Preliminary Vibration Analyses on the PROXIMA 1 Beamline at SOLEIL

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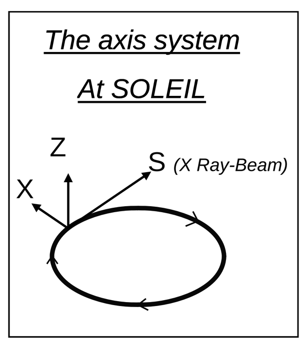
PROXIMA 1 is a beamline for macromolecular crystallography at the French national 3rd generation synchrotron source, SOLEIL (2.75GeV). Built on an in vacuum undulator source, its objective is to produce a tunable, highly collimated, intense and stable X-ray beam for the study of crystals with large unit cells. The beamline is currently operational, with 3 – 4 user visits per week of operation.

The beamline has its own system for measuring vibrations. Tri-axial accelerometers are permanently mounted on each optical component of the beamline, while other accelerometers are mobile and can be placed on different parts of the beamline for analysis. This system of vibration measurement complements other equipment, e.g. beam position monitors, X-ray cameras, etc.…

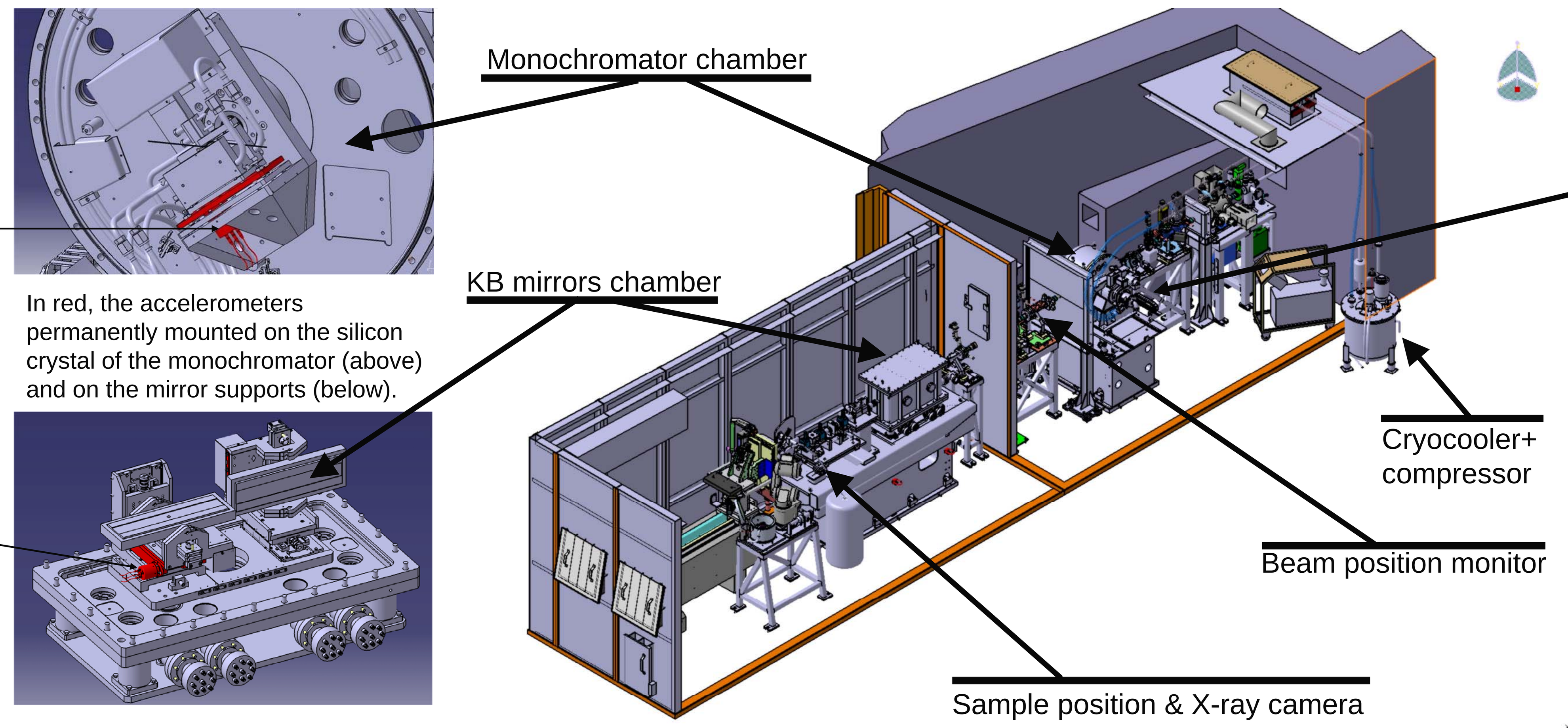


Due to a lack of place, most of the graphs of this poster show the spectra in the X direction only.

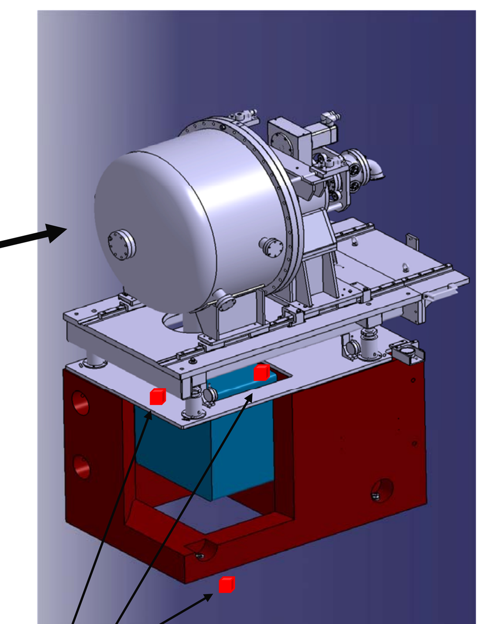
The accelerometer model mounted under the silicon crystal and the mirrors.

These accelerometers are mounted inside a box at atmospheric pressure. These boxes are then screwed on the support of the crystal or mirror.

This accelerometer model is very compact (17 × 17 × 17 mm), but because of its size, it is less efficient at lower frequencies (below a few Hz).

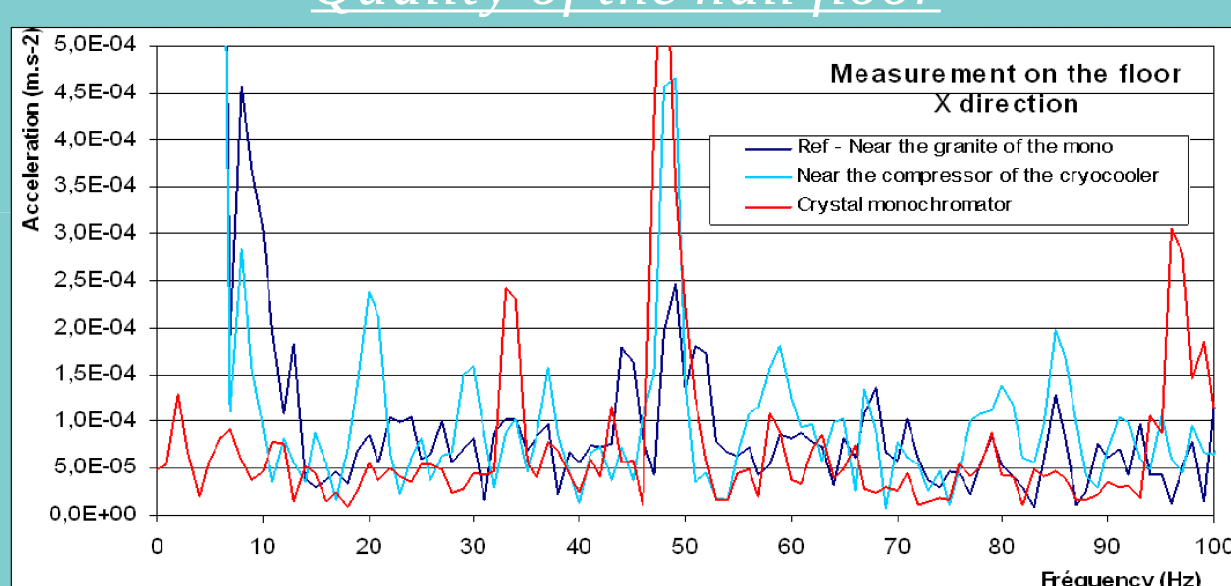


In red, the accelerometers permanently mounted on the silicon crystal of the monochromator (above) and on the mirror supports (below).




Fixation points of the accelerometers used for the reference (on the floor near the granite), on the top of the granite of the monochromator, and on the top of the ion pump.

Quality of the hall floor



The hall floor has been designed to minimize external vibrations, especially at very low frequencies. This graph shows the high quality of the floor.

We measured the vibrations on the floor near the granite (dark blue), the compressor of the cryocooler (cyan) and the monochromator crystal (red), simultaneously. Four meters separate the floor and cryocooler accelerometers. Vibrations coming from the cryocooler are strongly attenuated in general. But interestingly, the resonance near 48Hz is amplified on the monochromator suggesting that a mode of vibration has been excited.

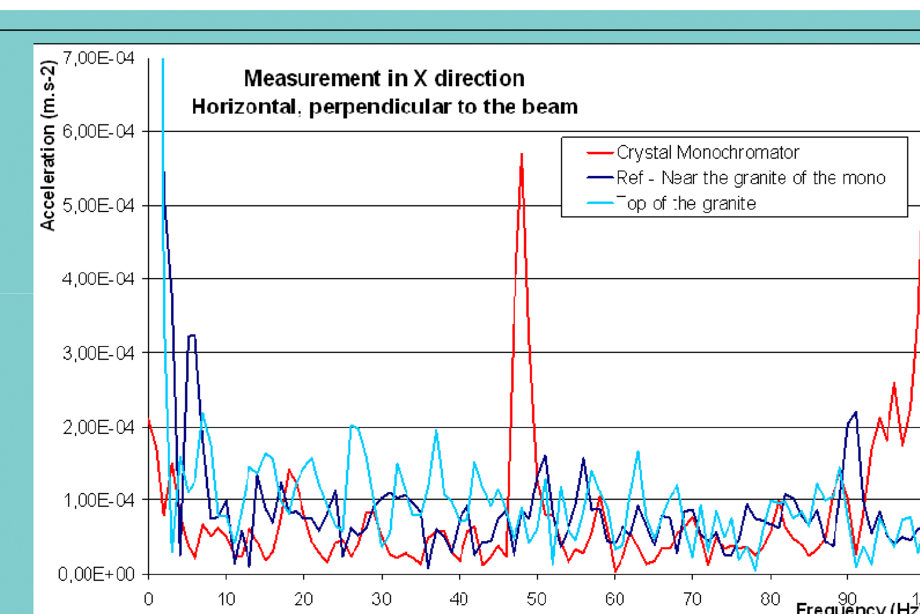
Vibrations of the Granite Blocks

On the Proxima 1 beamline, all the optical components & their supports are mounted on granite blocks.

The granite blocks of the monochromator and the experimental table are rigidly screwed on to aligned plates, which are in turn glued on to the hall floor. Thus the granite blocks behave as extensions of the floor, and this reduces the amplification of vibrations coming from the floor.

This graph shows the quality of the granite block of the monochromator. Differences between the floor and the top of the granite block are very small.

However, the vibrations measured around 48 Hz on the crystal of the monochromator are amplified (presumably) by another source of vibrations.

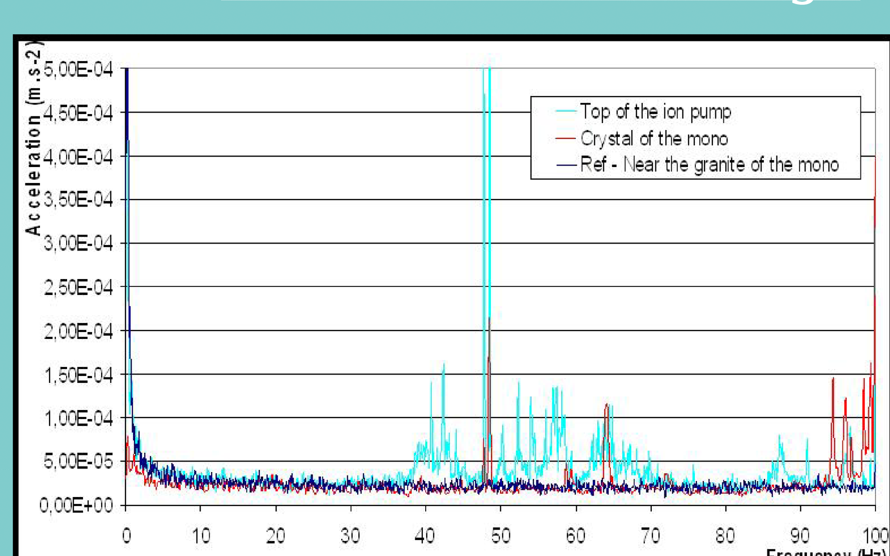


Monochromator design

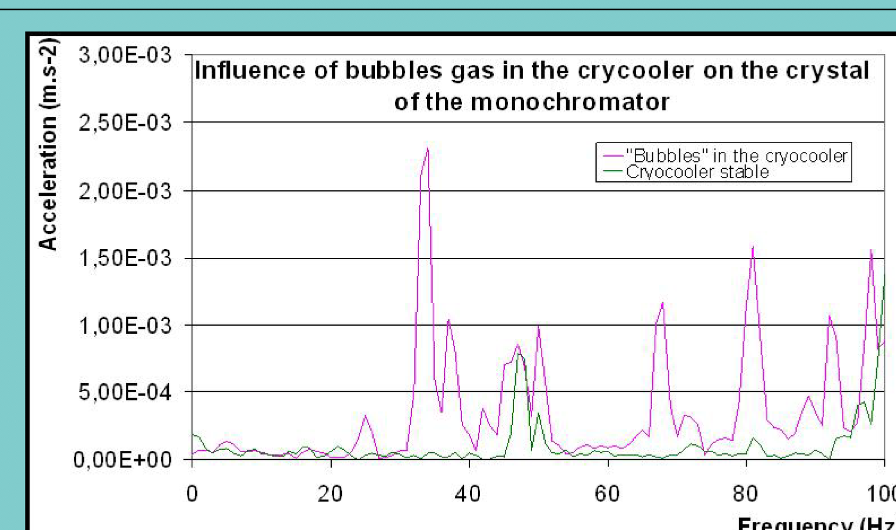
The structure of the monochromator absorbs much of the vibrations induced by external excitations.

The graph on the right shows that several modes of the ion pump under the monochromator chamber are excited between ~40 and ~90 Hz. The measurement made on the crystal shows that the structure of the monochromator is able to absorb a large part of theses vibrations.

The vibration mode around 48Hz measured on the ion pump is still present but attenuated on the crystal of the monochromator. This vibration mode is not measured on the floor.



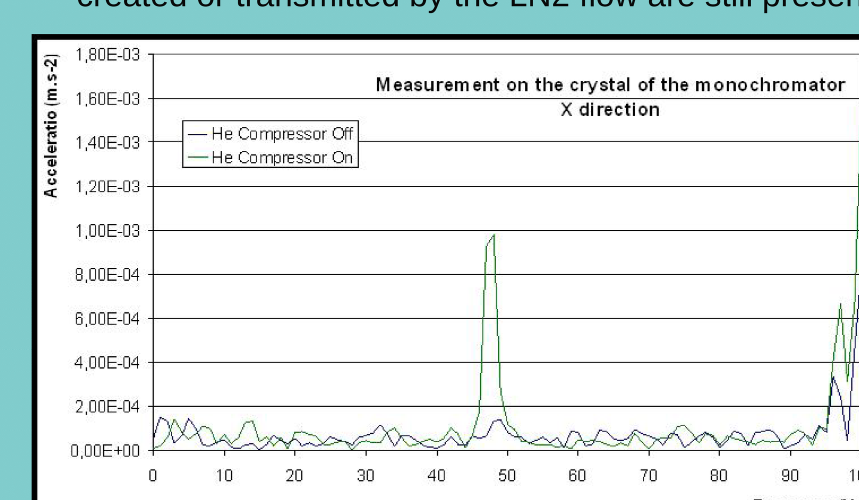
Influence of the Cryocooler



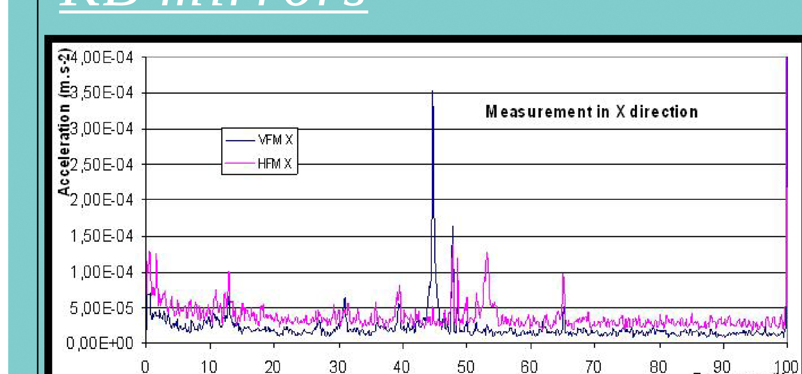
One source of vibrations on the silicon crystal was identified as the compressor. The graph below shows the consequences of switching off the compressor, which excites a strong vibration mode near 48Hz on the crystal of the monochromator. This excitation may travel through the floor or through the LN2 transfer lines. These perturbations were partially attenuated by isolating the compressor from the floor. Note that the circulation pump for LN2 continues to run even when the compressor is switched off. Thus any perturbations created or transmitted by the LN2 flow are still present.

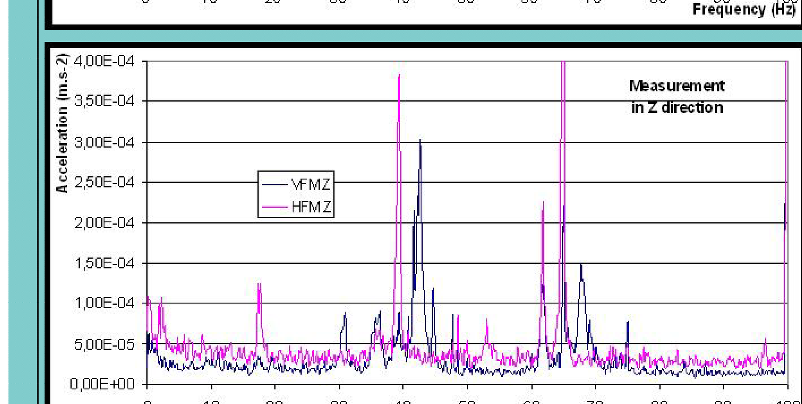
A large part of the vibrations measured on the monochromator comes from the cryocooler. The cryocooler circuit comprises of a helium compressor (Gifford McMahon cycle) which cools a cold head. A pump circulates the LN2 through heat exchangers clamped on to the silicon crystal via insulated transfer lines.

During a startup, a "gas bubble" inadvertently introduced into the LN2 circuit disturbed the liquid flow (see graph above). Such perturbations were immediately visible on the spectra and dampened down after 45s, but surprisingly they have little effect on the beam position just downstream of the monochromator. The possibility of an energy variation with the passage of a bubble has not yet been investigated.



KB mirrors



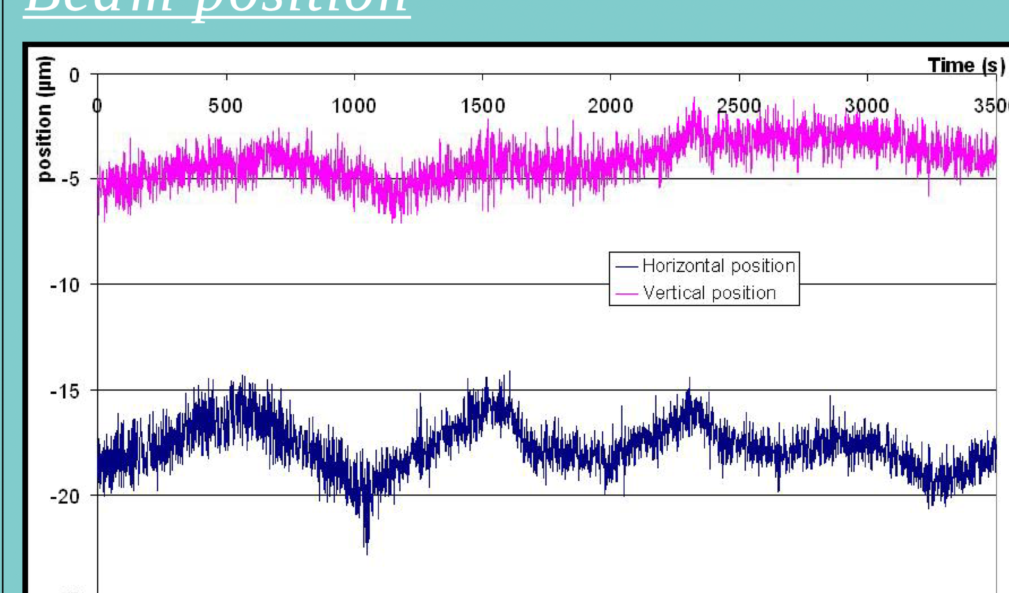


Like the crystal of the monochromator, the KB mirrors are equipped with accelerometers, which are mounted on the support of each mirror, as close to the mirror as possible (see above).

Preliminary measurements have just been made on the mirrors. The spectra on the left illustrate that each mirror has its own characteristic fingerprint of vibration. No vibration modes are visible under 30Hz in the horizontal direction (X), and only one harmonic is present on the HFM mirror in the vertical direction (Z).

Other measurements will be made in the future on the KB mirrors and on the experimental table to confirm the design and the quality of this ensemble.

Beam position



Beam centroid at sample position with KB mirrors

Finally, beam dimensions at the sample position can be varied by changing the focusing conditions – currently the minimum beam size available is 125 x 75 microns. The graph on the left shows the beam centroid position at the sample measured with a X-ray camera. The sampling rate is 120ms per point.

The stability of the focused beam is very good, only 2 – 3 microns in the both directions.

The "slow" beam movements are due to a response to the thermal feedback cycle in the cryocooling circuit of the monochromator. In principle, this variation could be controlled by a mechanical feedback system. Only this phenomenon of thermal drift is visible on the beam. The other perturbations coming from the compressor or the ion pump seem to have no direct effect on the beam position or intensity measured on the BPM.

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Conclusion

The approach developed for the PROXIMA 1 beamline of constructing a beamline from rigid blocks with minimum amplification of floor vibrations has resulted in the provision of a very stable beam with no vibrational resonances in the part of the spectra most dangerous for MX measurements (up to 30 Hz). The beam is "clean" enough to apply slow feedback corrections at very low frequencies, which should allow us to achieve positional stability of a tenth of a micron at the sample position during normal operating conditions.

We would like to thank BioXHIT for support, and the ESRF (Marc LESOURD, Lin ZHANG) for pioneering work in this area.

Future measurements… towards µ-crystallography on PROXIMA 2

There still remains much to do to fully characterize the PROXIMA 1 beamline. We plan to use all of the beam position monitors on the beamline (five along the beamline & two to be installed in the front end) in order to identify the different sources of vibrations which could have a direct effect on the beam position & intensity. This will include all of the elements in the experimental hutch, in particular the KB mirrors, the adjustable experimental table and the goniometer.

In the future, a continuous monitoring of the entire beamline will be installed with the accelerometers permanently mounted on all of the optical components as well as on other sensitive equipment.

This preliminary work on the PROXIMA 1 beamline will have an important impact for SOLEIL's second beamline for protein crystallography PROXIMA 2A, which will have a similar optical configuration to PROXIMA 1, except for the focused beam of 20 x 10µm. The experience gained with the vibration measurements on PROXIMA 1 will be applied to the design and construction of PROXIMA 2A.