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

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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). This effect may represent a problem for the KM3NeT experiment in which the DOMs contain upward pointing photomultipliers also upwards, resulting in a loss of efficiency in Cherenkov photons detection. In this note we describe our investigations on a micro vibration system to remove the deposits from the DOMs' surface.

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1 INTRODUCTION

KM3NeT will be a new research infrastructure consisting of a network of deep-sea neutrino telescopes in the Mediterranean Sea. It will consist of three blocks of 115 strings with 18 Digital Optical Modules (DOMs) containing 31 photomultipliers. The Astroparticle Research with Cosmics in the Abyss (ARCA) detector will be composed by two blocks, located at 100 Km from the italian site of Capo Passero (Sicily) at a depth of 3500 m. The remaining building block, referred as ORCA (Oscillation Research with Cosmics in the Abyss), will be located at 40 km off the shore of Toulon (France) at a depth of 2450 m. In the previous experiments, ANTARES and NEMO, which are located in proximity of ORCA and ARCA respectively, the deposit of a thin layer of material on the OMs' upper surface has been observed. In the case of KM3NeT this represents a bothersome effect because of the use of upward pointing PMTs in the upper hemisphere of each DOM: indeed, in the DOM, PMTs are arranged in 5 rings of 6 PMTs plus a single PMT at the bottom pointing vertically downwards, two rings (referred as E and F) are arranged in the DOMs' upper hemisphere and one (referred as D) is horizontal, as shown in fig. 1.

Figure 1: PMTs' rings for a DOM

In particular, in 2014 in the NEMO site, a prototype string consisting of three DOMs was deployed and operated for one year. The fig. 2 shows the variation of the PMTs' mean counting rate for the top DOM and for this time period. You can see that ring D, which is horizontal does not show, on average, any loss of efficiency whereas rings E and F which point upwards have losses of more than 10% in some cases. This effect is probably due to the deposition of a thin layer of material (sedimentation and biofueling).

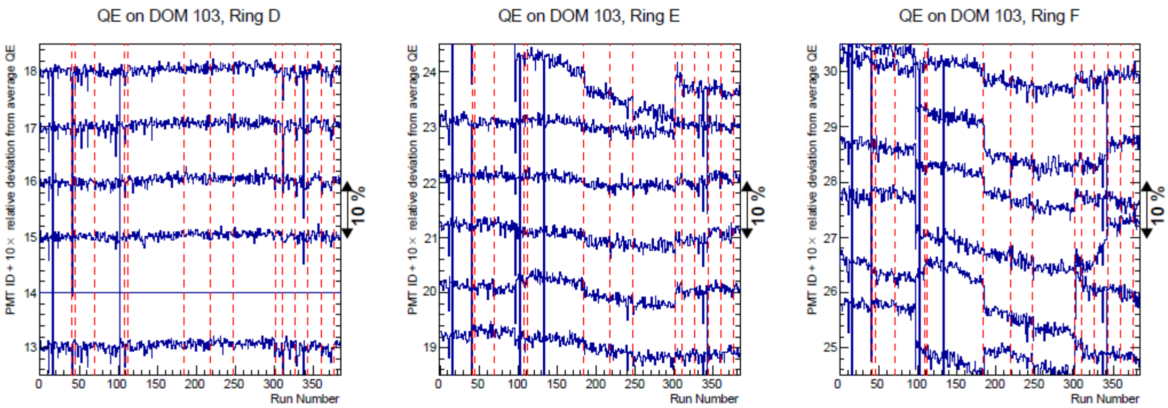

Figure 2: PMTs' mean counting rate: Ring ID (D,E,F) is specified in the text. Run Number refers to a time period of about 1 year. The blue lines represent each of the six PMTs that compose one ring, the red dashed lines indicate breaks in data taking.

2 THE PRINCIPLE

To mitigate this effect we made use of vibrations: two vibrating motors have been installed inside the DOM so that vibrations transferred to the glass will slide the deposited material. The advantages of this idea are:

- the motors can be integrated in the preexisting electronic: connectors won't be added outside the DOM,
- the motors will use directly the voltage of the power board,
- the small dimensions of the motors minimize the volume occupied by the system.

We have done some tests with a partially instrumented DOM to test this idea with these objectives in mind:

- the first is obviously that the motors must efficiently clean the DOM,
- the second, very important, is that the impact of vibrations on the whole system has to be minimized.

3 TEST

To test this principle we have to recreate in the best way the conditions in which the system will be once immersed in the sea. It is now impossible to perfectly recreate that conditions (the final objective is however to do so, thanks to the KM3NeT DOM integration group, at the INFN of Naples). However we started preliminary tests with a partially instrumented system composed by:

- the 17” DOM glass sphere,
- one 8 pins electrical penetrator to feed power inside and for signal read-out,
- $\sim$ 25 kg of lead to keep the DOM immersed in water,
- the KM3NeT suspension system,
- two vibrating motors glued inside the sphere,
- an accelerometer, to measure vibrations,
- different types of thin sediments,
- a water tank sufficiently high to contain the whole system,

3.1 Vibration Motors

The vibrating motors used for the test are produced by PRECISION MICRODRIVES, fig. 3 shows one of them: Their specifications are:

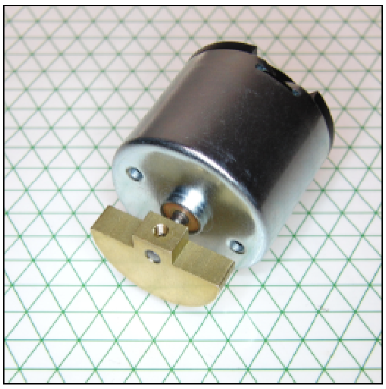

Figure 3: Vibrating Motor, MODEL: 334-401

- Body Diameter: 34 mm

- Body Length: 29.5 mm
- Rated Operating Voltage: 12 V
- Rated Vibration Speed: 7,700 rpm
- Typical Normalised Vibration Amplitude (peak to peak vibration amplitude normalized by the inertial test load of 1000 g at rated voltage): 110 G (where G=9.8 m/s^2).

We first used two other motors (model 320-102) which are smaller and have a typical normalised vibration amplitude of 17 G, but their power were too weak to give an observable effect so we excluded them by our tests.

3.2 Accelerometer

The accelerometer we used is made by Dimension Engineering, model DE-ACCM3D, and it is a tri-axis accelerometer.

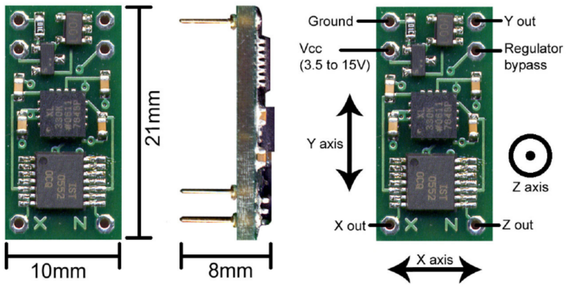

Figure 4: Accelerator

It's specifications are:

- sensitivity range: ± 3 G
- it gives an output $A_{acc} = 360$ mV/G with an operating volatge of 3.6 V (as in our case)
- operating voltage: 2.0-3.6 V

3.3 Sediments

The sediments observed in the upper surfaces of the optical modules in Capo Passero or in the ANTARES site were not available. Therefore we had to use other materials, which have some characteristic in common: the most important is that they have to be thin similarly to what observed in sea. We used three different types of material: the first one was simple mud, the second was a thin pure green clay, and the last, which is the closest to what we expect to be the real sediment, is a sample picked up from the sea bottom at a depth of 100 m.

4 ASSEMBLED APPARATUS

DOMs are formed by two hemispherical glasses kept together by vacuum. Inside the upper hemisphere (fig. 5) we have glued the metallic heath exchanger, the ”mushroom”, thanks to the KM3NeT optical gel: the mushroom will host the electronic components used for PMTs' operation and data acquisition. The gel softens the vibrations so to quantify the intensity transferred to the electronic components we have placed the accelerometer in the mushroom.

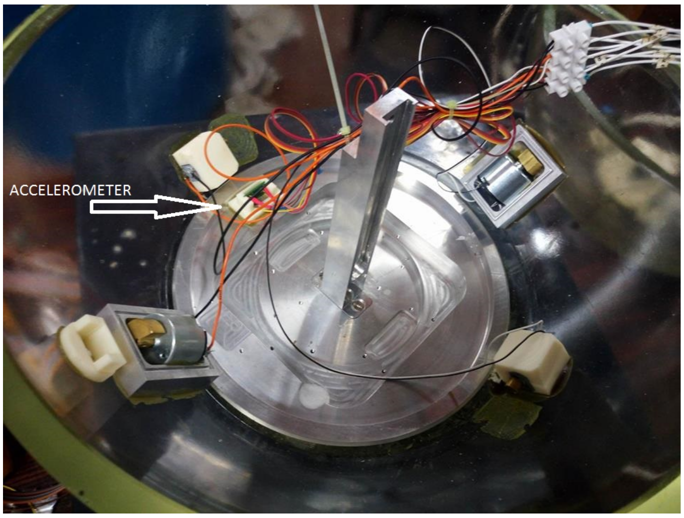

Figure 5: Our assembled apparatus, upper hemisphere: the two motors we used are the biggest fixed on a metallic support.

We operated at a tension of 12 V because this is one of the input voltages available in the real DOMs of KM3NeT. With this power supply the current reading was 160 mA corresponding to a total power of about 4 Watt for both motors. From fig. 6 we can see that for this voltage we expect a vibration amplitude of ~ 11 G for a test load of 1000 g.
In our case we have a DOM of 17.7 kg so the amplitude will be:

$$A = \frac{11G \cdot 1kg}{17.7kg} \approx 0.6\,G \tag{1}$$

This amplitude is for one motor and it is obviously only an estimate: we have a sphere with different components and different regions of the DOM will experience different am-

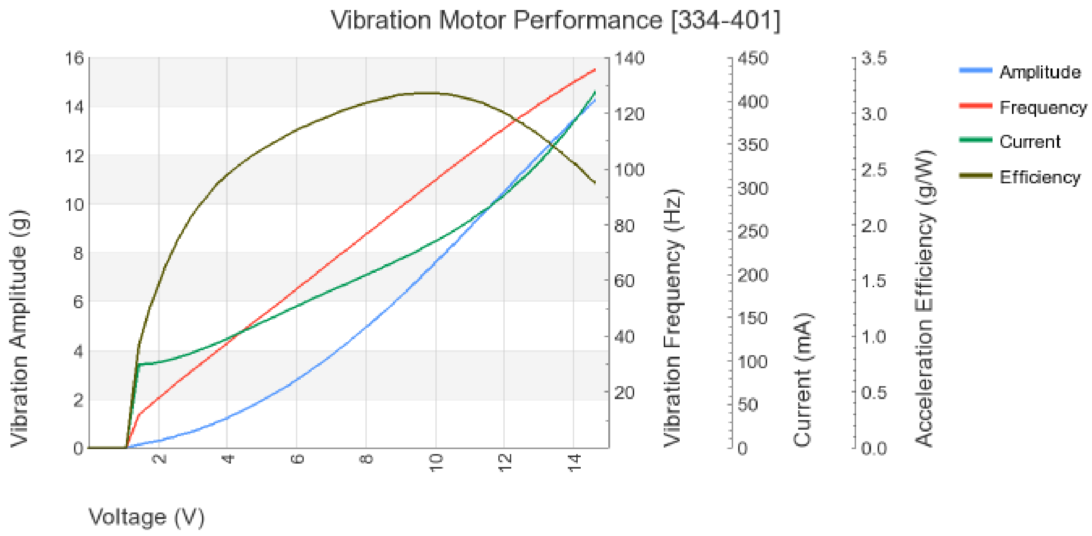

Figure 6: Vibration motor performance

plitudes, the nearer we are to the motors, the stronger will be the acceleration amplitudes. From fig. 5 you can see that the accelerometer is placed halfway from the motors.
In general, for two systems vibrating with the same frequency and amplitude, but non necessarily with the same phase, we have: $s_1 = A\sin(\omega t)$ and $s_2 = A\sin(\omega t + \phi)$. If we sum this two signals we obtain:

$$s_1 + s_2 = 2A\cos\left(\frac{\phi}{2}\right)\sin\left(\frac{2\omega t + \phi}{2}\right) \tag{2}$$

So a priori we can't say anything about the final amplitude until we watch the phase-shift between the two signals.

4.1 Test in Water

We made the test by immersing the DOM in the water tank. Fig. [7, 8, 9] show respectively the z, y and x acceleration components with their fast Fourier Transforms as experienced in the mushroom where the accelerometer was located. From fig. 6 we expect to have a frequency of $\sim$ 110 Hz for an input of 12 V. You can see that in the three axes we have a frequency of $\sim$ 100 Hz. We can also give an estimation of the vibration amplitude by watching this three graphs: for the z-axis we have a maximum amplitude $A_z \sim 150$ mV which corresponds to $150/A_{acc} = 0.42$ G, where $A_{acc} = 360$ mV is the accelerometer output defined in section 3.2, for the y-axis $A_y \sim 200$ mV = 0.55 G and for

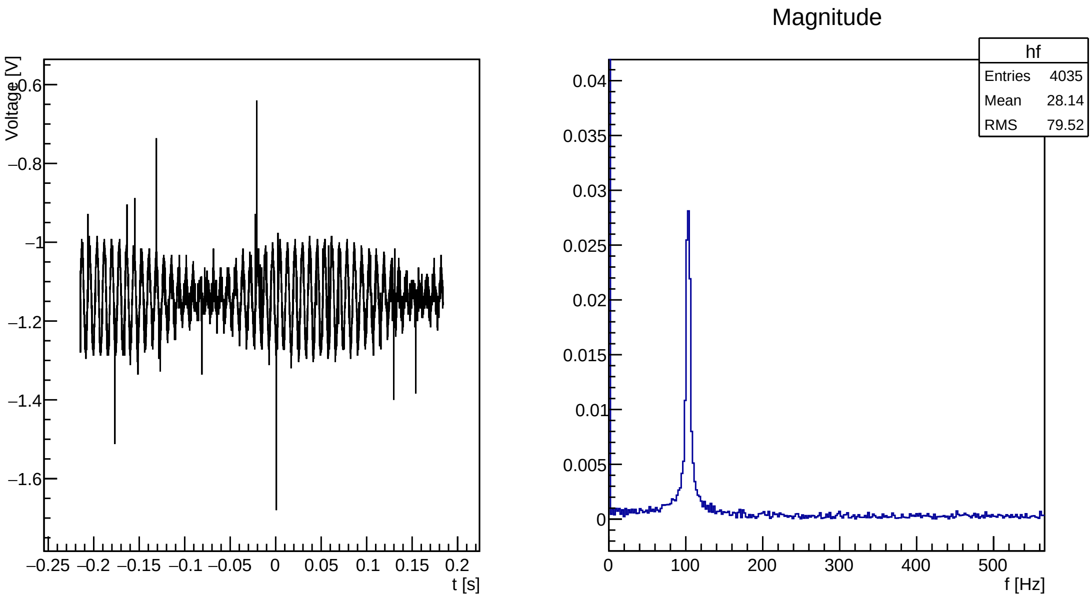

Figure 7: z-axis: in the left you can see the signal, on the right is shown its fast fourier transform

the x-axis $A_x \sim 250$ mV = 0.69 G. So the total amplitude is:

$$A = \sqrt{A_x^2 + A_y^2 + A_z^2} = 0.98\ G \tag{3}$$

5 Results

The test runs demonstrated that 2 minutes of vibration were enough to remove the deposit from the DOM. In fig. 10 you can see a pecture of the system before and after cleaning. We are confident that the system described in this report can be easily implemented in the DOM geometry to prevent the sediment deposition as observed in sea.

We also gave an estimation of the vibration at which the electronic will undergo. Now the last step is to do this measurement with the fully completed DOM and on doing a stress test based on the total in situ expected vibration time.

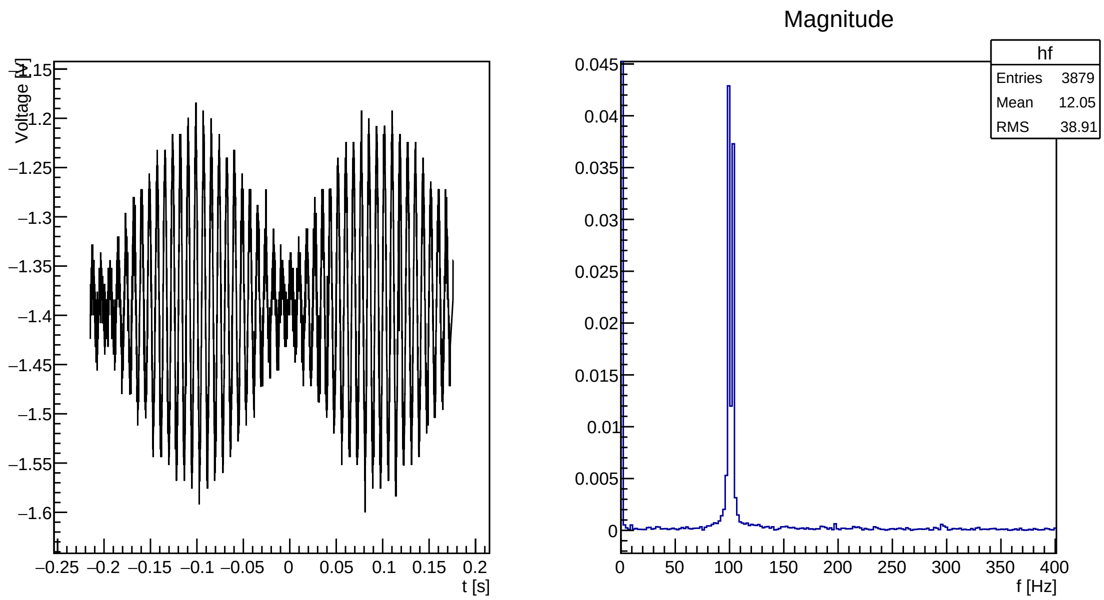

Figure 8: y-axis: in the left you can see the signal, on the right is shown its fast fourier transform

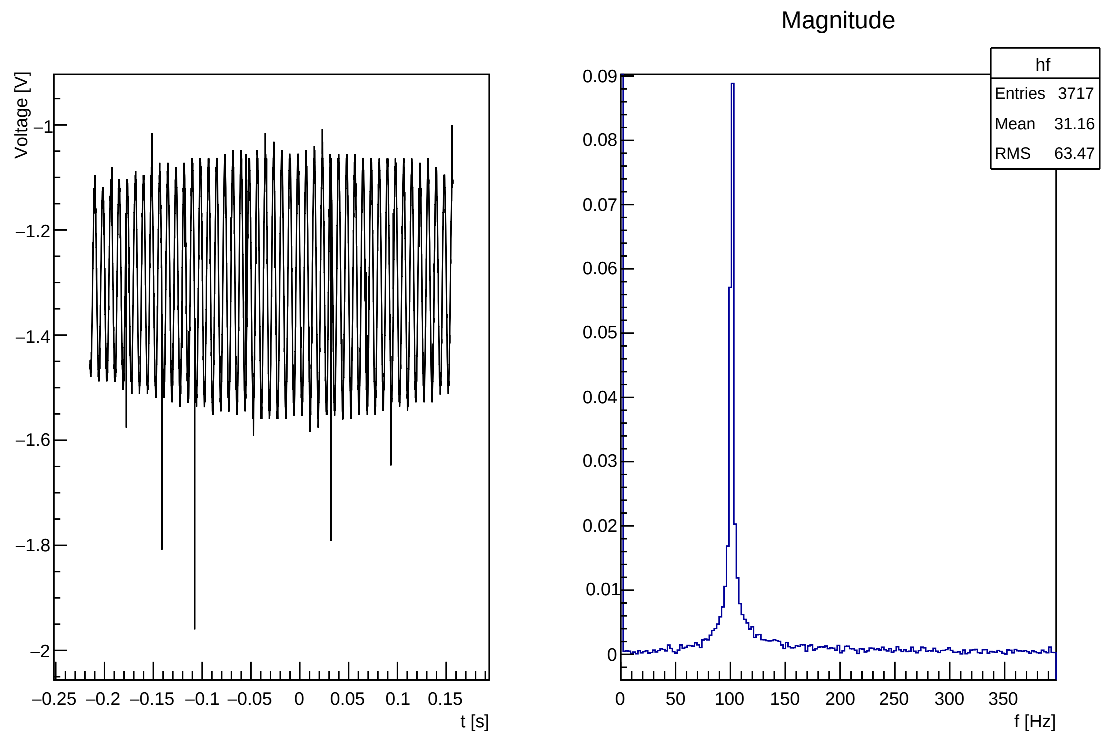

Figure 9: x-axis: in the left you can see the signal, on the right is shown its fast fourier transform

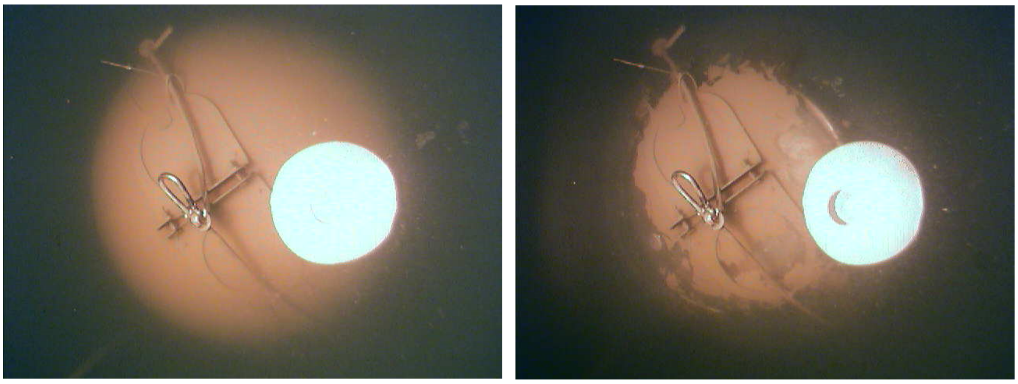

Figure 10: The DOM before and after the cleaning.

References

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