SITE VIBRATION STUDY FOR THE SPARC PROJECT

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Abstract

The positioning stability of the SPARC laser transfer line requested a specific study for the ambient disturbance, mainly due to the vehicular and railroad traffic and to the machinery of the whole facility itself. Here are revised the measurement setup and the results obtained before the start of SPARC installation, as well as the efforts done to foresee its real operating conditions.

1. Introduction

The Project SPARC (Sorgente Pulsata e Amplificata di Radiazione Coerente) will be built at LNF. The aim of the project is to promote an R&D activity on the development of a coherent ultra-brilliant X-ray source.

Vibrational behaviour of particle accelerators' structures was a known issue [1-5]. Possible causes of vibration source are inherent to the location of the SPARC project and are here summarized. The National Frascati Labs of the INFN stands near the railroad stop of the Tor Vergata station and also the Roma-Frascati railroad passes near the Labs. The E. Fermi Street, on which heavy-duty tracks too are allowed to travel, skirts the Labs. Moreover, the Frascati town stands on a volcanic valley, which could result in telluric movements. The nearness of the LNF facility and of the SPARC facility itself could be a vibration source too.

The position stability requirements for the laser transfer line components are in the order of 10μm RMS in a frequency range starting from 5 Hz [6]. Position jitters for frequencies below this value are managed by a feedback system that fixes the spot position on the target.

This paper revises the measurement setup and results obtained to assess the environmental vibration noise in the area where the SPARC project will be installed.

2. Measurement Setup

The vibration measurement setup was chosen to satisfy the requirements in terms of resolution and low structures loading effects. A trade-off was made between the excellent resolution, but the limited frequency range and heaviness, of a velocimeter and the good sensitivity and the lightness of an accelerometer.

All this considered, two PCB J356B18 triaxial accelerometers, with a sensitivity of 1000 mV/g in the 0.5-3000 Hz frequency range (± 5%), were used for measurements of structures and ground vibration in several places around the Frascati Labs. The probes were ICP® (Integrated Circuit Piezoelectric), so their output needed to be coupled in AC, introducing a high-pass filter from the DAQ board with a cutting frequency of 3.5 Hz, still enough for our requirements.

A National Instruments PCI 4474 DAQ board, with four channels synchronous acquisition, 24-bit resolution was used to perform signal processing. The board also featured anti-aliasing low-pass filters and a sampling rate of 102.4 kS/s.

The NI LabView®, was used to perform data analysis.

The measurement setup was calibrated with the BRUEL & KJAER 4809 exciter, and the output signal from the sensors was checked with the TEKTRONIX TDS 3054 digital phosphor oscilloscope. They agreed at the 5% level.

Table 1 below summarizes the setup features.

Table 1: Measurement Setup Specifications

Feature	***Value***
A Range [g]	±5
Threshold [μg_{RMS}]	*50*
Sensitivity [mV/g]	*1000*
Res. Freq. [kHz]	*≥20*
Freq. Response [Hz]	*0.5…3000*
Weight [gr]	*25*
Daq Resolution [bit]	*24*
Daq Sampling Rate [kS/s]	*102.4*
Daq Dynamic Range [dB]	*110*
Input Voltage [V]	*±10*

With these setup specifications the minimum displacement RMS we were able to detect at different frequencies is summarized in Table 2.

Table 2: Minimum detectable displacement vs frequency

Frequency [Hz]	***Minimum [μm]***
3.5	*1*
5	*0.5*
50	*$5E^{-3}$ (5nm)*
100	*$1E^{-3}$ (1nm)*
1000	*$1E^{-5}$ (10pm)*

For structures measurements the accelerometer was stud mounted on a “hard-coated” aluminium mounting base, glued on the structures by means of cyanoacrylate adhesive.

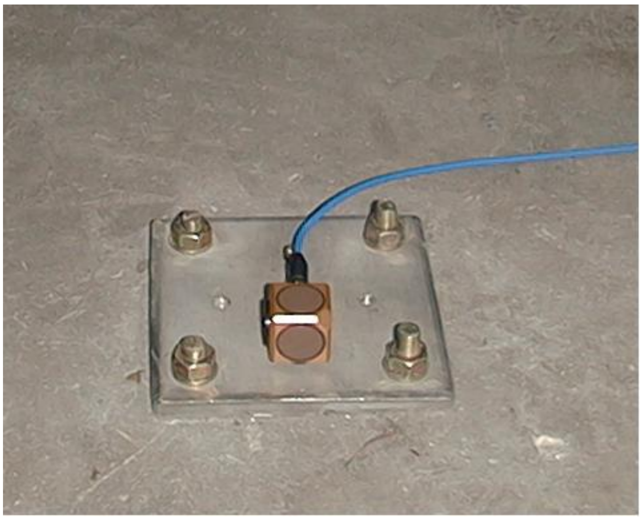

Figure 1: Stainless steel plate used for stud mounting the accelerometers

For ground measurements a 100x100x8 mm stainless steel plate (Figure 1) with stud mounting housing for the accelerometers was used as a support. The plate, fastened on the ground by means of four screw anchors, acts as a low-pass filter, whose cutting frequency was estimated with a FEM modal analysis performed with Ansys at 4920 Hz level, not affecting the measurements though. Figure 2 below depicts the analysis results.

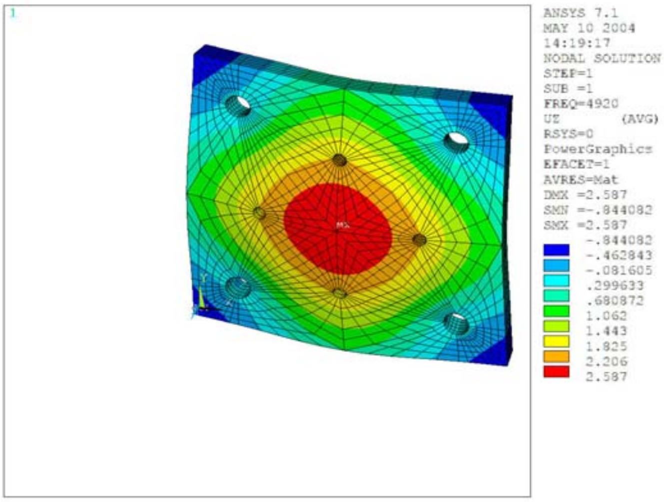

Figure 2: Plate-support low-pass filter first order frequency and modal shape

3. Measurement Results

Measurements were made in several places trying to reproduce SPARC operating conditions:

1. the empty bunker that will house the SPARK project, aiming to record the environmental vibration noise;
2. a quadrupole of one of the near Daϕne main rings and the ground of Daϕne's modulators' room, to represent surroundings and structures like SPARC ones;
3. the ground and a 75 kW pump's motor of the near Daϕne pump station, as a "worst case".

Moreover measurements were made triggering the arrival and departure of the train to/from the Tor Vergata station.

Figure 3 below depicts SPARC arrangement in section, showing the location of the modulators and of the facility hall.

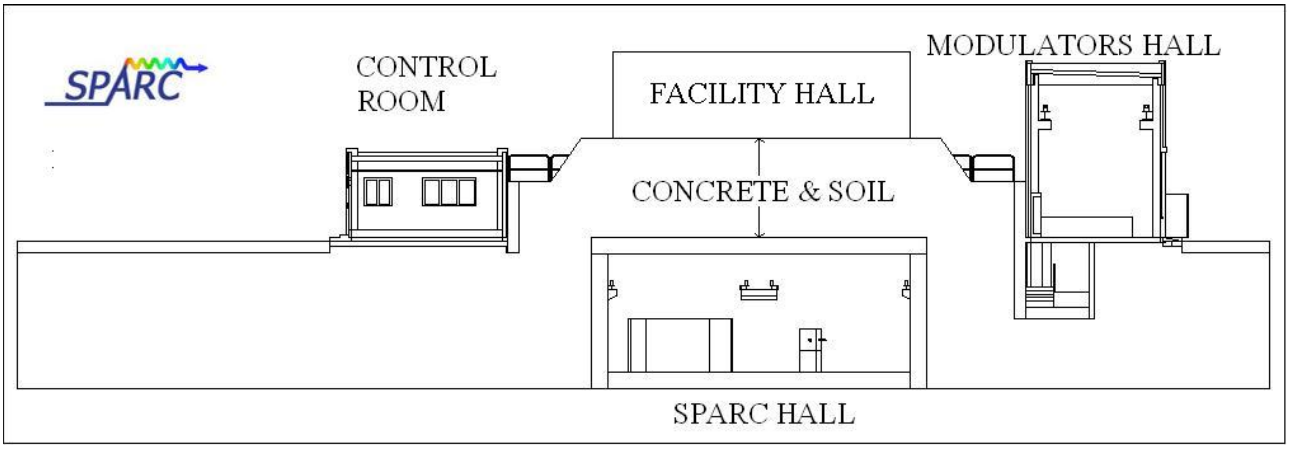

Figure 3: SPARC Arrangement. Section

Because of the very low level of the collected data for ground motion all over the Labs, it is assumed that vibration level is below the measurement setup minimum detectable displacement value (with an uncertainty within the 5% level) and then below SPARC requirements.
Nevertheless, a brief description and some comments on the measurements are presented next.

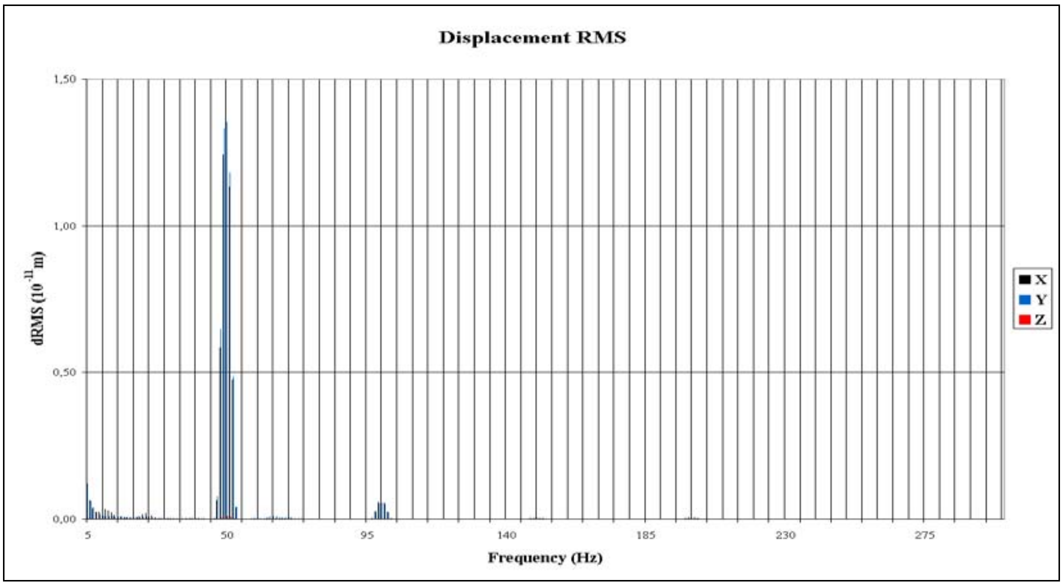

Figure 4: Ground vibration in the Dafne Hall with cooling water circulating

Figure 4 depicts the measurement results in the Daφne Hall. The measurements resulted from averaging 16 samples, with the z direction perpendicular to the floor, x like the positron beam trajectory and y in the transverse direction. Measurements on a large quadrupole showed similar amplitude behaviour, as depicted in Figure 5 below, either with cooling water circulating or not. The 10 Hz peak was a known issue in literature but thought not to be a problem because of his very low amplitude.

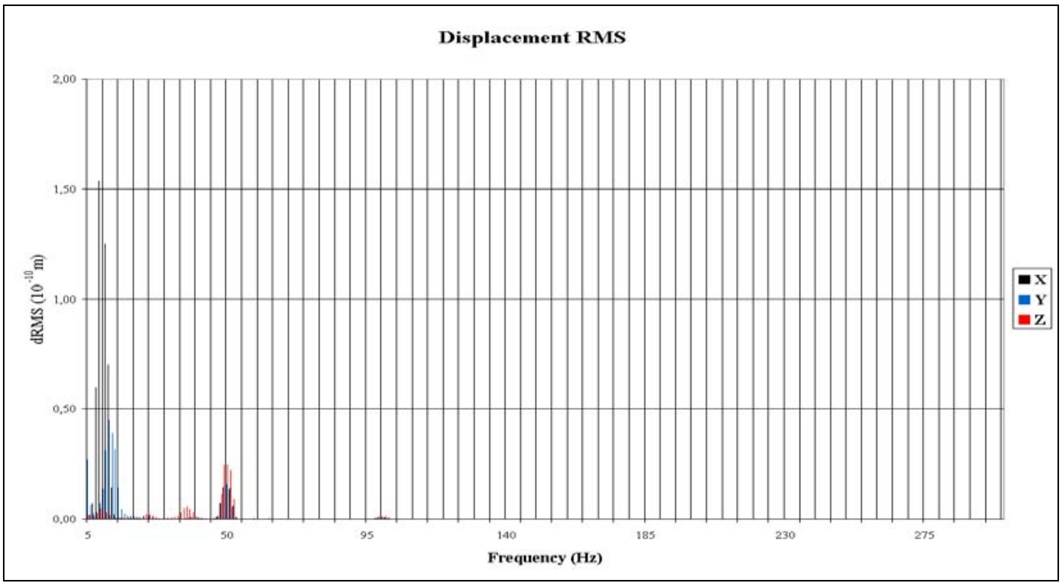

Figure 5: Dafne Quad Vibration with cooling water turned on

Measurements on the pump's motor were made on the external bearing housing. The motor was last maintained two years before (2002). The collected data revealed a low level, but this time within the probes' sensitivity reliable at the 5% level. Figure 6 below depicts the vibration level recorded, where the z-axis is perpendicular to the floor, x is the direction of the motor axis and y is the transverse direction. Peaks are shown at 50 Hz (the motor revolution frequency is 2900 rpm) and at 150 Hz. Vibration level is in the order of $10^{-6} \div 10^{-7}$ m and not over 1.3 μm all over the spectrum.
Measurements were made on other pumps, showing lower levels.
The lower vibration level recorded on the ground in the pump station should be justified by the adoption of vibration absorbers, installed on the motor's support.

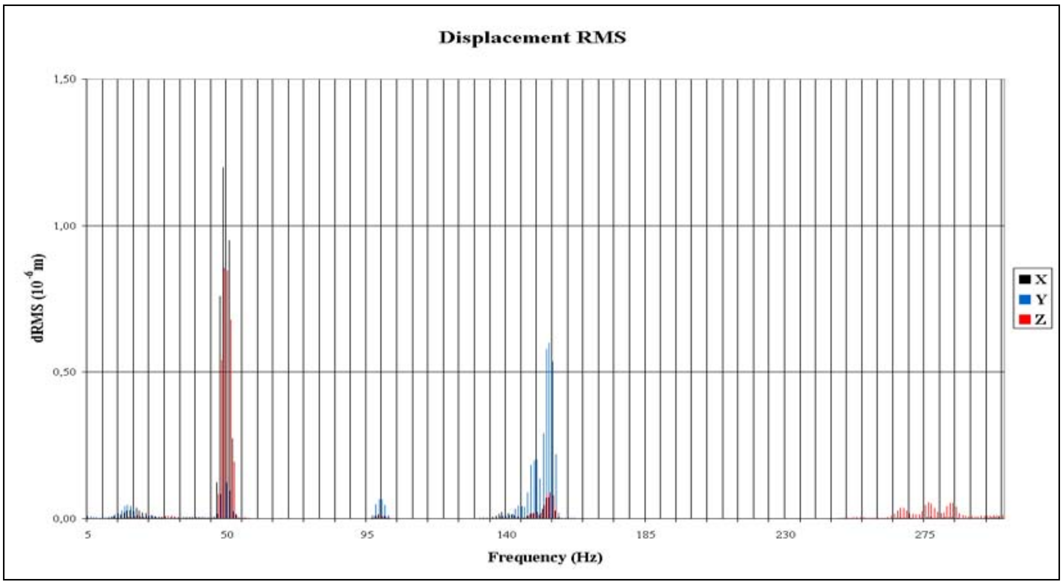

Figure 6: Vibration of a pump's motor in the Dafne pump station

4. Conclusions

At the end of the data acquisition campaign the vibration level was found to be lower than the positioning stability requirements for the optical components of the SPARC project, at a point that vibration at the LNF was thought to be not a concern. Checks will be performed at the time of the completion of the SPARC installation to verify the vibration stability of the facility's supports and structures.

5. References

[1] B. Baklakov et al., "Investigation of seismic vibrations and relative displacements of linear collider VLEPP elements," PAC 1991.
[2] V.V. Parkhomchuk et al., "Measurements of the ground motion and SSC dipole vibrations," SSCL-624, June 1993.
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[4] L. Zhang, "Vibration at the ESRF," 19 September 1996.
[5] L. Zhang, "Ground Vibration at the Site of ESRF and Comparison with some other Places," 22nd Advanced ICFA Beam Dynamics Workshop on Ground Motion in Future Accelerators, 6-9 November 2000, Stanford.
[6] A. Ghigo, Private communication.