INSTITUTE OF PHYSICS PUBLISHING CLASSICAL AND QUANTUM GRAVITY
Class. Quantum Grav. **22** (2005) S209–S214 doi:10.1088/0264-9381/22/10/011

# The Brazilian gravitational wave detector Mario Schenberg: progress and plans

**O D Aguiar[1], L A Andrade[5], J J Barroso[1], F Bortoli[6], L A Carneiro[1], P J Castro[1], C A Costa[1], K M F Costa[3], J C N de Araujo[1], A U de Lucena[1], W de Paula[3], E C de Rey Neto[1], S T de Souza[1], A C Fauth[4], C Frajuca[6], G Frossati[8], S R Furtado[1], N S Magalhães[3], R M Marinho Jr[3], E S Matos[1], J L Melo[1], O D Miranda[1], N F Oliveira Jr[2], B W Paleo[1], M Remy[1], K L Ribeiro[1], C Stellati[3], W F Velloso Jr[7] and J Weber[1]**

[1] Instituto Nacional de Pesquisas Espaciais—Divisão de Astrofísica, São José dos Campos, SP, Brazil
[2] Instituto de Física, Universidade de São Paulo, São Paulo, SP, Brazil
[3] Instituto Tecnológico de Aeronáutica, São José dos Campos, SP, Brazil
[4] Instituto de Física, Universidade Estadual de Campinas, Campinas, SP, Brazil
[5] Instituto de Aeronáutica e Espaço, São José dos Campos, SP, Brazil
[6] Centro Federal de Ensino Tecnológico de São Paulo, São Paulo, SP, Brazil
[7] Universidade de São Paulo, Ribeirão Preto, SP, Brazil
[8] Kammerlingh Onnes Laboratory, Leiden University, Leiden, The Netherlands

E-mail: odylio@das.inpe.br

Received 29 October 2004, in final form 13 January 2005
Published 21 April 2005
Online at stacks.iop.org/CQG/22/S209

**Abstract**
The Schenberg gravitational wave detector is almost completed for operation at its site in the Physics Institute of the University of São Paulo, under the full support of FAPESP (the São Paulo State Foundation for Research Support). We have been working on the development of a transducer system, which will be installed after the arrival of all the microwave components and the completion of the transducer mechanical parts. The initial plan is to operate a CuAl6% two-mode parametric transducer in a first operational run at 4.2 K with nine transducers and an initial target sensitivity of $h \sim 2 \times 10^{-21}$ Hz$^{-1/2}$ in a 50 Hz bandwidth around 3.2 kHz. Here we present details of this plan and some recent results of the development of this project.

PACS numbers: 04.80.Nn, 95.55.Ym

## 1. Introduction

Cryogenic resonant-mass antennas are still the most sensitive instruments for detecting high frequency burst signals of gravitational waves [1]. Bar antennas have achieved strain noise

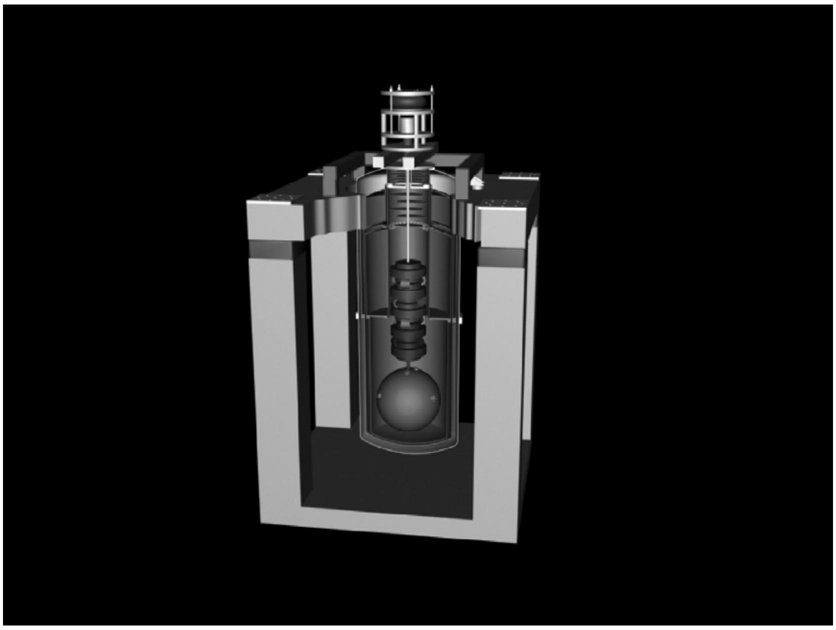

**Figure 1.** Schematic view of the Schenberg detector.

power spectral density as low as $10^{-21}$ $Hz^{-1/2}$ around 900 Hz [2]. Spherical antennas of similar or higher sensitivity, which will be able to localize the emitting source in the sky because of their omnidirectionality, are under construction [3]. One of these is the Brazilian Mario Schenberg antenna [4]. Figure 1 shows a schematic view of this detector.

This 1.15 ton and 65-cm-diameter CuAl6% antenna will have a strain noise power spectral density of $2 \times 10^{-23}$ $Hz^{-1/2}$ when it reaches the standard quantum limit of sensitivity, at about 20 mK [5]. It will be operating in coincidence with the Dutch Mini-GRAIL antenna and some long baseline laser interferometer detectors, [6] searching for high frequency events in the 3.0–3.4 kHz frequency bandwidth.

## 2. The progress made

The Mario Schenberg gravitational wave detector is almost completed at its site at the Physics Institute of the University of São Paulo, in São Paulo city, Brazil, under the full support of FAPESP (the São Paulo State Foundation for Research Support). This includes all the ‘heavy’ parts of the detector (the cryogenic chambers, the antenna vibration isolation system and the antenna itself). We have made a first cryogenic run for an overall test, in which we measured the mechanical $Q$ (figure of merit) of some of the five spherical antenna quadrupole modes, which are spread in the 3172–3240 Hz range due to the broken symmetry caused by the axial hole machined inside the spherical antenna. Values close to $Q = 2.7$ million were found around 2 K [7]. We also changed the ‘springs’ of the vibration isolation system in order to improve its performance in both vibration and thermal isolation. Instead of the old CuAl6% C-shape springs, we are using titanium–vanadium (90Ti-4V-6Al) little rods or pins. Figure 2 gives a close view of one of these pins and the overall vibration isolation system assembled.

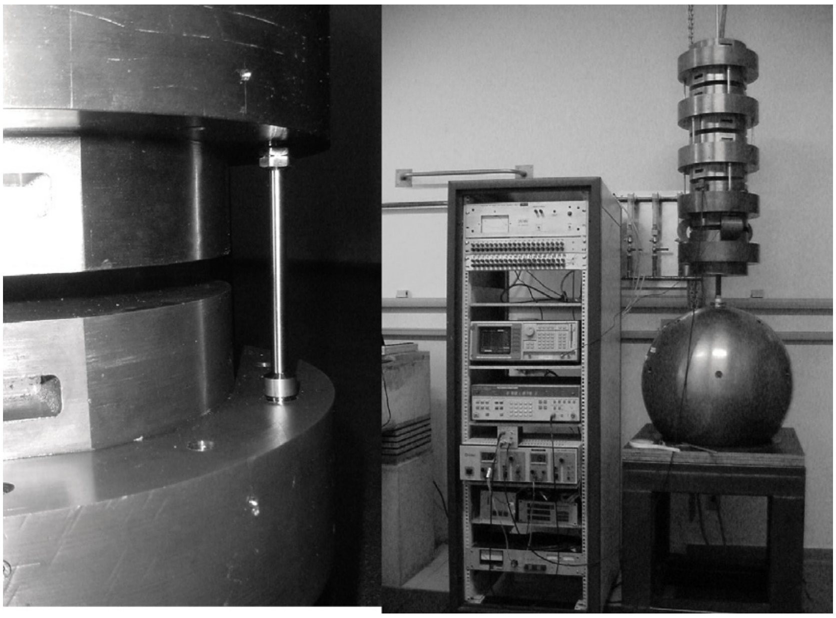

**Figure 2.** New vibration isolation system for the antenna.

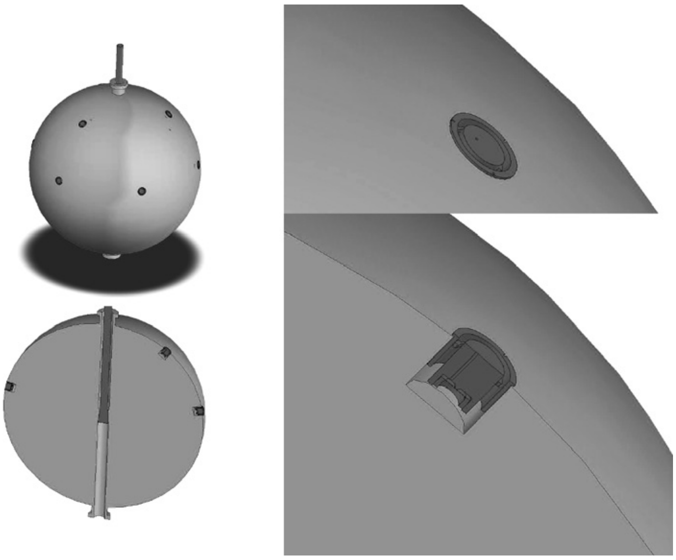

**Figure 3.** Details of the transducer attachment to the spherical antenna.

## 3. First goal and future plans

We will install nine complete transducer-amplifier systems and the data acquisition hardware. Figure 3 shows details of the transducer attachment to the spherical antenna. Six of the positions follow the truncated icosahedron configuration and the other three were chosen to have the same 'latitude' as the bottom ones and the same 'longitude' as the top ones.

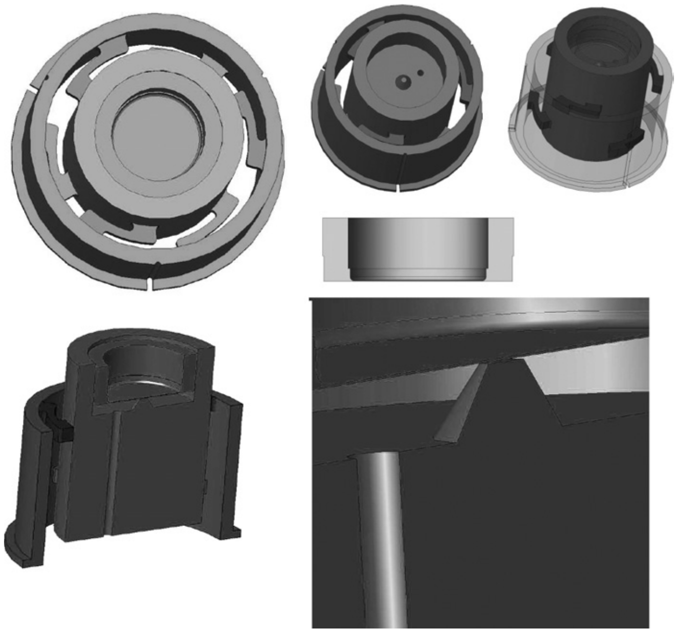

**Figure 4.** Schematic view of the non-contacting 2-mode CuAl6% parametric transducer with closed reentrant cavity.

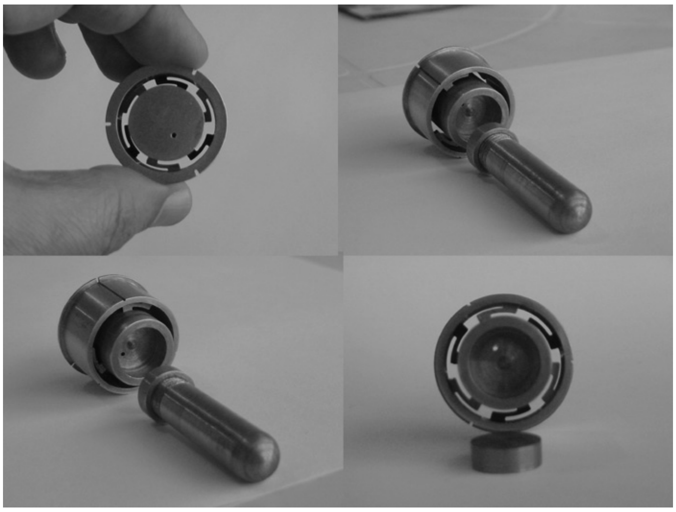

**Figure 5.** The 2-mode CuAl6% parametric transducer.

Our plan is to make a test with nine transducers attached to the antenna at 4.2 K, trying to reach a strain noise power spectral density of $2 \times 10^{-21}$ Hz$^{-1/2}$, in a 50 Hz bandwidth around 3.2 kHz by the end of 2005. This will be our first goal.

After that we plan to assemble a dilution refrigerator in order to be able to operate the antenna with the same transducer–amplifier system at 15–20 mK in 2006. We also plan to equip Schenberg with cosmic ray detectors for veto purposes by 2006.

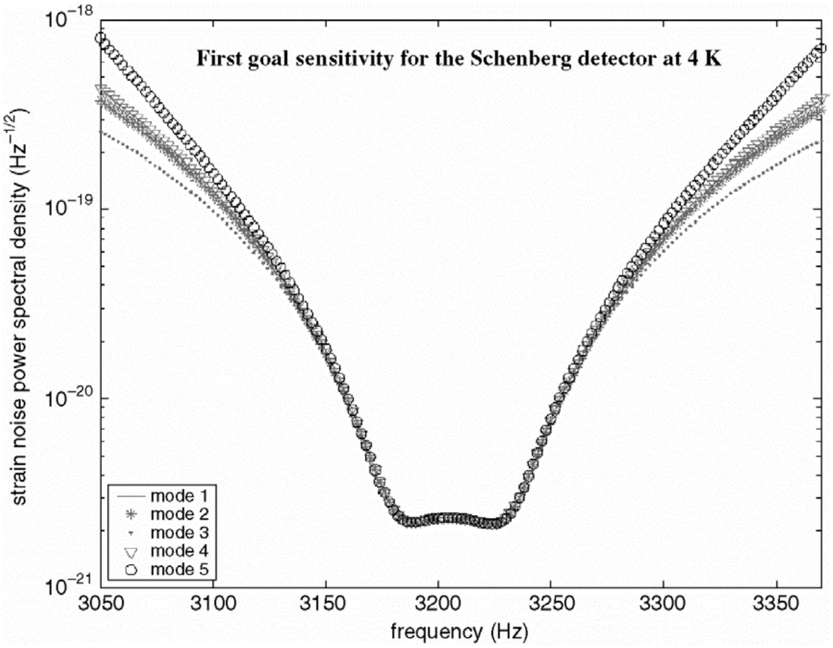


**Figure 6.** First goal sensitivity for the Schenberg antenna at 4.2 K. The curves are strain noise power spectral densities for the five quadropole modes (mode channels).

We will use parametric transducers, each of them composed, among other parts, by a re-entrant (klystron) cavity pumped at a microwave frequency (X-band). The schematic view and pictures of the non-contacting (microstrips) 2-mode CuAl6% parametric transducer with closed re-entrant cavity are shown in figures 4 and 5. The transducer will have two mechanical modes tuned to 3.2 kHz, one will be composed by a 53 g intermediate mass and the other by a 10 mg (membrane) mass. When coupled to the 1.15 ton spherical antenna, which has an effective mass of about 287 kg in each of its fundamental quadrupole modes [8, 9], the transducer will amplify the amplitude oscillation of the spherical antenna by a factor of $(287\ \text{kg}/10\ \text{mg})^{1/2} \sim 5$ k.

A microstrip antenna manufactured at the back of the transducer will receive the microwave carrier, which will activate the cavity, and transmit back the modulated signal to the cryogenic amplifier. We are going to use HEMT amplifiers, as the Australian group was planning to use in Niobè [10]. These amplifiers are available on the market with noise temperatures of about 8 K, which represents less than $12\hbar$ in sensitivity ($T_n = 8\ \text{K} \sim 11.5\hbar\,\omega/k_B \ln 2$) [11].

Figure 6 shows the predicted strain noise power spectral density considering conservative parameters and the Schenberg antenna operating at 4.2 K.

## Acknowledgments

This work has been supported by FAPESP (under grant nos 1998/13468-9, 2001/12606-3, 2001/14527-3, 2002/01528-4, 2002/07310-0 and 2003/05852-3), CNPq (under grant nos 306467/03-8, 304666/02-5, 150854/03-0 and 380237/04-0), CAPES and MCT/INPE.

## References


[1] Florides P S 2005 *Proc. 17th Int. Conf. on General Relativity and Gravitation (Dublin, Ireland, 18–23 July 2004)*

[2] Fafone V 2004 Resonant-mass detectors *Class. Quantum Grav.* **21** S377

[3] De Waard A, Gottardi L and Frossati G 2005 *Class. Quantum Grav.* these proceedings

[4] Aguiar O D *et al* 2002 *Class. Quantum Grav.* **19** 1949

[5] Tobar M E, Ivanov E N and Blair D G 2000 *Gen. Rel. Grav.* **32** 1799

[6] Aguiar O D *et al* 2000 *Proc. 3rd Edoardo Amaldi Conf. on Gravitational Waves (Pasadena, CA, 1999)* (*AIP Conference Proceedings* vol 523) (New York: AIP) p 413
De Waard A, Gottardi L and Frossati G 2002 *Class. Quantum Grav.* **21** S465

[7] De Souza S T 2003 *Master Dissertation* Instituto de Física da Universidade de São Paulo
Aguiar O D *et al* 2004 *Class. Quantum Grav.* **21** S457

[8] Harry G M, Stevenson T R and Paik H-J 1995 *Phys. Rev.* D **54** 2409

[9] Richard J-P 1984 *Phys. Rev. Lett.* **52** 165
Pang Y and Richard J-P 1992 *Rev. Sci. Instrum.* **63** 56

[10] Tobar M E 2000 *Physica* B **280** 520

[11] Heffner H 1962 *Proc. IRE* p 1604