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Infrastructure works for the mitigation of environmental noises during VIRGO commissioning and plans until VSR2

I.Fiori – EGO

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VIRGO * A joint CNRS-INFN Project
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Introduction

This document summarizes major works performed during Virgo commissioning (from September 2006 to October 2008) in order to reduce observed ITF noise driven by environmental sources. For each work a brief description is given of (1) motivation, (2) noise mitigation achieved, (3) limitations/side effects (if present) and (4) residual noise. For each work are provided links to reference documents. At the end a list is made of the mitigation works planned before VSR2.

List of Acronyms:

CB = Central Building
LL = Laser Laboratory
DL = Detection Laboratory
EIB = External Injection Bench
LB = Laser Bench
EDB = External Detection Bench
WEB = West External Bench
NEB = North External Bench
VSR1, VSR2 = Virgo Science Run 1 (May to Oct. 2007) and 2 (planned to start June 2009)
INJ = injection
DET = detection
PR = power recycling

1. Acoustic enclosures LL benches (27-29 Sept. 2006)

Motivation: Detected large coupling of acoustic and seismic noise from LL (racks cooling fans) to dark fringe, likely via input beam jitter [1].

Implementation: Enclosures made of high-density material around EIB and LB [2].

Result: Acoustic noise at benches and seismic vibration of both benches reduced a factor 3 to 5 above 100Hz. Indication that acoustic noise is largely coupled to bench seismic noise [3].

Side effects: Some turbulent air fluxes cause increase of beam jitter below 10Hz to mHz. The situation then improved with installation of silenced openings in the enclosures [3]. But problems with air fluxes reappear from time to time. Tight space left around benches.

Residual noise: Isolation not effective below 100Hz. Residual noise from racks cooling fans starting from 30Hz. No good isolation of LL from experimental hall especially on INJ-tower side. Evidence of residual noise from racks in central hall (around INJ tower). See other actions in Section 9.

2. Acoustic enclosures around terminal benches (3-5 May 2007)

Motivation: Acoustic and seismic noise at benches excited optics mounts and coupled to dark fringe via diffused light. Peaks at the resonant frequency of the mounts were seen in sensitivity, identified with tapping tests [4].

Implementation: Enclosures made of high-density material around WEB and NEB [5].

Result: Acoustic noise and seismic motion of bench reduced by roughly: a factor 2 at 50Hz, a factor 4 at 100Hz, a factor 10-15 at 1kHz [6]. Also see concomitant mitigation action of mounts stiffening, described in Section 4.

Residual noise: No or poor isolation below 100Hz. Projection of acoustic noise above 100Hz is now slightly below VIRGO design. No measure below 100Hz [6].

3. Acoustic enclosure around detection bench (4-7 April 2007)

Motivation: as for Section 2, although noise was not limiting sensitivity.

Implementation: EDB was displaced and detached from DET tower. An acoustic enclosure made of same type (as 1 and 2) material was built around EDB to isolate it from experimental hall, the DET tower and DET racks [7].

Result: Measured a reduction of acoustic noise and bench seismic motion similar to that measured for terminal benches enclosures [8].

Residual noise: No or poor isolation below 50-100Hz. The projected noise associated to bench vibration is below VIRGO design [8]. No measurement below 50Hz. No projection done for acoustically coupling noise (difficult to excite locally only the bench).

4. Stiffening of optical mounts on external benches

This item is not strictly speaking an infrastructure work, but it is linked to mitigation actions of Sections 1, 2 and 3.
This was done for terminal benches (Feb. 2007) and BMS mounts on EIB (Jan. 2008).

Motivation: Peaks (100-300Hz) in sensitivity were associated to mechanical modes frequency of optics mounts. Critical optical mounts were identified by tapping tests and (only in case of BMS) by noise injections on BMS actuators. The seismic motion of mounts at resonances is excited by acoustic noise and seismic motion of benches. They coupled noise via diffused light in the case of NEB and WEB [4] and via beam jitter in the case of EIB [9].

Implementation: Replacing critical optical mounts with more rigid ones [9].

Result: NEB and WEB peaks disappeared from sensitivity [6]. New BMS mounts have resonances above ≈600Hz. Input beam jitter noise largely reduced above 50Hz [9].

Residual noise: For Terminal benches acoustic noise projections above 100Hz indicated noise from acoustically induced bench and optics motion is now slightly below VIRGO design [6]. For EIB we suspect some residual peaks between 150 and 300 Hz from beam jitter on EIB, which show up in February 2009 data.

5. DAQ room acoustic isolation (January 30-31, 2008)

Motivation: Acoustic noise from electronic racks in DAQ room, coupled to dark fringe via (at least) the DET Brewster window [10]. Evidence is that Brewster vibration noise and dark fringe noise increase if DAQ room windows are opened [12].

Implementation: Installation of acoustic isolation panels at DAQ room windows. Replacement of DAQ room back door with acoustically isolated one [11,14].

Result: Acoustic noise in hall, just outside of DAQ room reduces approximately a factor 2 above 100Hz. Small, but significant, seismic noise reduction at Det. Brewster (few lines and peaks between 100 and 150Hz) [12].

Residual noise: Apparently none, after the removal of Detection Brewster window [10].

6. DAQ room new air conditioning (February 2008)

Motivation: Peaks in sensitivity (80-120Hz) likely coupling via Detection Brewster [13].

Implementation: The HVAC machine was replaced with a new one. The new machine was moved outside the DAQ room. The air flux remained roughly the same, around 5000 m^3/hour. Fan and engines were put on rubber isolating layers. Air circulation was improved adopting inlet and outlet ducts and collectors [14].

Results: About 5 times reduction of acoustic and seismic noise of floor inside DAQ room, between 30 and 20Hz. Measured a significant reduction of vibrations of EDB at 50-150Hz (acoustic noise also reduced, but less) [15].

Residual noise: The new machine produces some residual seismic and acoustic noise at EDB between 50-80Hz [15]. Seismic lines likely associated to HVAC fan/engine are seen on CB hall floor. Suspect of some small noise coupling to dark fringe in February 2009 data.

7. Water pump 1 (Jan. 2008)

Motivation: Intense peaks in dark fringe at pump rotation frequency (46Hz) and harmonics, affected VSR1 data. Significant (10 times above background) acoustic and seismic noise peaks detected inside and around DL. Coupling to VSR1 dark fringe seemed to occur mainly via DET Brewster [16].

Implementation: This is the recycling pump of chilled water to the CB hall HVAC. A soft rubber bellow was added downstream of the pump.

Results: No significant reduction of seismic and acoustic emissions (about a factor two). Dark fringe coupling reduced after DET Brewster removal [17].

Residual noise: A residual noise effect in dark fringe is evidenced in February 2009 data.

8. Turbo pump DET bellow (March 19, 2008)

Motivation: The turbo molecular pump at the detection tower was found (before VSR1) to produce large noise in dark fringe (extended from 100 Hz up to 2-3kHz). Most of this noise was coupling through seismic vibrations of the DET Brewster. Until the DET Brewster was in place this pump could be switched off and replaced with a smaller, less noisy one, dedicated to the vacuum volume of the DET tower alone. After the substitution of the DET Brewster with the Cryogenic-trap, the necessity of a larger pumping capacity (the DET tower vacuum being no more separated from the rest of the interferometer) required the standard turbo-pump to be put back in operation. The pump produced still a significant residual noise in dark fringe between 80 and 200Hz [18].

Implementation: Instead being rigidly hanged to the tower vessel, as all other turbo-pumps still are, the DET turbo pump has been hanged to a rigid support (placed on a rubber isolating layer and attached to the platform) and it is connected to the tower through a soft bellow steel tube.

Results: Seismic noise to the tower is filtered significantly (factor 3 to 20) above 100Hz (eLog 22196). The noise in dark fringe disappeared [18].

Residual noise: Suspect residual seismic noise coupling through the Detection output window or the tower walls, possibly via back scattering (see [18]). Some evidence also in February 2009 data).

9. EE room (summer 2008)

Motivation: cooling fans of racks inside the LL were seen in dark fringe, lines around 200 and 400Hz [19]. Shaking tests gave indication that the interferometer operation is sensitive to intense mechanical vibrations of the last section of the MC tube [20].

Implementation: Most racks (almost all racks carrying cooling fans) have been displaced from inside LL to EE-room, about 5m away. EE-room is separated by LL by two walls (MC tube goes between them): one is the original wall made of concrete and, for a small part, of light panels; the second wall has been added and it is made of acoustically isolation material. One acoustic isolation door separates EE-room from central hall. At the same time the laser chiller has been moved from underneath the MC tube to a separate room with concrete walls. This implementation is detailed in reference [21].
A cooling system based on fan-coils has been adopted. Preliminary tests showed this to produce very little noise, not detectable inside LL [22].

Results: Measured good acoustic isolation of EE-room from LL benches (inside acoustic enclosures): factor 100 at 100Hz, factor 1000 at 1kHz [14]. Acoustic noise in LL reduced above few hundred Hz. No evidence of coupling of noise from EE-room racks to dark fringe (February 2009 data).

Side effects: possible problems with over-heating of some laser electronic components related to not good air circulation in room.

Residual noise: Residual acoustic and seismic noise of EIB and LB above one hundred Hz is associated to the Master Laser Power Supply rack which could not be displaced. No evidence of residual noise in dark fringe from cooling fans left inside LL.

10. Slow down of fans of CB hall HVAC (October 2008)

Motivation: Low frequency acoustic and seismic noise produced by the air conditioning machines increases motion of external benches at 10-20Hz (legs resonances) which couples back-scattered light in the interferometer. Up-conversion peaks are seen in dark fringe. After VSR1 this noise was limiting VIRGO sensitivity below 100Hz [23]. The noise coupling was significantly reduced by decreasing the amount of scattered light on the benches through clean up actions (see [24]).

Implementation: Reduced rotation speed of CB hall air conditioning fans by 25% (from 11Hz to 8Hz). Instead the air flux into and out of the hall did not change (≈23000 m^3/hour), because of the opening of one air valve. The two engines (one of the inlet fan, and one of the out-let fan) were replaced with slower ones (24Hz to 12Hz) and the fans speed regulated by changing pulleys on engines and fans [25].

Results: Measured a reduced of seismic and acoustic noise RMS noise at EDB by about a factor 2 in ≈5-40Hz band for seismic, ≈0-40Hz band for acoustic.

Side-effect: Added one seismic peak at 12Hz associated to the new engines. This is potentially disturbing since it matches one main resonance of the EDB bench legs and it is thus amplified on EDB.

Residual noise: In central hall the seismic noise is still a factor 1.5 above background with AC off, acoustic noise is a factor 2 above background noise (RMS noise in same bands quoted above). In the LL the noise from this machine reduced at the level of background noise. Evidence of some residual noise coupling to dark fringe in February 2009 data [26].

11. New electrical net (summer 2008)

The power line distribution (IPS and UPS) and the electrical grounding in central building have been renewed. The work was mainly motivated by safety (cure not-CEE regulation complaints) and by having a more rational and thus easier to maintain electrical net. Some improvements have been made that could have ultimately reduce or prevent EM disturbances: (i) light circuits have been checked for inductive loops and cured, (ii) power cables paths are now further away from suspended mirrors and un-necessary cable loops around towers have been eliminated, (iii) the grounding connection of single racks has been checked and improved [27]. In this contest, magnetic emissions from the main electrical panels, some located at less than ~5m from suspended mirrors, have been measured and found to drop to negligible level at 1m distance.

Works planned or being finalized for VSR2

Slow down of fans of WE HVAC:
It is motivated by the fact that coupling of back-scattered light at WEB is still large and a factor at least two reduction of the noise in dark fringe is needed [26].
Reduction of air fans speed and of air fluxes at WE. We expect a reduction of acoustic noise, and consequent reduced excitation of the WEB legs first mode.

Spring dampers under CB HVAC fans and engines:
It is motivated by the fact that we observe ([26] and eLog 22612) some noise reduction in dark fringe associated to the switch off of the CB hall HVAC.
Insertion of an isolation stage (springs, with ≈5Hz cut-off frequency) underneath fans and engines. We expect to reduce seismic noise on ground above ≈10Hz. Expect to gain a factor of two or three on the 12Hz peak. Side effect might be the enhancement of seismic excitation in correspondence of the spring resonance. The springs can be blocked and bypassed in case of malfunctioning.

Bellows on PR and INJ turbo pumps:
The seismic noise from these pumps is found responsible of some residual noise in dark fringe (eLog 22182) and also to have large effect on frequency noise (eLog 22116). Insertion of bellows (same described in Section 8) on two turbo pumps (PR and INJ) [27].

Replacement/removal of water pump 1:
This action has not been yet finalized. This pump is found to affect dark fringe (see Section 7) and it is presently kept off, however it might need to be operated during hot summer months. Three options are being evaluated: (1) The pump might be removed. The optimization of water fluxes sharing among other utilities and the removal of the pump itself that causes a pressure drop, might assure a sufficient water provision to CB hall machine. (2) This pump is old. Replacing it with a new, slower one, might help. The result is uncertain. (3) Increase the pumping power of the main pump located in the Tech. Building. This would require rearranging water fluxes to other utilities. There are concerns about the capability of the pipes to stand increased water pressure. Option (1) is preferred. Two flux meters are to be installed upstream and downstream of this pump to determine the pressure drop caused by the pump itself, when not operational.

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