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The system to mitigate sediment deposition in the upper surface of the Digital Optical Module in KM3NeT: Part II

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Abstract

The experiments ANTARES and NEMO have shown the accumulation of a thin layer of material in the upper surface of the Optical Modules (OMs). The proposed vibration system to remove this sedimentation from the DOMs surface was tested successfully in a water tank at atmospheric pressure (see [2]). In this note we describe the behaviour of the system in an hyperbaric chamber at a pressure of 360 bar, close to the operating conditions in the sea. We find that the effect of the pressure does not significantly affect the vibration intensity in the glass sphere.

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1 INTRODUCTION

In the previous note INFN-16-09/GE [2] we have shown that a couple of vibrating motors installed inside the Digital Optical Modules of the KM3NeT experiment (DOM) [1] are effective to remove the deposition of a thin layer of material (sedimentation and biofouling) which seems to affect the upper part of the glass spheres after several months of operation at sea. In this system the vibrations are transferred to the glass by two motors. The test runs demonstrated that a 2 Watt - 2 minutes activation of the motors is enough to remove the deposit. In this test the DOM was located inside a water tank at sea level pressure. In these conditions the amplitude of the vibrations transmitted to the sphere were recorded via a tri-axis accelerometer from Dimension Engineering, model DE-ACCM3D and found in the 0.4-0.6 G (G=9.8 m/s^2) range for each axis.
In this report we investigate possible effects on the vibration transmission due to the relevant external pressure (350 atm at 3500 m depth) during operation. In particular we focus on two effects:

1. The deep sea pressure shrinks the volume of the glass sphere. Being the vibrating motors housed on a special metallic support directly glued to the sphere's inner surface, the volume reduction can affect the stability of this matching. In particular we may expect that hard glues like epoxy adhesive will better propagate vibrations but could crack when surface shrinks. To this extent we have tested three different types of glue: bi-component epoxy adhesive, Bostik Superchiaro (http://www.garotti.com/wp-content/catalogo/07-PRODOTTI_CHIMICI/07-10-COLLE/07-10-24-bostik_superchiaro/07-10-24-bostik_superchiaro.pdf) and silicone.

2. The relevant external pressure may alter the propagation of vibration on the glass sphere. To quantify this possible effect we have measured the vibration intensity at the glass inner surface in the pressure interval: 0-360 bar.

2 THE EXPERIMENTAL APPARATUS

Comparing to the configuration described in the previous report [2] we have used a similar 17" VITROVEX glass sphere equipped with 4 vibrating motors plus one accelerometer: all of them are of the same type described in [2]. The sphere was immersed in the hyperbaric chamber of the INFN-Laboratori Nazionali del Sud in Catania. The chamber is provided by a special feed-through with 12 electrical pins to allow the supply of the 4 motors, of the accelerometer and read out. A corresponding electrical dry-mate 12 pins connector was used in the glass sphere. We operated with the same tensions of [2]: 12 V for the motors and 3.6 V for the accelerometer: at this voltage its sensitivity is $A_{acc} = 360$ mV/G (G=9.8 m/s^2).

2.1 THE SPHERE

The glass sphere is a VITROVEX of 17" diameter, the same of the DOMs used in the KM3NeT experiment. Fig.1 shows the layout of the two hemispheres. The lower hemi-

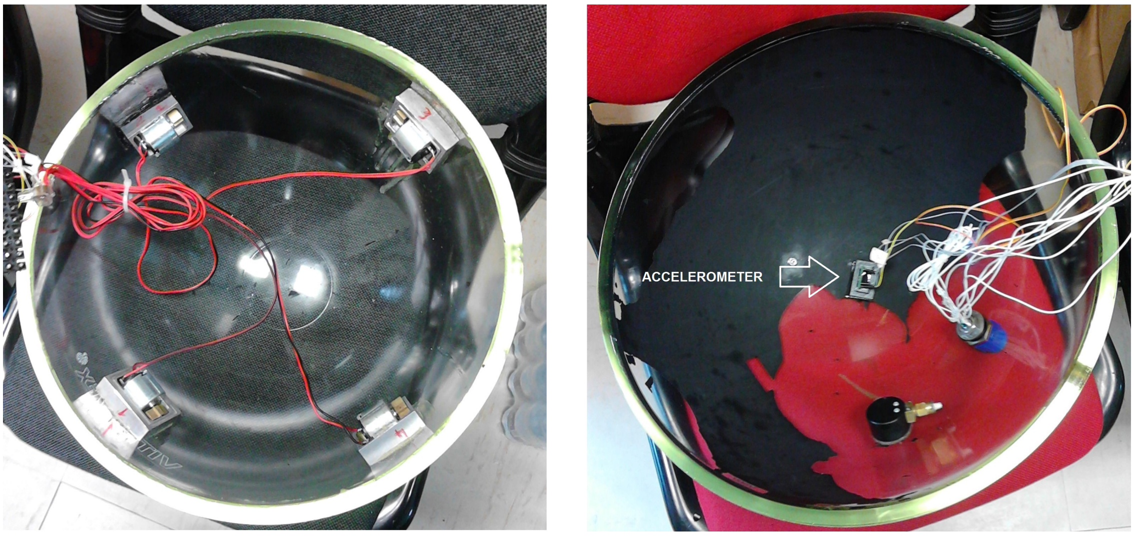

Figure 1: Sphere used for the test: on the left you can see the lower hemisphere with the vibrating motors, on the right is shown the upper hemisphere with the alimentation pins and the accelerometer (in the center).

sphere contains the 4 vibrating motors and the accelerometer is on the top of the upper hemisphere. The configuration is fully symmetric. With respect to the configuration described in the previous report, here the accelerometer is not fixed to the metallic heat exchanger (mushroom) but directly on the top of the sphere, using the same support. We are confident that in the present configuration the measured vibration intensity will represent an upper limit with respect to the measurement in the mushroom. The 4 vibrating motors are from PRECISION MICRODRIVES, MODEL: 334-401, the same as described in report [2]. The motors can be activated separately or in any other combination. Each motor is housed in a special metallic support (see fig. 5 in report [2]) where one of the surfaces is machined with the same curvature of the sphere in order to guarantee a perfect match. This surface was fixed to the glass with a bicomponent epoxy adhesive for motors number 1 and 3, silicone for motor number 2, Bostik for motor number 4.
It is important to note that motor number 1 was glued on an innner sphere's surface part where it was partially present a plastic transparent band with the sign "VITROVEX"on it.

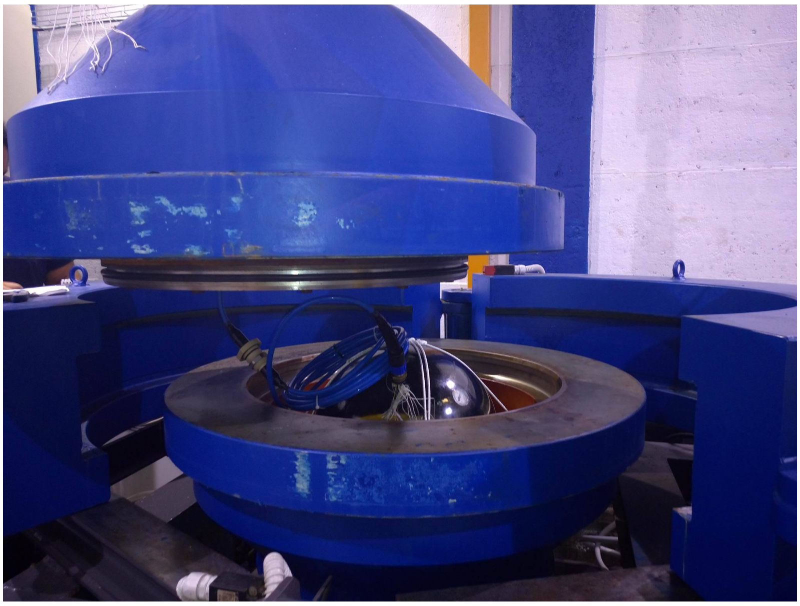

Figure 2: Hyperbaric chamber with the sphere in the center of it.

This was evident only at the end of the test after inspection. This fact is relevant because it may have increased the grip between the glue and the surface.

2.2 THE CHAMBER

Fig.2 shows the hyperbaric chamber with the sphere ready for the test. The blue cable connects the sphere to the feed-through of the chamber to allow the communication from the inner part of the sphere to the power supply and to the digital scope to record the signal from the accelerometer. The rate of the pressure increase/decrease can be set automatically in bar/min up to 400 bar. In our test we started from atmospheric pressure and reached the 360 bar. Then we operated the motors one at the time but also in opposite couples (1+3) and (2+4) in order to reproduce the configuration described in [2]. During descent we took some data at intermediate pressure values.

3 RESULTS AND CONCLUSIONS

As an example of the signal given by the vibrating motors, we show it for motors number 1, 2, 4 and 2+4 (operating together) for a pressure of 360 bar (fig. 3,4,5,6). The signal due to motor number 3, glued with bicomponent epoxy adhesive, is absent because it broke off from the sphere's surface when the pressure reached 170 bar. Since this was the second time that this happened with the epoxy adhesive, we decided to discard it as a glue candidate for real DOMs: it is likely that the matching with this glue becomes fragile when the sphere's surface shrinks. Fig. [3-6] are interesting as they show differences in vibration due to the glue: in particular we can see from the amplitudes of the signals that silicone absorbs part of the vibration, (the amplitude of the signal is smaller than the other cases and the signal has less noise). The response from motor 4 shows a more irregular behaviour compared to the others, and has the biggest amplitude. This may indicate that Bostik has good transmission but seems to have scattering effects with the vibrating motor which give a signal not so reproducible in time.

Fig. 6 shows the signal due to motor 2+4: we can see that at 360 bar the amplitude is $\sim$ 120 mV/A_{acc}=0.33 G (for one axis) wich is comparable to the result found in the configuration described in [2] at atmospheric pressure.

In the right part of each figure is also reported the Fast Fourier Transform wich shows a main peak at a frequency of $\sim$ 110 Hz, which is the frequency of the vibrating motors.

For comparison, fig. 7, 8 show the signal for a pressure of 2 bar for motor 1 and 4: the amplitude of the signal is lower than the case of 360 bar but they are comparable, expecially for motor 4: in particular, the amplitude of motor 1 at 2 and 360 bar is $\sim$ 40 mV and $\sim$ 65 mV respectively wich gives: 40/A_{acc}=0.1 G and 65/A_{acc}=0.18 G, for motor 4 we have: 65 mV/A_{acc}=0.18 G for 2 bar and 70 mV/A_{acc}=0.19 G for 360 bar. During the test, motor 2 became inoperative so we don't have its signal's graph at 2 bar.

Finally, fig. 9 shows the amplitude in funcion of the pressure in the range 2-360 bar for motor 1, 2, 4 and 2+4 (since motor 2 became inoperative we have its contribution from 170 to 360 bar). Error bars were assumed 10% to take into account electrical noise in the signal from the accelerometer and calibration uncertainty.

We can see that motor 2, glued with silicone, gives the smallest amplitude, compared to the others: this is due to the fact that silicone is a soft and flexible glue which absorbs part of the vibration. Moreover it holds at 360 bar, so it is a good candidate for the final configuration. Motor 4 gives bigger amplitudes than the other motors but as shown in fig. 5 it has a more irregular response in time. Nevertheless it also held at 360 bar so it can still be considered a good candidate. As stated before, bicomponent epoxy adhesive is not a good candidate because it detached twice.

Finally, the amplitude due to motor 2+4 is the biggest, and this is reasonable. We can also see that the amplitude at 360 bar, even if bigger than smaller pressures, is comparable (also if we compare it with [2]), so this is a good result because we can say that at the operating pressure, vibrations do not affect the DOM's performance.

This result, together with the evidence that silicone is a good candidate to match the mechanical support of the motor to the inner surface of the sphere, indicates that the vibration system described in [2] can be effective also at nominal pressure.

Final tests in a full integrated DOM will be needed to complete the qualification test.

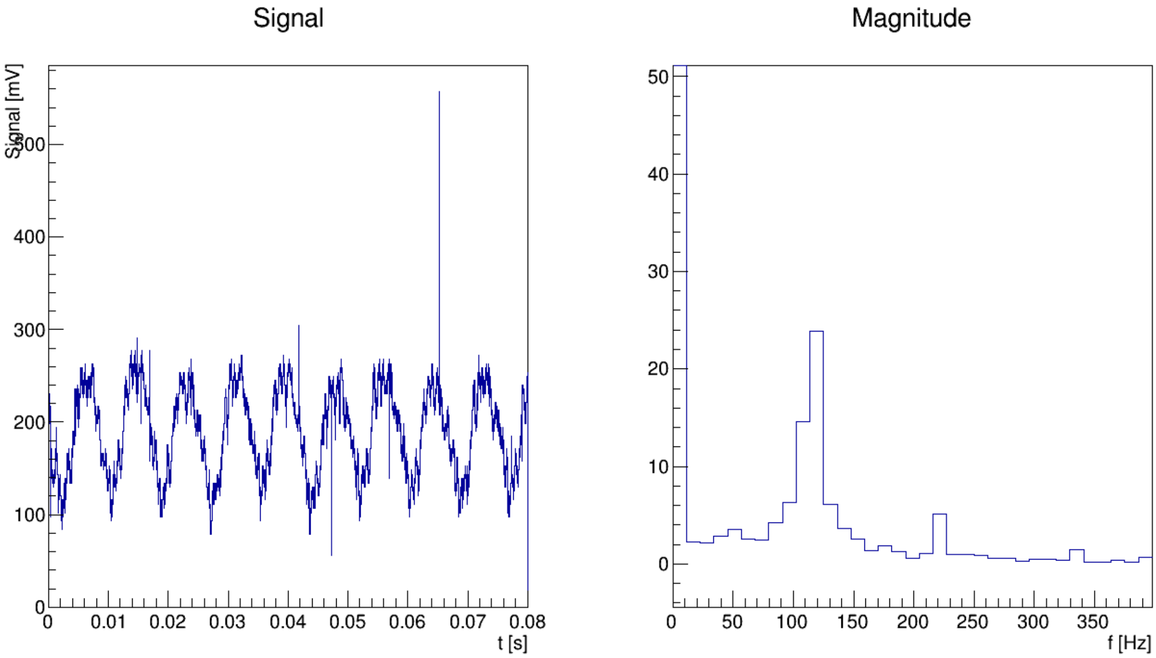

Figure 3: Signal due to motor 1 (glued with bicomponent epoxy adhesive) for one accelerometer's axis at P=360 bar: on the right there is also its Fast Fourier Transform which shows a peak at $\sim$ 110 Hz.

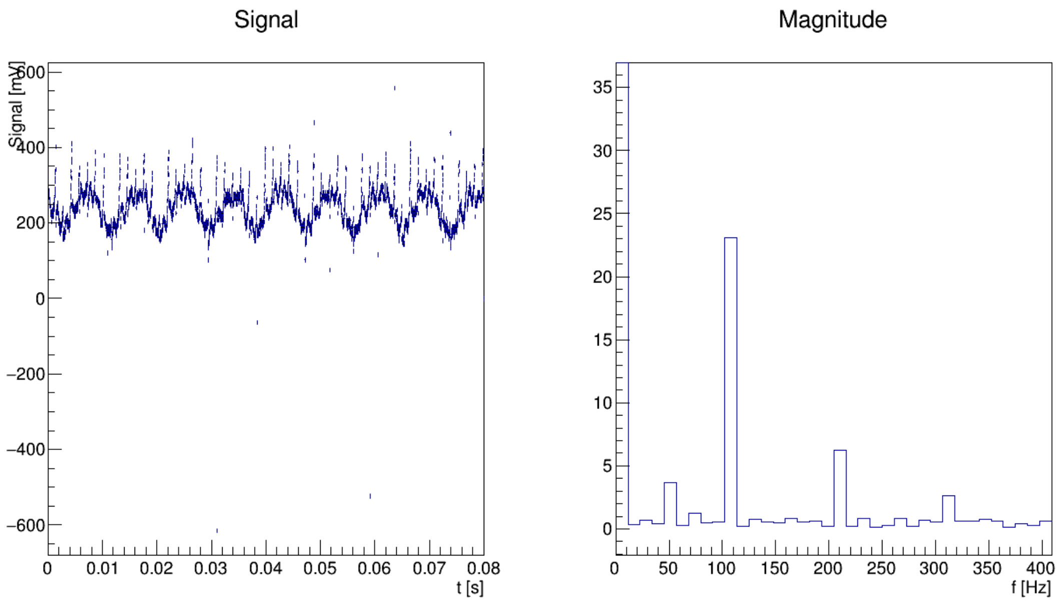

Figure 4: Signal due to motor 2 (glued with silicone) for one accelerometer's axis at P=360 bar: on the right there is also its Fast Fourier Transform which shows a main peak at $\sim$ 110 Hz.

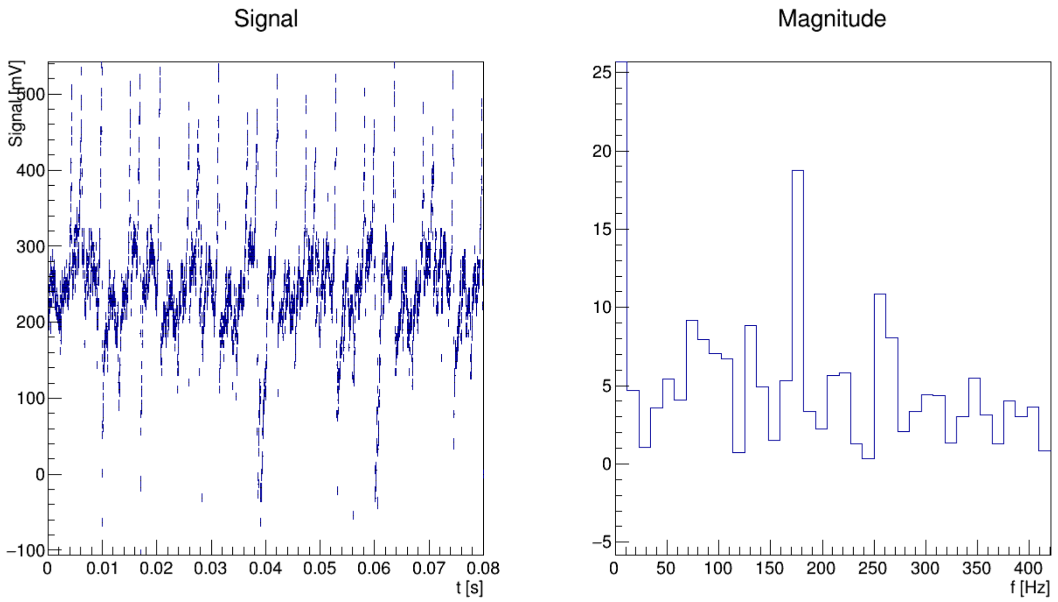

Figure 5: Signal due to motor 4 (glued with Bostik) for one accelerometer's axis at P=360 bar: on the right there is also its Fast Fourier Transform which shows more peaks than the other motors and in this case, even if there is the peak at $\sim$ 110 Hz, the main peak is at $\sim$ 170 Hz.

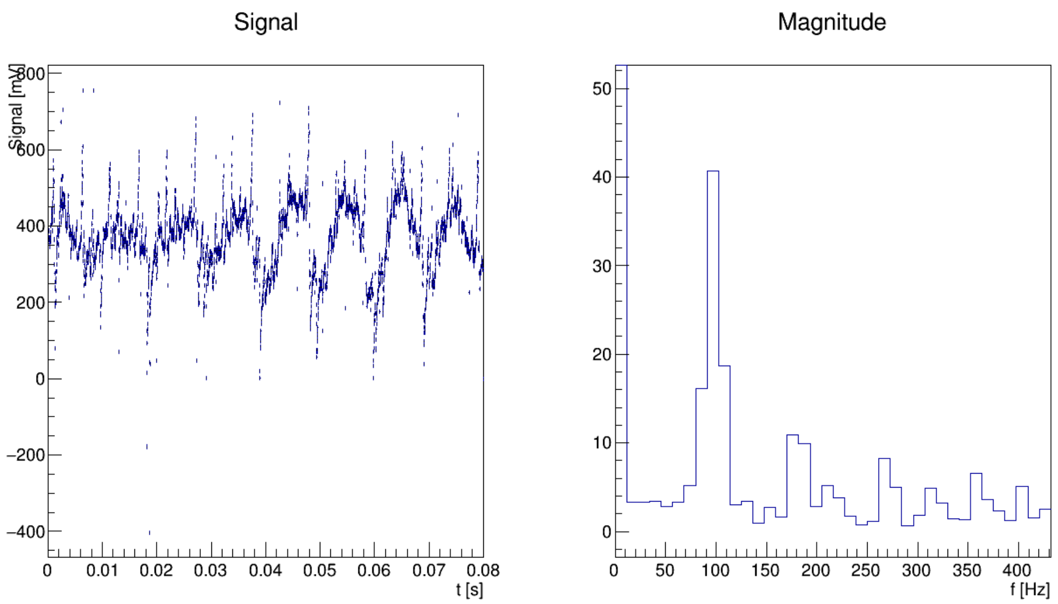

Figure 6: Signal due to motor 2+4 (glued with silicone and Bostik) for one accelerometer's axis at P=360 bar: the contribution of motor 2 is shown by the fact that the signal is less noisy than the case of only motor 4, and the amplitude is bigger than the other cases. Now we have again the main frequency peak at $\sim$ 100 Hz.

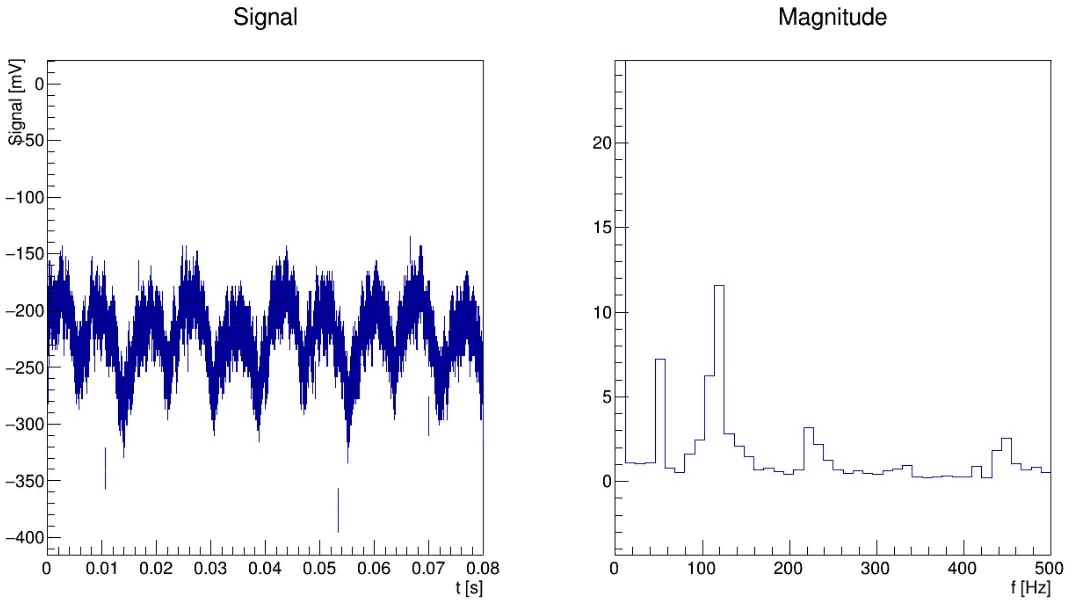

Figure 7: Signal due to motor 1 (glued with bicomponent epoxy adhesive) for one accelerometer's axis at P=2 bar: on the right there is also its Fast Fourier Transform which shows a peak at $\sim$ 110 Hz.

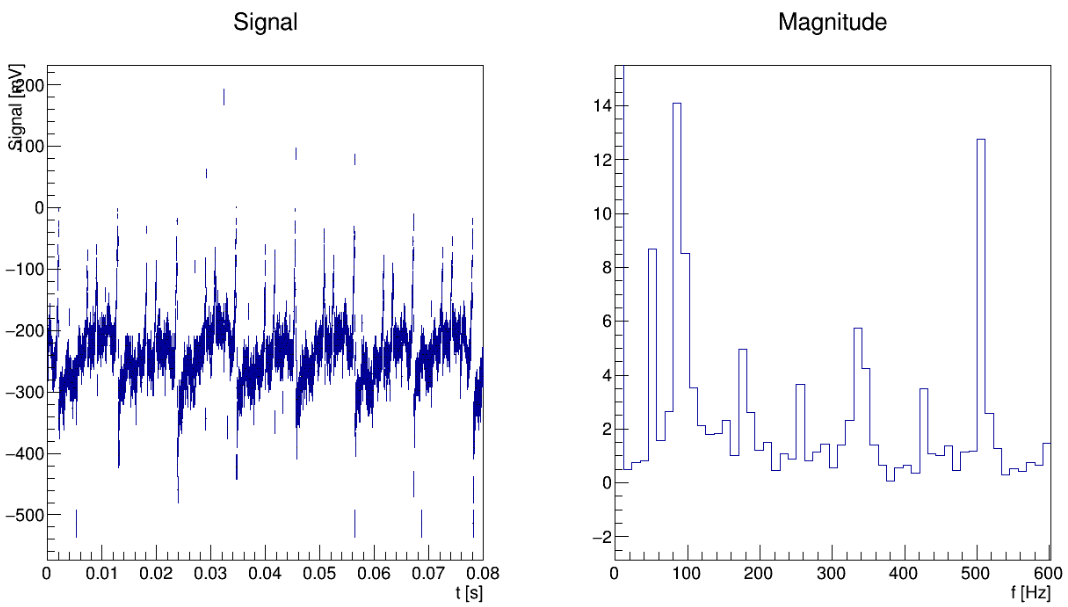

Figure 8: Signal due to motor 4 (glued with Bostik) for one accelerometer's axis at P=2 bar: on the right there is also its Fast Fourier Transform which shows more peaks than other motors (as in the case of P=360 bar) and now we ave two main peaks at $\sim$ 90 Hz and 500 Hz.

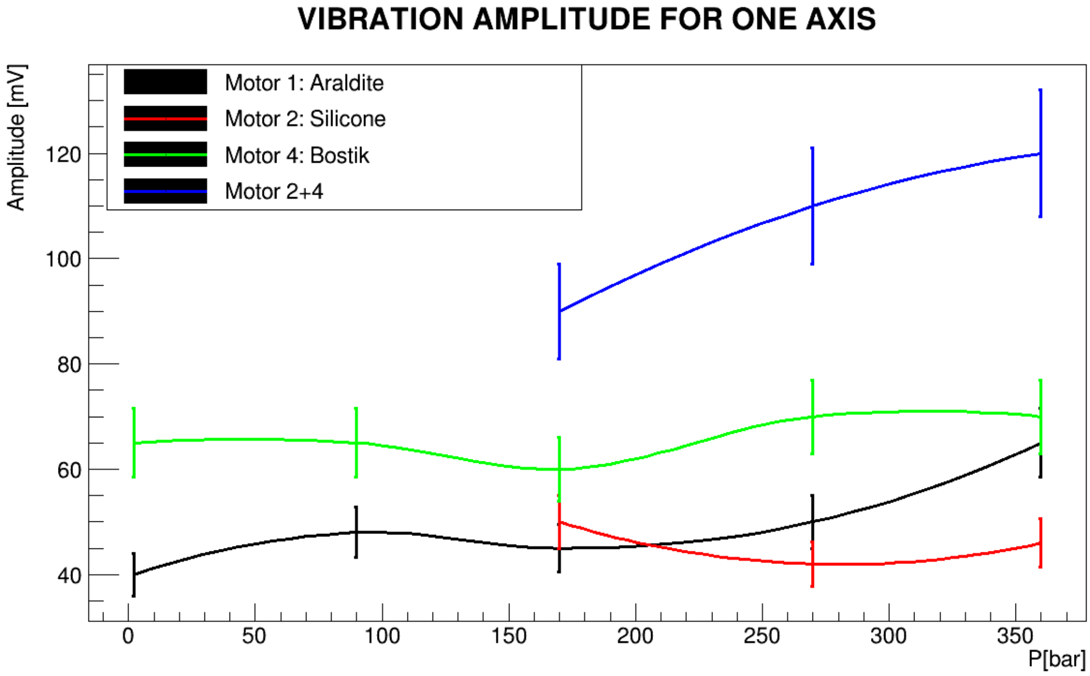

Figure 9: Vibration amplitude in function of the pressure for all vibrating motors.

References

[1] KM3NeT collaboration, *Letter of Intent for ARCA and ORCA*

[2] C. Hugon, A. Domi, M. Sanguineti, M. Anghinolfi, *The system to mitigate sediment deposition in the upper surface of the Digital Optical Module in KM3NeT*