MAX-lab, Lund University
Box 118
S-221 00 Lund
Phone: +46 46 222 98 72
Fax: +46 46 222 47 10

Visits and goods:
Ole Römersväg 1
S-223 63 Lund

Status Report on Stability Work 09, 2011

There is a lot of activity regarding stability for the MAX IV Laboratory. This report summarizes the present status, philosophies and policies defined. A condensed summary can be found in the last section of this document.

1 Intro

The work on stability is covering a very broad spectrum. The purpose of this report is to give an overview at a medium detailed level. The "Stability Group" at MAX IV – lab is only counting 3 people, whereof 2 are mainly working on alignment (which will not be treated in this report). Therefore we have involved external expertise at different levels.

The "Dynamics Group" is a working group organized by the ML4 project office. Several consultants with different expertise are engaged. Brian Jensen is representing MAX IV-lab in the group.

The Department of Construction Sciences at LTH is involved, formally mostly at an academic level. However it has turned out also to be very fruitful and valuable for the project at the practical level. The persons at the department are very good at keeping discussions and speculations in the Dynamics Group at a practical and realistic level.

The work of the Dynamics group is covering soil dynamics, civil engineering, defining sources (dynamic loads), analytical and Finite Element Method (FEM) calculations, etc. The goals are to estimate the effect of foreseen dynamic loads and find cost effective solutions to reduce the vibration level and its effect on equipment.

2 Risk Handling Policy

The project work for the construction of the buildings for MAX IV-lab is defined to be of the "collaborative" kind ("samverkande" in Swedish). This implies that all information is flowing freely between the customer (MAX) and the vendor/future landlord (ML4).

It has turned out that it is not cost effective to set up a fixed and formal set of vibration tolerances for the buildings which have to be guaranteed by ML4. Tolerances can be set conservatively so that the cost will be high. It might be physical impossible to fulfill very tight tolerances. The construction company might set a higher price in order to insure itself for future unforeseen remedies. There might be better cost effective solutions than by civil engineering.

2.1 Philosophy and Policy statement

When the Dynamics group, including the MAX IV Laboratory and the Department of Construction Sciences, is confident with a solution, this solution is accepted and taken for the construction. **The MAX IV Laboratory will accept the risk of not reaching the vibration tolerances in this case**. Our philosophy is that we have done as well as we can within a reasonable cost limit. If, in future, it is necessary to take extra measures to reduce the effect of vibrations, this cost will be covered by the MAX IV Laboratory. The extra measures might not involve Civil Engineering, but could be local and more cost effective isolation of sensitive components. Some of these possible extra measures are being investigated in the Dynamics group.

One implication of this policy is that solutions should not obstruct future extra remedies in order to handle vibrations. The Dynamics Group should be confident that the building performance is good in a cost effective manner.

3 Linac, SPF and FEL Areas

The vibration tolerances for the Linac, SPF and FEL areas are not as tight as for the 3GeV ring and beamlines. The calculations for the areas are finished and the conclusion is that the tolerance goals will be met. The building process is in progress. The preparation for the casting of the floor in the SPF – end of the building is almost finished. Casting will commence in mid-September 2011.

4 Vibration Sources

4.1 General Infrastructure Supply

ML4 has engaged external consultants to look for solutions to reduce vibrations from cooling water supply, ventilation etc. These consultants are also members of the Dynamics Group. Low frequency disturbances gives rise to larger translations, so one of the methods is to increase the frequency of pumps etc.

4.2 Own Cultural Vibration Sources

Internally at the MAX IV Laboratory there will be several projects on reducing disturbance from own equipment. One project, which has been initiated, is to isolate roughing pumps from the floor by designing a new pumping unit cart. The method is to put the pump on a concrete inertia block, mounted on springs.

The same method will be used for local cooling water supplies at beamlines, accelerator parts etc.

Walking people is an important source for vibrations. The Dynamics Group contains several people with experience in this area. There are standards for how to treat this question, but the standards are not giving the full picture. The dynamic content of walking and “forced speed” walking is being used as sources in the FEM calculations in order to foresee the effect.

4.3 Policy

The MAX IV Laboratory takes a **pragmatic approach** regarding vibrations in the operational phase. Using the seismometers, any unforeseen disturbance will be located and the source will be isolated or its effect will be sought reduced. It is not seen economical to be sure that everything has been thought of, analyzed and solved beforehand. Furthermore this approach will find equipment with degrading vibration performance due to wear or failure.

5 Dynamics of Soil and Buildings

5.1 Geotechnical Investigations

Several geotechnical investigations have been done. The dynamic and static properties of the soil are known to a reasonable good level from the top soil and down to the underlying shale/sandstone bedrock starting at 12-17m depth. In general two layers of till are identified. The lowest layer is relatively hard, which is good when it comes to vibrations. This layer starts at 2-10m depth in the area of the facility, the more to the east the shallower. The knowledge of this will be used when planning the stabilization of the layers below the floor for the rings and beamlines.

5.2 Vibration measurements

ML4 has acquired 5 seismometers from Güralp for the project. They are measuring vibrations in 3 directions up to 200Hz. They are wireless and can be placed anywhere in the area for the site. The plan is that the seismometers will be used inside the future facility for documentation and identification of the vibration levels and their sources.

Unfortunately there has been some technical problems due to the melting snow last wither, so there is not a continuous record of vibrations.

We have enough statistics, however, to know the background vibrations and the spectrum stemming from the highway. A camera is used simultaneously to make it possible to identify the reason for extraordinary “events” in the history.

Small cars are not giving any levels of importance. It is mainly heavy trucks which are observed as significant sources. There are indications that we get the highest levels of vibrations from traffic when heavy trucks on the highway are crossing the nearby bridge. The role of the bridge will be further investigated.

There are also indications that the trench in the landscape for the small road crossing over to the tunnel under the highway is acting as a barrier for vibrations. This is as expected. This indicates that the idea of digging a trench along the facility as a future remedy is a realistic solution. Furthermore it also points at some effect of the landscape modulations as designed by the architects will have some effect.

The traffic vibrations are mainly low frequency. The peaks are at the soils natural frequency, which is in the area of 7-10Hz. The effect of this is that the wavelengths are long and thus not so harmful to the performance of accelerators and beamlines.

5.3 Calculations

Several techniques are being used for the prediction of vibration levels and effects of dynamic loads on the facility. In order to get a realistic picture with a reasonable level of details, the Finite Element Model (FEM) becomes very large. In order reduce the model a combination of analytical calculations (for the surroundings) and FEM is used. Despite of this one calculation for a certain frequency takes several hours on a computer cluster LUNARC Lund University, Center for Scientific and Technical Computing.

5.3.1 3GeV Building

The calculations are well under way. The calculations are done with unit loads at different frequencies, so they can be assembled to dynamic loads, like walking. The principle of reciprocity makes it possible to calculate vibration levels at any place in the facility for a given load or calculate the vibration level at a certain place for distributed loads in the facility.

The calculations are not yet finished, but enough information is collected in order to describe the dynamic motions at the floor surface. This will be used in the work on refining the vibration tolerances for the 3GeV ring, taking into account the correlation of movements of magnets.

The calculations will be used to set tolerances on what dynamic loads should be allowed to be put on the floors and other places. This will give tolerances for future equipment.

The use of stabilized soil under the floors ensures high stiffness and thus even longer wavelengths for vibrations. This enhances the correlation of motions of equipment on the floors and in tunnels.

The varying shallowness of the stiff till in the geologic profile will be used in order to optimize the use of stabilized soil. It is probably not necessary to stabilize where the till is stiff, enabling deeper stabilized layers in areas where this till lies deeper.

5.3.2 Office building

The office building is not perfect as seen from the perspective of stability. Investigations are done in order to reduce the disturbances coming from walking people in the building. The construction will exhibit a rather low natural frequency, which in principle could couple to the surrounding soils and then excite vibrations in the experimental and accelerator areas.

Stiffening the “bridge” construction and piloting the foundation of the building down to the bedrock with different techniques are being investigated.

5.4 Discussion

So far there are no indications that we will get uncontrollable problems with vibrations in the facility. New and more qualified tolerances will be more relaxed when taking into account the larger correlation of low frequency movements.

The detailed level of knowledge on the geologic profile may enable a more cost effective distribution of the stabilization of soil.

The natural variation of soil properties is helping to disperse vibrations from the surroundings.

6 New Tolerances for 3GeV ring

As mentioned in previous sections the vibration tolerances will be reworked, using the knowledge gained from the FEM calculations. This work is in its startup phase.

More detailed knowledge on wavelengths of vibrations in the facility will make it possible to take into account the correlated motions of ring magnets. This will give a more qualified value for the amplification factor for electron beam oscillations. The current choice of a factor 10 for frequencies down to 5Hz is rather conservative.

The previous vibration tolerances are specified as integrated RMS translation for frequencies above 5Hz. Since the sensibility for the ring is dependent on wavelength, the form might be different. A de facto standard for vibration tolerances is the Vibration Criteria (VC) system. This standard specifies max velocities in a spectrum. Such a criterion is more flexible if the sensitivity is dependent on the frequency.

During the rework of tolerances, the integration time criterion of 1 second will be reconsidered. Also here the demands must be in line with what is really needed at the beamlines.

7 Beamline work

The new reworked tolerances for the 3GeV ring will also be the tolerances for the general beamline floor. The floor for beamlines and storage rings is common. The new tolerances will be used when writing specifications for beamline components etc.

A document exists with policy and recommendations for beamline design. This will be updated when new tolerances are ready.

7.1 NANOMAX

The NANOMAX beamline will have tighter tolerances than the general beamline at MAX IV-lab. The project organization and project work has not come so far yet when it comes to tolerances.

Also here the VC- standard for vibration tolerances seems realistic, since the mechanical construction has many similarities to STM and other types of equipment used for nanotechnology.

It is important to set a reasonable level, so more experience and calculations are needed here. We do not want either to overkill or underestimate the demands.

8 Stands and Girders for Accelerators

The work on stands and girders falls naturally in under the Stability Groups responsibility. The Stability Group is not only responsible for vibration management, but for alignment at the facility. Kinematic mechanisms are being designed for high precision alignment, which will also fulfill the stability criteria.

Stands and girders need to be designed in order not to degrade the performance of accelerator parts. The philosophy here is to have light and stiff constructions to ensure high natural frequency. When the system consisting of a magnet and stand has a much higher natural frequency than the disturbance on the floor it will just follow the floor without amplification of motions.

The general goal for stands and girders is to ensure natural frequencies higher than 55Hz. This will ensure that we do not get any problems with ringing at frequencies for pumps etc.

8.1 3GeV Ring

The stands for the 3GeV ring are designed and we have the first set for an achromat delivered. The concrete blocks are set up in a mockup area where several procedures and methods will be tested out before the real installation commences at the facility.

The design has already been tested when it comes to stability and adjustment screws. Some further refinements regarding kinematics are still going on.

8.2 1.5GeV Ring

The magnet blocks for the 1.5GeV ring are much heavier (10T) than the 3GeV blocks. This maybe calls for new designs, but certainly tests to ensure the adjustability and stability of stands and kinematics.

This work has not started yet, but is next in the pipeline when the 3GeV components are defined.

8.3 Linac

The Linac sections are mounted on aluminum beams. These beams have to be aligned, but also be stable. The vibration tolerances are not very tight, so a somewhat bold

design facilitating the alignment and reducing cost has been suggested. The design will be tested in the mockup area in “Södra Apparathallen”.

The philosophy is to align the aluminum beam with the Linac section supported only at the ends. After alignment, extra stiffening will be added, locking the assembly into place and increasing the natural frequency.

8.4 Bunch Compressors

A preliminary design for the girders for BC1 is finished. The wish to enable fine tuning (during the commissioning) of certain magnets in the bunch compressors has added to the complexity.

A setup for testing the solution is planned and is under construction. The method that is developed for these magnets might be used other places in the facility where needed.

Also here the emphasis is on stability and ease/resolution of adjustments.

9 Summary

Much work has been done and much work is to come.

A policy is defined for risk management regarding vibrations MAX IV-lab. Policies for beamline design are defined.

New tolerances are being defined, taking into account newly gained knowledge from FEM calculations. The tolerances will be more relaxed than the previous that were based on conservative assumptions. Policies and tolerances are updated accordingly.

The work on the buildings in the Dynamics Group is getting closer to its ending. The Linac tunnel is being built now and the planning for the storage ring and beamline buildings are well in progress.

The dynamic properties of the geology are well known and are being used in the design work and the production phase.

The tolerances for the Linac, SPF and FEL are met with the design of the tunnels.

No problems are foreseen in order to meet the new tolerances for the 3GeV ring and the rest of the facility. Traffic induced vibrations are low frequency. The long wavelengths at low frequencies increase the correlation of motions. Increased correlation reduces the sensitivity to vibrations for accelerator and beamline components, enabling higher tolerance.

Sources for internal vibrations are being identified and will be isolated if needed. This goes for both general supply of cooling water, air etc. and for more local activity, vacuum pumps local cooling systems etc.

Seismometers will be used in the operational phase for the facility in order to monitor the vibration levels and to identify emerging problems.

The tolerances for beamlines will be the same as for the 3GeV ring. These tolerances will be the base when writing specifications for what beamline components should withstand. Certain beamlines (NANOMAX for instance) will have their own special set of tolerances. Most of the work on this is to come.

Stands and girders for the accelerator components are designed by MAX IV-lab. This work is commenced. The current state is that work is done for the Linac stands and for the Bunch compressor 1. Currently, general design studies are done for the alignment and trimming kinematics for girders and magnets.