or spectroscopy measurements at visible and infrared wavelengths.

**Cryogen-free 4 K cryostat** (VeriCold Technologies)
The low-vibration pulse tube based cryostat from Vericold Technologies replaces any 4 K Helium bath cryostat where liquid Helium is neither available nor desired. The system has been especially adapted for very low vibration needs by eliminating moving parts in the cold head.
An initial cool down time of < 4 hours and a sample cool down time of < 2 hours from room temperature to 4 K allow fast cycle times maximizing your productivity.

**Vibration measurement technique**
The system vibrations are measured optically by means of confocal microscopy. Having an ideally flat, reflecting sample, the optical signal reaches a maximum when the sample surface lies in the focal plane.
By positioning the fiber at half maximum of the signal, a change in Z-position (e.g. vibrations) will change the intensity of the measured reflected light significantly, thus providing information on the system vibrations.




VeriCold Technologies

attocube systems
www.attocube.com

## RELATED PRODUCTS

| | |
|---|---|
| attoCFM II | highly stable confocal microscope for low temperatures |
| ANPxyz100/LT | high precision, piezo electric, inertial positioner for big loads |
| ANC150/3 | electronic controller |
| attostep | data acquisition software |
| cryostat | closed cycle cryostat (VeriCold T.) |



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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.

## 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.

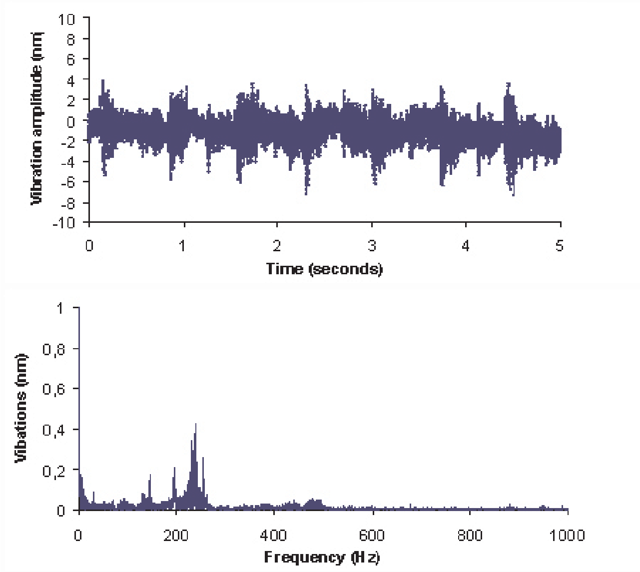


*Figure 1: Vibrations (top) and vibration spectrum (bottom) of the complete system (confocal microscope inside the cryostat) recorded at 4 K with the cooler on.*

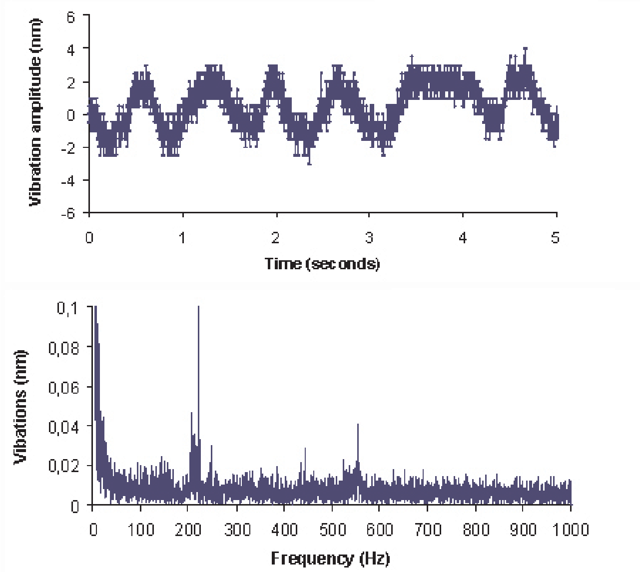


*Figure 2: Vibrations (top) and vibration spectrum (bottom) of the complete system (confocal microscope inside the cryostat) recorded at 4 K with the cooler off.*

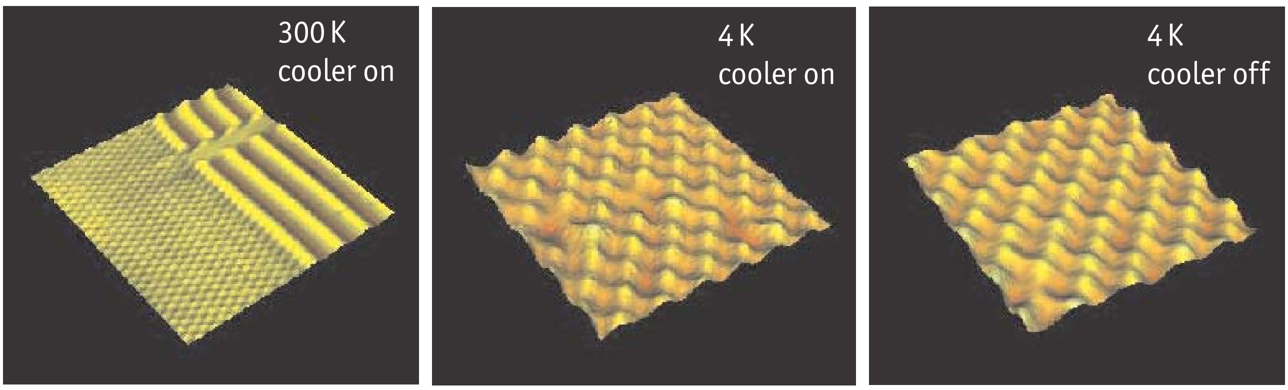


*Figure 3: (left) CFM image of a $SiO_2$ on Si sample recorded at 300 K with the cooler on. The grating has a period of 4 µm and the chess board a period of 2 µm. The step scan range is 30 x 30 µm. (middle) CFM image of a $SiO_2$ on Si chess board sample recorded at 4 K with the cooler on. The chess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