

Cryomirror:

A Fast Cooling System for Cryogenic Gravitational Wave Interferometers

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Status

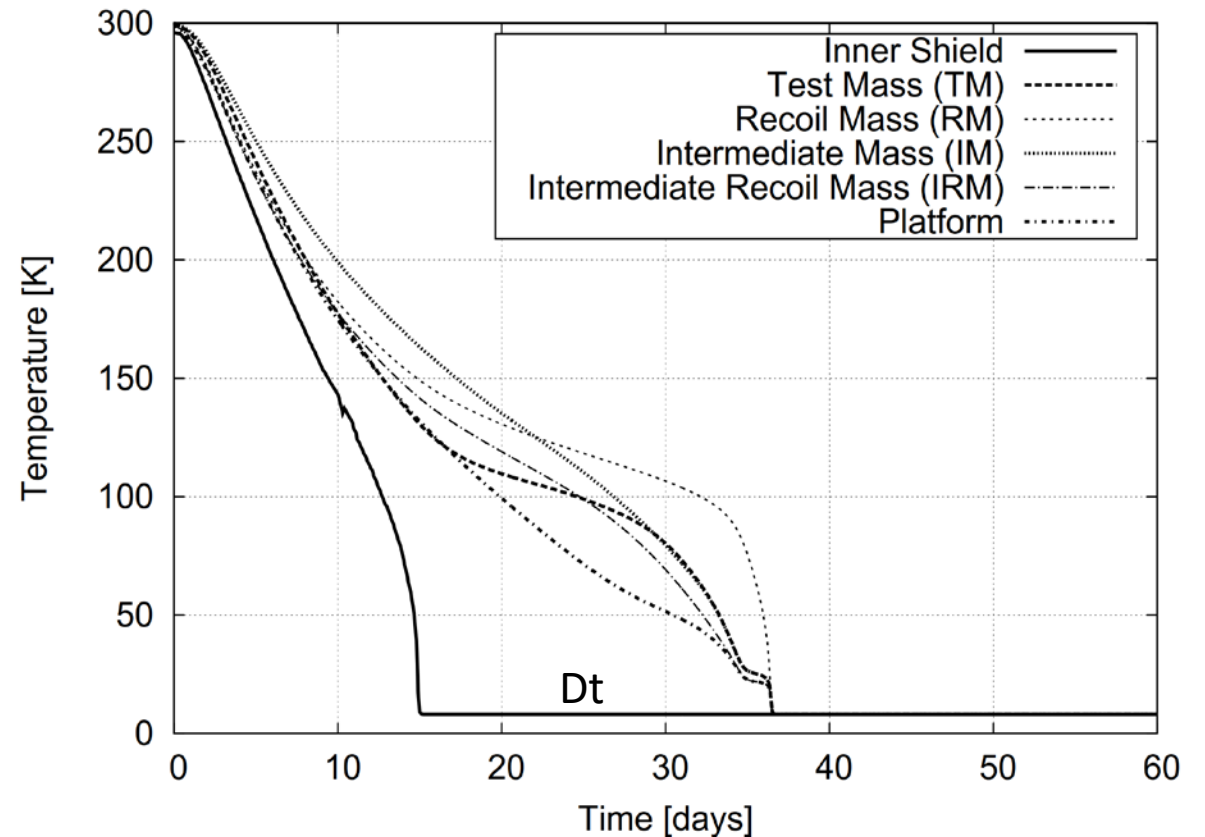
- Future upgrades or completely new instruments for Gravitational Waves detection, like the Einstein Telescope (ET) or the Japanese KAGRA (under construction) will be operated in cryogenic conditions and aim to increase the sensitivity by a factor of few to ten.
- The thin fibers used to suspend the mirrors are usually designed with high priority to the minimization of noise while the detector is in operation. This poses a serious limit during initial cool-down, when the required heat flux is much larger. For example, the time required for cooling the KAGRA mirrors from room temperature to the goal 20 K is 1 full month.
- This clearly represents a severe constraint on the schedule of commissioning and maintenance activities. For ET the situation will be even worse due to larger payloads and even weaker thermal links.

Cryomirror project

- The “Cryomirror” project aims at *disentangling the process of initial cooldown of the mirrors from that of keeping them cold during operation*, exploiting the widely different set of requirements and constraints of the two phases.
- This will be obtained by establishing an efficient *temporary thermal link* between the mirror and a cold source; the link will be disengaged once the target temperature has been reached, leaving the cooled mirror ready for operation.
- **The goal is to lower to the order of 1 week** the time required for cooling the payload of an ET-like detector, substantially improving the overall duty cycle and with no negative impact on the mechanical noise isolation performance during operation.

KAGRA

- The main technological challenge is to keep the mirrors cold without spoiling the extreme vibration isolation that characterizes the interferometers.
- Efficient extraction of the heat deposited on the mirror requires *strong thermal links* to the cold source. These links inevitably act as a short-circuit for the suspension system, *transmitting unwanted vibrations to the mirror*.
- The common design choice is to connect the thermal link towards a mechanically pre-isolated cold finger to the penultimate mass.



Goal of the project

- The goal of the “Cryomirror” project is to *provide a solution to the problem of the long cooling times* for a cryogenic GW interferometric detector *while not spoiling its sensitivity when in operation*.
- The approach that we propose here is to *disentangle the problem of initial cool-down of the mirror from the problem of keeping it cold when in operation*.
- ***The core of this project will thus be the design and realization of a movable thermal link prototype*** compliant with the requirements and to measure its performances, primarily in terms of cooling rate and of mechanical forces exerted on the payload.
- **We target a *Dt* of one week or less.**

In KAGRA the testmass reaches the goal temperature of 20K with a *Dt* of 22 days.

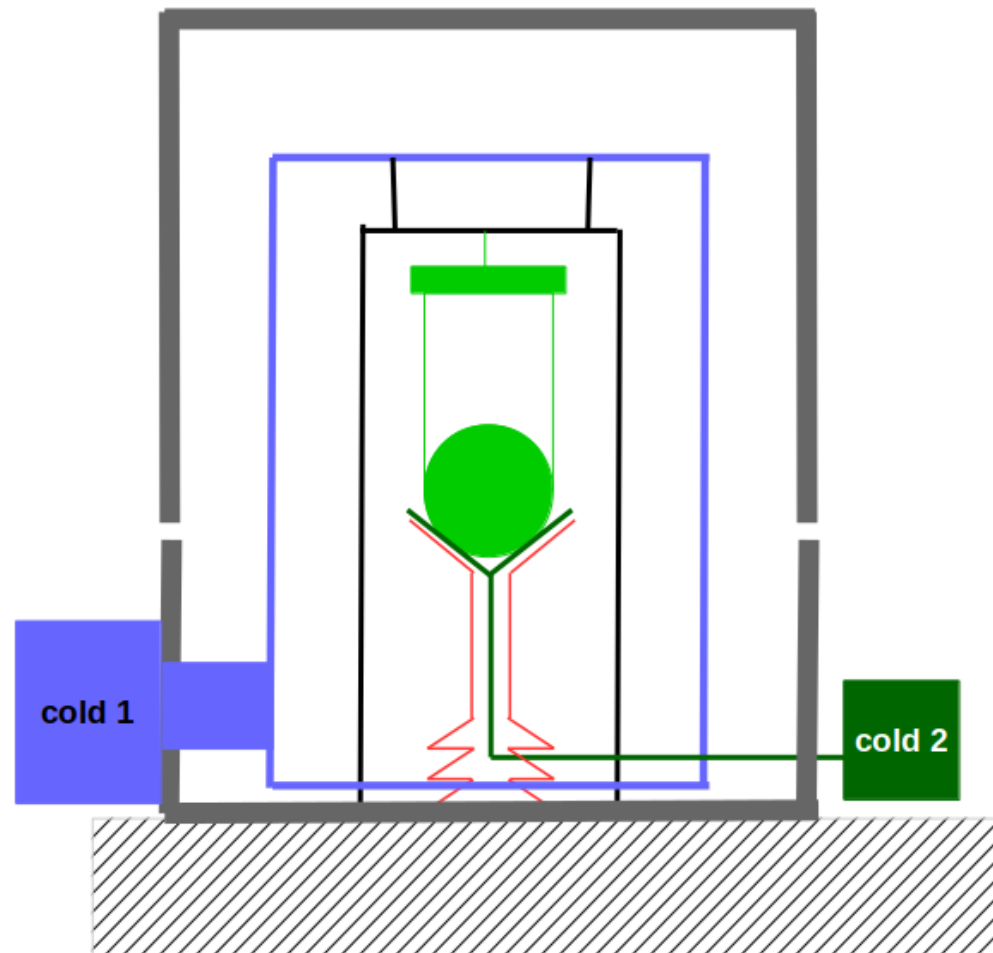


Figure 3: conceptual scheme (not to scale) of the cryogenic facility to be installed at LNL for testing the prototype. The dummy payload is shown in green, the movable link in red, the vacuum chamber in gray (with separated top and bottom part, see WP2), the cold1 and cold2 sources are shown respectively in blue (as the shields) and dark green, the frame to hold the payload and the shields in black.

Cryomirror project and Einstein Telescope

- The timing of this proposal perfectly matches the ET roadmap: the ET team is planning to produce a technical design document, to constitute the base for a proposal for funding, in 2023.
- This project is strategic in defining the Italian participation into the international Einstein Telescope (ET) consortium which is one of the main activities of CSN2 of INFN. Our project attacks a key technological problem for future GW cryogenic instruments, and as a detector development, this activity falls strategically into CSN5 scope.
- The relevance of the project for the international GW community is demonstrated by the letters of endorsement of the international coordinator of the ET project, Michele Punturo, of the PI of the KAGRA project, the Nobel Laureate Takaaki Kajita, and of the KEK Chief Scientist of the KAGRA Cryogenic Group, Takayuki Tomaru.

Organization

- **WP1 Definition of requirements and control observables**
- *WP2 Development of cryogenic test facility*
- **WP3 Development of the dummy payload**
- *WP4: Development of the movable thermal link prototype*
- *WP5: Development of in-loop and out-of-loop sensors*
- *WP6: Development of the payload/device interface*
- **WP7: Functional test of the prototype**
- *WP8: Tests of high-vacuum compatibility*

Unit	participant	YEAR 1									YEAR 2									YEAR 3								
		WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	tot	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	tot	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	tot
Firenze	Filippo Martelli	1		1						2			2						2								1	1
	Francesco Piergiovanni	1		1						2			2						2								1	1
Padova	Bazzan Marco						1		1	2						2		1	3				1		0		2	3
	Ciani Giacomo	1			1	1				3				1	1		1		3				1			3		4
	Conti Livia	1			2	1				4				3	1		1		5				2			3		5
	Taffarello Luca		1					1		2	1					1			2							1	1	1
Perugia	Zendri Jean-Pierre	1								1				1					1							1		1
	Helios Vocca	1		2						3			2		1				3				1			1		2
	Flavio Travasso	1		2						3			2						2				1			1		2
Trento	Antonio Perreca	1			1	1			3				1	2				3				1	1		1		3	
total months per WP per year		8	1	6	4	3	2	0	1	25	0	1	8	6	5	3	2	1	26	0	0	0	7	1	0	13	3	23

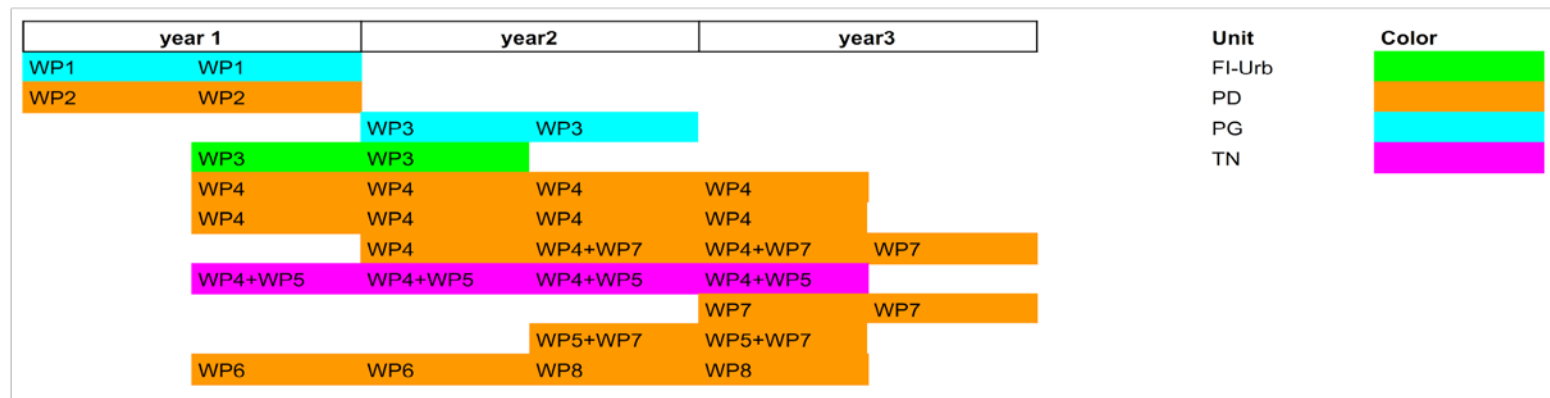


Figure 5: (top) table of months/person dedicated to each WP by participant. (bottom) table of post-doc contracts allocation by time and unit, with indication of main activity

Budget

	YEAR 1					YEAR 2					YEAR 3				
	consumable	equipment/ apparatus	travel	personnel	outsourcing	consumable	equipment/ apparatus	travel	personnel	outsourcing	consumable	equipment/ apparatus	travel	personnel	outsourcing
Firenze-Urbino	2000	0	2500	12500	0	4000	10000	2500	12500	0	0	0	500	0	
Padova	30000	75000	10500	62500	30000	55000	110000	17000	112500	40000	35000	5000	15500	100000	0
Perugia	8000	0	4500	25000	0	16000	40000	4250	25000	0	0	0	1000	0	0
Trento	0	0	2250	12500	0	30000	30000	3750	25000	0	10000	0	2250	12500	0
SUBTOTAL	40000	75000	19750	112500	30000	105000	190000	27500	175000	40000	45000	5000	19250	112500	
TOTAL	996500														

Figure 6: budget request breakdown by unit and year

Cryomirror Firenze-Urbino

- Responsabile locale: Filippo Martelli (20%)
- Partecipanti: Francesco Piergiovanni (20%)
- The group will develop the mirror suspension fibers (main candidates are fused silica, silicon or sapphire fibers), thanks to its expertise on the realization and characterization of the suspension fibers for the AdVirgo which were tested in its laboratory

