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Thermal connection and vibrational isolation: an elegant solution for two problems

C Frajuca^{1*}, F S Bortoli¹, N S Magalhaes² and O D Aguiar³

¹ Sao Paulo Federal Institute, Rua Pedro Vicente 625, Sao Paulo, SP, 01109-010, Brazil

² Federal University of Sao Paulo, Department of Exact and Earth Sciences, Rua Sao Nicolau 120, Diadema, SP, 09913-030, Brazil

³ INPE Astrophysics Division, Sao Jose dos Campos, SP, 12227-010, Brazil

E-mail: frajuca@gmail.com

Abstract. Schenberg is a detector of gravitational waves resonant mass type, with a central frequency of operation of 3200 Hz. Transducers located on the surface of the resonating sphere, according to a distribution half-dodecahedron, are used to monitor a strain amplitude. To improve the performance of the detector it is essential to decrease the temperature, then it will be cooled down, this temperature could reach as low as 50 mK. This refrigerator produces vibration noise that could compromise the performance of Schenberg detector. In this work we study such vibration noise and how it could be minimized proposing a new connection from the dilution refrigerator to the sphere suspension. The vibration attenuation is studied by finite element modeling (FEM) and an attenuation higher than 10^{24} is found, higher enough to note compromise the performance of Schenberg detector.

1. Introduction

SCHENBERG is a spherical resonant-mass Gravitational Wave (GW) detector [1, 2] built in Sao Paulo, Brazil, can be seen on figure 1. The sphere with 65 cm in diameter and weighting 1.15 ton, is made of a copper-aluminum alloy [3] with 94 % Cu and 6 % Al. The detector will have six electromechanical transducers (motion sensors that monitor the sphere surface movement, transforming the mechanical oscillation in electrical signal [4, 5]), arranged on the spheres surface in a half-dodecahedron distribution. The sensors will be located as if in the center of the six connected pentagons in a dodecahedron surface, following the studies by Merkwowitz and Johnson [6, 7] confirmed by Magalhaes and collaborators [8]. By analyzing the signal of such sensors, the amplitudes and the direction of the incoming gravitation wave can be determined [9, 10]. The history of the decisions process that has determined Schenberg characteristics can be seen in [12]. The sphere, in a commissioning phase is cooled to 4.2 Kelvin. In a next phase will be cooled down to a lower temperature using a dilution refrigerator, this temperature could reach as low as 50 mK. This refrigerator produces noise because of the Helium evaporation and this noise is transported by the connections to the sphere. In this work we study such vibration noise and how it could be minimized. The conventional method used in detectors with this kind of refrigerator is to connect the refrigerator to the sphere using thin copper wires, but it reduces the cooling capability by a great factor. The vibration attenuation should make the dilution refrigerator noise lower than the thermal vibration noise on the sphere surface keeping the temperature as lower as possible. Figure 1 shows Schenberg schematics. The analysis



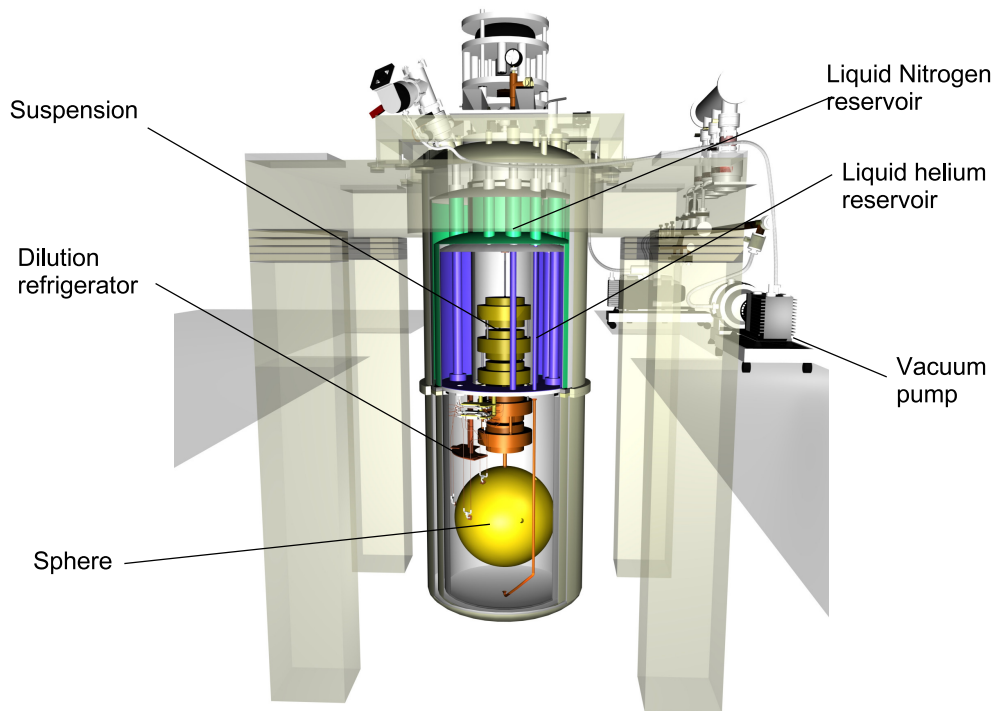


Figure 1. Schenberg schematics, the green area is liquid nitrogen and the blue one is filled with liquid helium.

of the vibration attenuation is done by frequency response obtained finite element modeling (SolidWorks Simulation 2010-2011). Figure 2 shows the the 1 K pot in Schenberg detector and the mixing chamber.

2. Requirement for the noise attenuation

In order to allows the Schenberg detector to measure vibrations due to gravitational waves instead of vibrations due to diluitor refrigerator noise, it is essential to attenuate such noise to an amplitude below the noise to the thermal vibrations. The Noise vibration on a sphere surface due to thermal noise at a temperature of 50 mK is equal to $10^{-46} \text{ m}^2/\text{Hz}$ [7]. An estimation for the dilution refrigerator noise can be find in [?] as a value below $10^{-22} \text{ m}^2/\text{Hz}$. Then, in order to get the noise below the thermal noise, an attenuation of, at least, 10^{24} is needed.

3. The Mixing Chamber connected to the last but one suspension mass

Using the idea that a mass connected to a wire can reflects part of the vibration traveling across the wire, a series of masses connected to parallel wires should do the same. Figure 3 shows the proposed connection from the dilution refrigerator to the sphere suspension.

4. Frequency response from a $10^{-2} \text{ m}^2/\text{Hz}$ signal on the mixing chamber disk

In order to estimate the attenuation of the proposed connection a finite element modeling was performed using SolidWorks Simulation 2010-2011 version, with a dumping ratio of 0.0005. Figure 4 shows the frequency response obtained on the sphere surface due to a white noise of

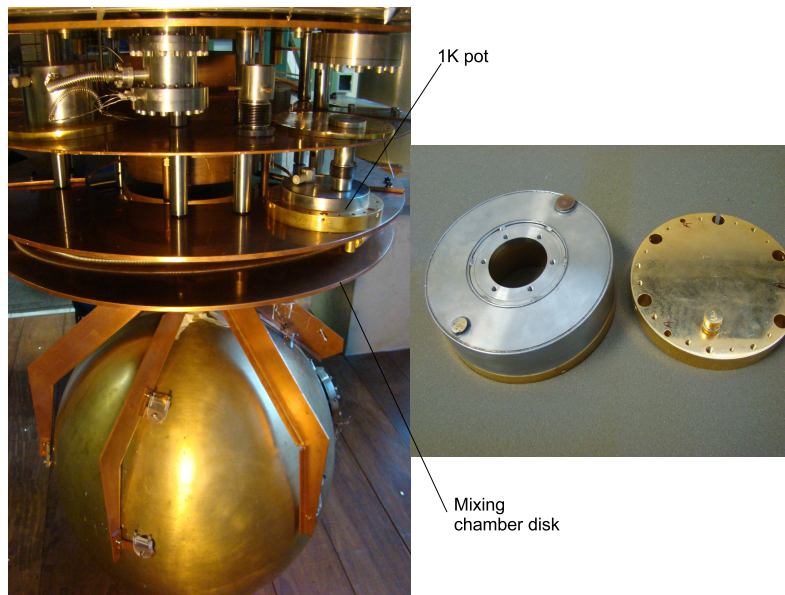


Figure 2. Schenberg suspension with the 1K pot dilution refrigerator and, on the right, the mixing chamber.

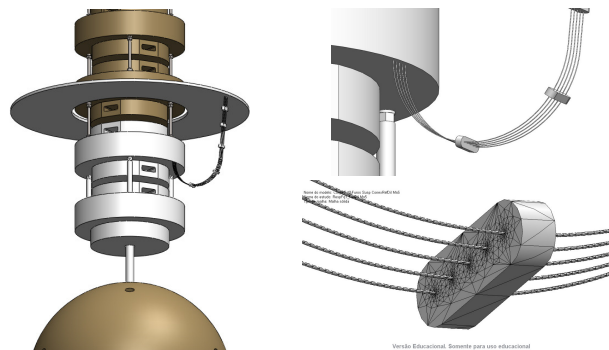


Figure 3. The proposed connection, the wires could be welded to the masses.

the $10^{-2} \text{ m}^2/\text{Hz}$ signal applied on the mixing chamber disk, the value of such displacement is chosen because of the limitation on the finite elements program.

5. Conclusions

We considered the vibration noise on the sphere surface as $10^{-46} \text{ m}^2/\text{Hz}$ due to thermal noise and the vibration noise in the region close to the dilution refrigerator was estimated as $10^{-22} \text{ m}^2/\text{Hz}$. One configuration of the connection of the mixing chamber were modeled in a finite element program. By the results of this finite element modeling, the dilution refrigerator when connected to the suspension last but one mass, has an attenuation equal to 10^{24} found in the frequency response graphic. Barely the attenuation needed as the total vibration on the sphere surface due to the dilution refrigerator noise is of the order of the thermal noise. The noise considered should be much lower due to a concrete weighting of 4 ton, where the dewar is supported, such calculation is difficult as the size of the model becomes too big. Considering this 4 ton mass, the noise should be much lower than the one estimated above.

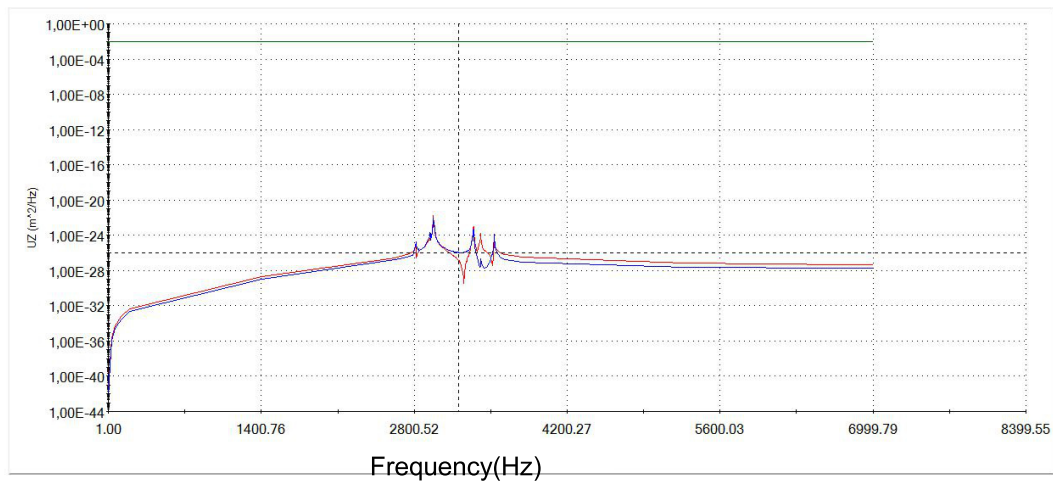


Figure 4. Frequency response on the sphere surface.

Acknowledgements

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