Beamline Stability Guidelines

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Revision history

Version	Date	Description	Sign
0.5	2013-05-24	Creation of document.	BNJ
0.9	2013-05-27	Minor update	BNJ
1.0	2013-06-11	Adopted as recommended practice	BPO

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This text contains information and guidelines on how to handle stability and vibration issues when designing and/or writing specifications on beamline hardware. Alignment is part of the stability work, so this is also included in the document.

Figures:

1 Background

The stability tolerances for the 3GeV ring are the most well-known and worked through set for the MAX IV facility. It is also estimated to be the toughest tolerances, generally speaking, for the facility. However, there will still be special cases, for example for Nano focusing, where the tolerances will be even tighter in limited areas.
The goal for the 3GeV ring is expected to be fulfilled also for the 3GeV and 1.5GeV beamline floors. The calculations behind the 3GeV tolerances are dealt with in the DDR (1), chapter 6. The result is a tolerance of **20-30nm** RMS integrated for all frequencies >5Hz.
This is assuming rather uncorrelated vibrations of the magnet blocks. It means we are setting a conservative tolerance since correlated vibrations of the ring magnets will reduce the sensitivity. That might not be the case generally for beamlines.
The vibration level at the MAX IV facility will be a combination of external and internal vibrations. Since the building is not there yet it is not possible to give a precise set of predicted vibration spectra.

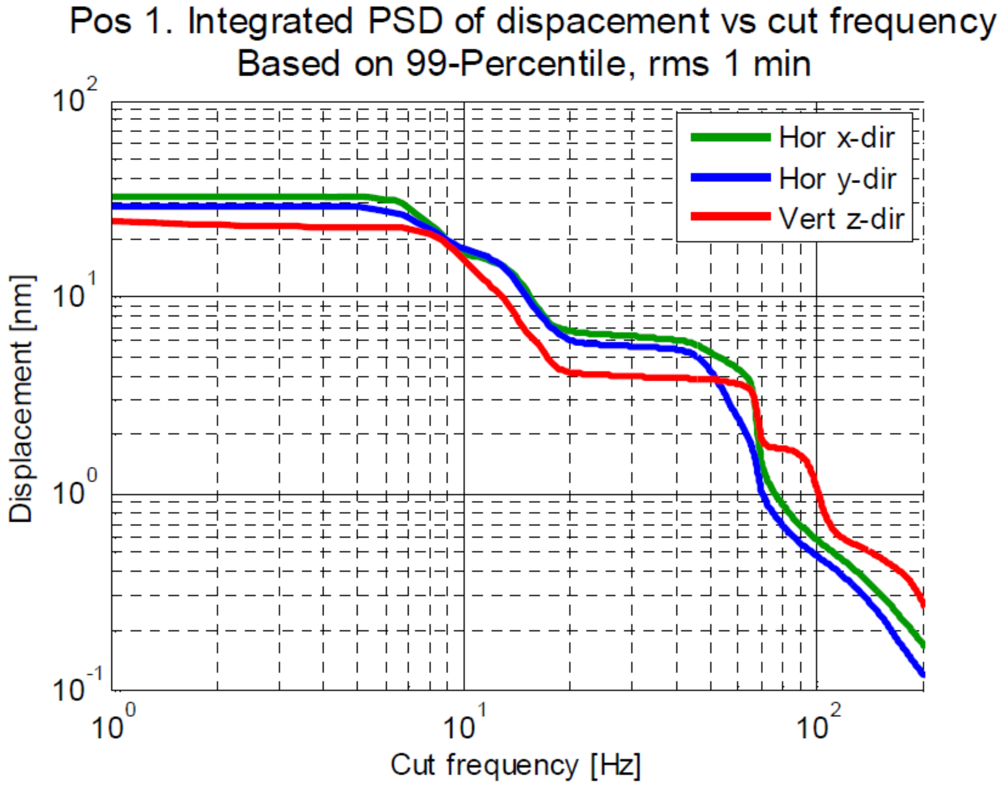

Figure 1 Rush hour vibration level at green field. (2)

The graph shows the level of integrated vibrations RMS for frequencies above the cut frequency. For example the integrated level of vertical vibrations at frequencies above 20Hz is 4nm.
The building will have a reducing effect on the external vibrations, especially in the horizontal direction. When looking at the spectrum from the MAX II floor it is clear that we are dominated by internal vibrations from rotating pumps, fans, compressors etc. Even the HV transformers which are showing a very clear 100Hz fingerprint are seen.

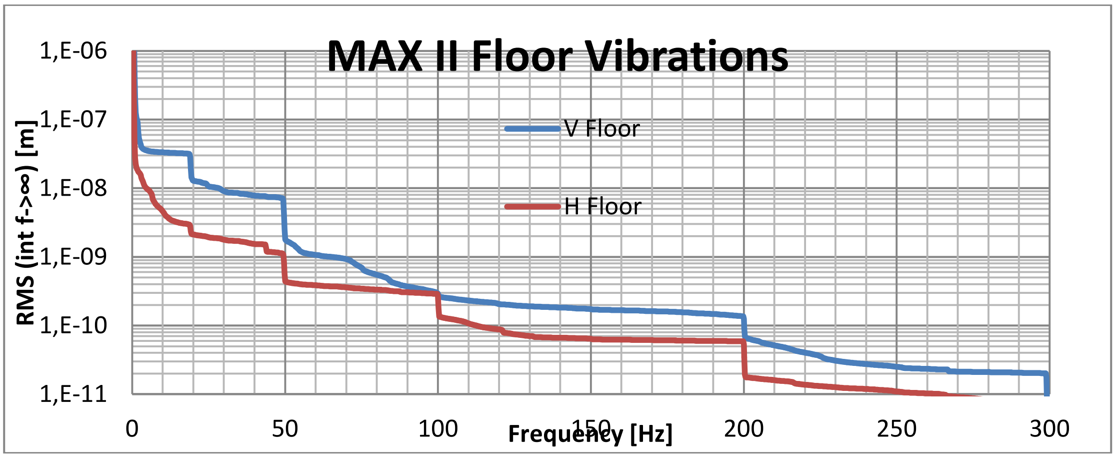

Figure 2 Floor vibration level measured in the center of MAX II.

From the figure it is evident that 50Hz and higher harmonics are present, but looking at the integrated levels, however it is clear that it is the low frequency parts that are giving the significant contributions to the overall level.
At the MAX IV facility there will be an ongoing work to ensure that internal sources of vibrations are identified and isolated. There will be continuous monitoring of the whole experimental floor and a set of policies for what can be brought to the lab will be specified and some solutions how to isolate vibrating equipment will be available.

2 Managing Vibrations with Beamline Design

For most beamlines it is not the absolute level of vibrations that is the main concern. The issue is that the floor motion works as an excitator of vibration modes of structures in the beamline. Also turbulent coolant flow could be an important source.
A first approach to minimize the vibrations of optical components is to make sure that mechanical structures do not have natural Eigen modes with similar frequencies as what is present in the surroundings.
Since all frequencies can be present, especially in the lower part of the spectrum, a more general approach is to design the structures so that they do not have any Eigen modes at low frequencies.
When a structure has a lowest natural frequency X there will be no amplification of the vibrations below this frequency. The structure is stiff and will just follow the floor vibrations.
Each beamline component needs to be analyzed. In order to be cost effective it is not feasible to state that all structures in a whole beamline should have high natural frequencies. An example is ion pumps that are mechanically isolated by bellows and separate supports.

2.1 Mechanical stability and alignment

It is recommended to state that all structures must have high natural frequency for Eigen modes that influence the resolution, spot sizes etc. Dependent on the case it should be possible to state that optical components and their mechanical structures should not have natural frequencies below 55Hz.
Structures, in this sense, are the combination of stands and mechanics from the floor all the way up to the optical component.
The impression is that many vendors do not have the stability issue in high priority when designing their standard solutions. When implementing motorized control of several degrees of freedom for an optical component, these motions are often stacked upon each other. Having such a philosophy, using modules, makes sense when it comes to reducing costs for design and construction. But most solutions are not optimal when it comes to stability.
Stacking the control of different degrees of freedom often has the results that the system has unnecessary large inertia and lever arms. Stable systems are **compact, light and stiff**.
Stiff systems are only as stiff as their connection to the surroundings. Connecting supports to the floor can be done at MAX IV using, for instance under grouting or a thin layer of glue or for instance tile fixation grout. Strong connections do not always imply stiff connections.

Statically undetermined systems will often impose internal strains to the construction. This is the reason that three legs are preferred for any system that has to be aligned.
The kinematic system for aligning components is a part of the stability defining structure. The quality of the alignment scheme is important for the performance of the component. Screws should be stiff in order to increase Eigen frequencies, but also to reduce problems with items "jumping" during adjustment due to static friction.
It is advantageous to spring-load lateral adjustment screws. Disc springs are used widely at MAX IV to push the aligned object back against the screws. This is also reducing the "jumping".
Adjustment screws should be placed so that they are close to the component and its fiducials. Also decoupling degrees of freedom as much as possible increases the quality of the alignment.

2.2 Disturbance from optics cooling and attached equipment

Concerning vibrations from the cooling of optics it is possible to be more specific regarding vibration tolerances. The effect on beamline performance can be calculated and thus it is possible to calculate the tolerance on angular fluctuations of the optics stemming from cooling and also other known equipment attached to the system. This could be pumps and other vibrating equipment that will be attached to the beamline in operation.
These calculations should be very similar to the calculations on effect from slope errors on optics. Specifying these component tolerances, which can be checked already at the site of the manufacturer, will help to reach the proper performance of the beamline.

3 Measurements and Acceptance Tests

MAX-lab has equipment for vibration measurements. It is possible to measure natural frequencies of structures and stands. It is also possible to measure amplification factors from floor to top of stands, chambers etc.
In order to measure small amplitudes at low frequencies it is necessary for the sensor to be rather large and heavy. It is thus not generally possible to measure on optical components or dummies, since the mass of the sensors will change the system under investigation. The limitations will be different from case to case.
Simpler equipment can be used to measure the angular fluctuations of optical components. This is using laser light and a position sensitive detector. The resolution is not fully investigated, but it should be in the area of 1µrad. If the laser light is being focused by the optical component there might be limitations. This problem can be solved using a mirror dummy with a small plane mirror attached.

4 Summary of Guidelines

General guidelines for design of beamline components:

- Beamline components should be designed to work in the conditions of our stability goal (20-30nm RMS for all frequencies > 5Hz).
- Eigen frequencies of systems that influence performance should be at least 55Hz (System means from floor to optical component, for instance).
- Systems should be Compact, Light and Stiff
- Integrated systems, not "Stacked Systems", are generally more stable
- Adjustment Screws /Kinematic Systems should be:
    - Stiff , "Oversized" and fine-threaded (M34x1 for vertical and spring loaded M24x1 for lateral adjustments are widely used at MAX IV)
    - Close to the Component to adjust
    - Decoupled with respect to degrees of freedom
    - Close to fiducials
    - Discussed with the Alignment Team
- Supports must have good, well-defined, mechanical contact to the floor
- 3 legs is a must if the system has to be well aligned, unstrained and well-defined
- MAX IV Lab can supply
    - Standard adjustments screws
    - Fiducials (laser tracker target nests)

- o Calculations (FEM, modal analysis)
- o Assistance with design and concepts
- o Assistance during CDR and DDR discussions with Vendors
- o Assistance with Acceptance Tests

5 References

1. Detailed Design Report on the MAX IV Facility. [Online] August 2010. https://www.maxlab.lu.se/node/1136.

2. **Rothschild, Karin.** *MaxLab IV – Mätning av vibrationer från omgivningen.* Oslo : NGI (Norges Geotekniske Institutt), 2009. 20091528-00-5-R..