PROPOSED WIRING FOR CUORE EXPERIMENT: A RADIATIVE SOLUTION.

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The wiring of CUORE experiment consists of about 2600 NbTi leads. One end of each lead is at 300 K whereas the other end is at 10 mK. Due to the design of CUORE cryostat, a thermal grounding at the first refrigerating stage (40 K) is not feasible. Moreover, for such a large numbers of wires, sinking heat at 4 K by glues is hazardous. Hence, we propose an unconventional thermal grounding of the wires carried out completely by radiative exchange. The thermal loads onto the sinks at 4 K, 0.7 K, 10 mK are reported.

Keywords: cryogenics; heat transfer

1. Introduction

CUORE (Cryogenic Underground Observatory for Rare Events[1]) experiment is a large arrays of detectors for the research of $\beta\beta(0\nu)$ decay. CUORE, to be installed in 2011 at LNGS, consists of a tightly packed array of 988 TeO_2 detectors cooled to ∼10 mK. The cryostat housing CUORE is made of six nested vessels[2] . There are two vacuum chambers: the Outer Vacuum Chamber (OVC) at room temperature and the Inner Vacuum Chamber (IVC) at ∼4 K. The cooling of the IVC and of the 40 K radiation shield is provided by five Pulse Tubes (PT) mounted on the OVC top-flange. The cooling of the experiment is provided by a high-power cryogen-free $^3He/^4He$ dilution refrigerator heat sunk to the IVC flange. Inside the IVC there are two radiation shields connected respectively to the Still (∼0.7 K) and to the Cold Plate (∼50 mK) of the dilution unit (DU). The innermost shield is connected to the DU Mixing Chamber (MC) to protect the experimental space. Its temperature is expected to be ∼10 mK. Due to the design of CUORE cryostat:

(1) a thermal grounding of wires at the first stage (40 K) of the pulse tubes

(as in the case of SCUBA II[3]) is not feasible;

(2) to make a good thermal contact at 4 K by pressing wires cause electrical shorts of wires which are twisted pair.
(3) for such a large numbers of wires (2600), sinking heat at 4 K by conduction using glues is alike hazardous.

Hence, we suggest a fully radiative thermal sinking of wires, by the use of four exchangers at 10-4 K, 4 K, 0.7K and 50 mK respectively. We hypothesize a total length of wires of 3750 mm; the resulting thermal load onto the sinks are evaluated. It is worth noting that such wire length could be slightly reduced in order to lower the input time constant of the front-end amplifiers[4] .

2. Wiring layout

Wiring to the CUORE detectors is made of ∼2600 (1300 twisted pairs) CuNi clad niobium titanium wires, woven into ribbon cables[5] . Each ribbon cable is heat sunk at the 4 K, 0.7 K , 50 mK and 10mK stages before reaching the detectors. To compensate for the crucial lack of grounding at 40 K, peculiar thermal exchangers are proposed. The wiring layout is depicted in Fig. 1. At room temperature, the 2600 wires are soldered to 100 connectors housed in six vacuum-tight boxes. The twisted wires are soldered to PCBs which fit (and are soldered) on the connectors at 300 K.

In Fig. 2 (a) shows one box : two groups of 8 ribbons (2 x 8 x 13 = 208 twisted pairs) get out parallel through the vacuum flange. The 16 ribbons getting out from a connector box cross a 50 cm long tombak vacuum tube to reach the 4 K plate (see Fig. 2 (b)).

The silver plated shields used to reflect 300 K radiation fixed to the upper part of the ribbons. In this zone the temperature decreases from 300 to about 40 K. Below this level the ribbons cross a Continuous Radiative Heat Exchanger (CRHE) where the temperature of ribbons decreases from ∼10 to ∼4 K.

The CRHE consists of an Al tube 20 cm long, wall 3 mm, placed inside the lower part of the 40mm tombak tube. The Al tube is made up of two parts A and B. Part A is depicted in Fig. 2 (b). Part B is simply a half cylinder cover. Parts A and B are independently bolted to the 4 K flange After the insertion of the ribbons into the A part of CRHE, Part B closes the tube. Part B is also fixed to the 4 K flange.

Then ribbons enter and cover a long path inside a copper Step Radiative Heat Exchangers SRHE fixed to the 4 K plate of the cryostat. Figure 3 (a)

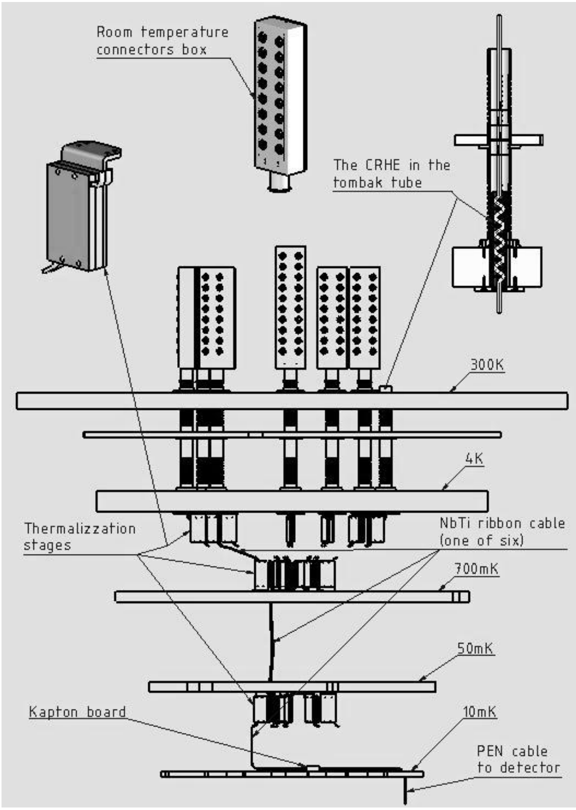
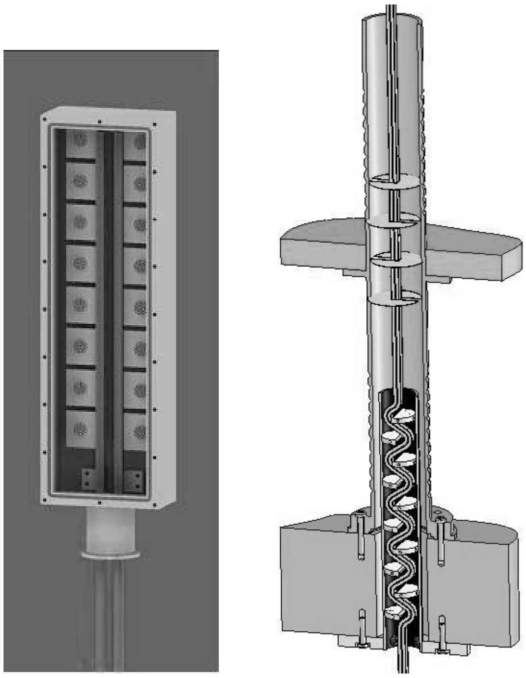


Fig. 1: Scheme of wiring.

shows how ribbons are arranged inside a SRHE and how two SRHEs (six in reality) are paralleled. The same type of SRHE is adopted for the sinking posts at 0.7K (Still) and 50 mK (shield). At the 10 mK sink the wires are soldered to planar, Kapton ZIF connectors (see Fig. 3 (b))

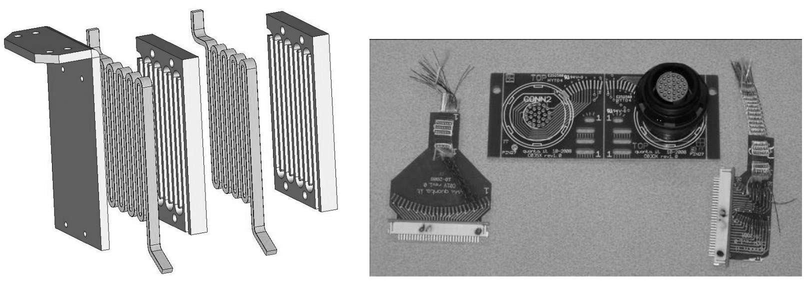
3. Power budget

Table I-III report the budget of power loading onto the sinks in the hypothesis of perfect thermal grounding. The experimental check of this assumption will be done in the next future.



(a) (b)

Fig. 2: (a) One open connector box. (b) Wire ribbons in the vacuum Tombak tube Shields to reflect 300 K radiation: upper surfaces are silver plated. CRHE: Ribbons are inserted in the part A.



(a) (b)

Fig. 3: (a) Paralleling 2 SRHE (b) Photograph of ribbon electrical end connections.

Table 1: NbTi/ CuNi wires load. g.f.=geometrical factor. P_{tot} is for ~ 2600 wires.

T range	L(m)	Diameter	Wire g.f.	Clad g.f.	P per wire (W)	P per strip (W)	P_{tot} (W)
300-4K	1.24	$1.00 \cdot 10^{-4}$	$1.78 \cdot 10^{-8}$	$4.55 \cdot 10^{-9}$	$2.2 \cdot 10^{-5}$	$5.61 \cdot 10^{-4}$	$5.61 \cdot 10^{-2}$
4-0.7K	1.3	$1.00 \cdot 10^{-4}$	$1.57 \cdot 10^{-8}$	$4.00 \cdot 10^{-9}$	$8.03 \cdot 10^{-9}$	$1.68 \cdot 10^{-7}$	$2.27 \cdot 10^{-5}$
0.7-0.05 K	1.0	$1.00 \cdot 10^{-4}$	$3.93 \cdot 10^{-8}$	$1.00 \cdot 10^{-8}$	$4.0 \cdot 10^{-10}$	$1.0 \cdot 10^{-8}$	$1.0 \cdot 10^{-6}$
0.05-0.01K	0.4	$1.00 \cdot 10^{-4}$	$1.96 \cdot 10^{-8}$	$5.00 \cdot 10^{-9}$	$1.90 \cdot 10^{-12}$	$4.94 \cdot 10^{-11}$	$4.94 \cdot 10^{-9}$

Table 2: Nomex tissue load.

T rang	Lenght (m)	Thickness	Geometrical factor	Power per strip	P_{tot} 100 strips
300 - 4K	1.24	0.01	$1.14 \cdot 10^{-6}$	$3.2 \cdot 10^{-4}$	$3.2 \cdot 10^{-2}$
4 - 0.7K	1.3	0.01	$1.00 \cdot 10^{-6}$	$6.0 \cdot 10^{-8}$	$6.0 \cdot 10^{-6}$
0.7 - 0.05 K	1.0	0.01	$2.50 \cdot 10^{-6}$	$1.2 \cdot 10^{-9}$	$1.2 \cdot 10^{-7}$
0.05 - 0.01K	0.4	0.01	$1.25 \cdot 10^{-6}$	$3.56 \cdot 10^{-12}$	$3.56 \cdot 10^{-10}$

Table 3: Total load to the sinks.

T	Power per strip	Total W
4K	$2.0 \cdot 10^{-3}$	$1.98 \cdot 10^{-1} + 045 from CRHE = 0.47$
0.7K	$3.3 \cdot 10^{-7}$	$7 \cdot 10^{-6}$
0.05 K	$1.3 \cdot 10^{-8}$	$1.2 \cdot 10^{-6}$
M.C. 0.01K	$5.3 \cdot 10^{-11}$	$5.29 \cdot 10^{-9}$

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