GIANO: pre-slit optics & telescope interface

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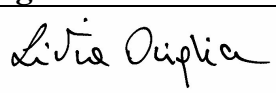
Livia Origlia	INAF - Bologna	
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Change Record:

Issue	Date	Section affected	Reason
1.0	10/06/2009	All	First issue
2.0	30/10/2009	4,5,6	New information on fibres, pre-slit lenses and design.
3.0	10/08/2010	4	Include first tests of mechanical interface at TNG

Content

1 Scope

This document presents a tradeoff analysis and risk assessment of two possible configurations for the GIANO pre-slit optics and telescope interface. This follows from a specific request by the TNG to study solutions for mounting the instrument at a focal station of the Nasmyth-A. It is also part of the documentation requested by the Dipartimento Progetti of INAF in view of the acceptance tests and commissioning of GIANO.

2 Overview

GIANO was designed to be located at the only available focal station, namely the Nasmyth B. However, in March 2009 the TNG announced that new focal stations could become available at the Nasmyth A, and asked our team to study the possibility to locate GIANO there.
In the same period, we were also able to have first quantitative measurements of the performances of IR fibers, thanks to a collaboration with ESO in the context of the SIMPLE E-ELT project. These laboratory measurements are extremely encouraging as shown in Section 4, thus making it very attractive the option of fiber-feeding GIANO, at least for the first science operations.

The scientific impact of the two possible feeding solutions, namely with fibers or with a standard pre-slit optics is discussed in Section 3.
The fiber fed configuration for the Nasmyth A is described in Section 4. The pre-slit optics configuration as originally designed and built for the Nasmyth B focal station, is presented in Section 5.

3 Scientific impact

GIANO-TNG in the high spectral resolution mode is a strategic instrument in the following hot scientific areas

- quantitative spectroscopy of brown dwarfs
- chemistry & kinematics of cool stellar populations
- search for earth-like planets around low mass stars
- stellar magnetic fields
- chemistry & kinematics of extra-galactic stellar clusters
- galaxy nuclei
- DLA systems illuminated by bright/lensed QSOs and GRBs

Broadly speaking, typical reference limiting magnitudes (within 1 magnitude) are those achieved by the 2MASS sky survey. The exact values depend on the selected spectral resolution and exposure time, representative values are listed in Table 3.1 where we also include the different efficiencies between the Nas-A (fiber-fed) and Nas-B solutions.

From the observational point of view, the main targets of GIANO in the high resolution mode are thus point sources, either single stars or unresolved, compact objects (e.g. distant stellar clusters and galaxy nuclei). Hence, there is not a primary, scientific need for using all the slit length (6”) other than for nodding and sky subtraction purposes.
However, the same requirements can be fulfilled with two fibers along the slit, which simultaneously measure the object and the sky, and nodding the object between the two fibers. Therefore, when using GIANO in the high resolution mode, a standard feeding through a pre-slit optics or through fibers are equivalent in terms of observational strategy.

A fiber-fed instrument gives a major scientific advantage in the measurement of precise radial velocities, since fibers provide the best scrambling. Simultaneous arc lamps measurements can be obtained by taking advantage of the multiple non- destructive read-out of the IR array, thus avoiding the use of the absorption cell, which turned out to be much less efficient than expected, with a limited number of usable lines and not sufficiently well distributed in wavelength.

Finally, in the specific TNG environment, fibers probably allows the easiest and fastest interfacing of GIANO at the telescope, minimizing the time for technical commissioning and speeding up the procedures of first light and first science observations.
In this respect, it is worth noticing that the main features of a fiber fed system can be also tested and scientifically characterized, in a kind of pre-commissioning, directly in Arcetri, by pointing at the sky using a small telescope and taking advantage of the *in situ* laboratory facilities for fine tuning.
A telescope interface through a standard pre-slit optics can remain an open option which could be implemented at later time if scientifically relevant.

Table 3.1: Expected performances of GIANO.

Limiting magnitudes (Vega) for spectra with the 1" (R=25,000) slit, T_{int}=2hr, at different S/N ratios (per resolution element). First entry is for the fiber-fed configuration, while the second entry is for direct feeding from the telescope.

Band (λ)	S/N values					
	10	**20**	**50**	**100**	**300**	**10^3**
Z (0.95 μm)	16.0	15.2	14.0	13.0	11.0	8.5
	16.3	15.5	14.3	13.3	11.3	8.8
Y (1.05 μm)	16.3	15.5	14.3	13.3	11.3	8.8
	16.6	15.8	14.6	13.6	11.6	9.1
J (1.25 μm)	16.3	15.5	14.3	13.3	11.3	8.8
	16.6	15.8	14.6	13.6	11.6	9.1
H (1.65 μm)	16.1	15.3	14.2	13.2	11.2	8.7
	16.4	15.6	14.5	13.5	11.5	9.0
K (2.20 μm)	15.2	14.5	13.4	12.4	10.7	8.3
	15.4	14.7	13.6	12.6	10.9	8.5

4 Fiber fed interface at the Nasmyth A

The spectrometer is positioned on the floor of the Nasmyth room, close to its dedicated electronics rack and LN2 plant (see Figure 4.1). We do not expect problems related to the vibrations induced by the dome movement, since this should mainly occur during the telescope slewing.

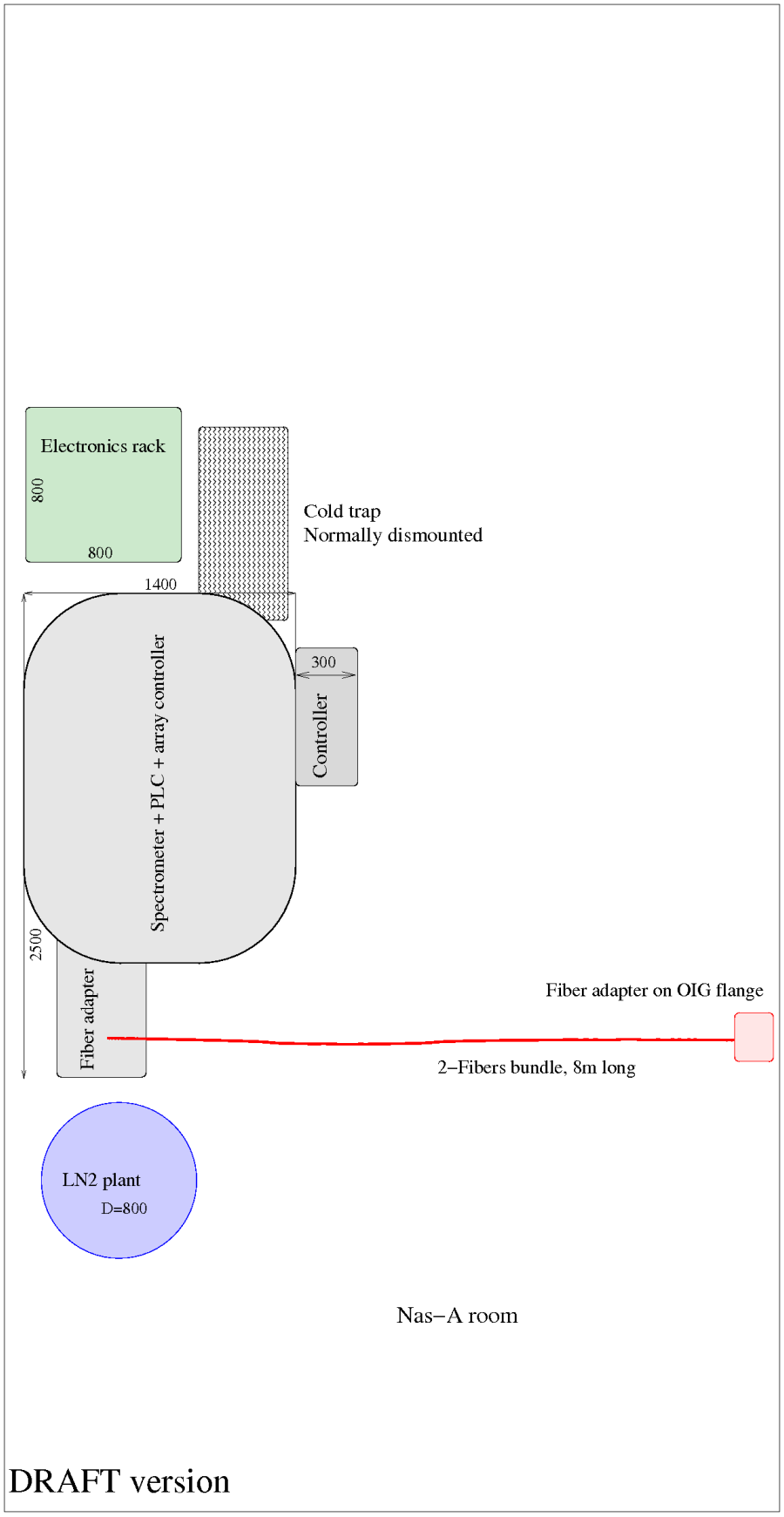

Figure 4.1: Schematic layout of GIANO positioning in the Nasmyth A room.

The spectrometer is fed through a bundle of 2 ZBLAN fibers manufactured by IR-photonics. These are standard off-the-shelf products with a core of 85µm, which corresponds to a sky-projected angle of 1", and a cladding of 125µm. These fibers are quite transparent in the wavelength range of interest (Fig. 4.2) and have very good values of efficiency and focal ratio degradation (see Fig. 4.3, based on laboratory measurements conducted at ESO).

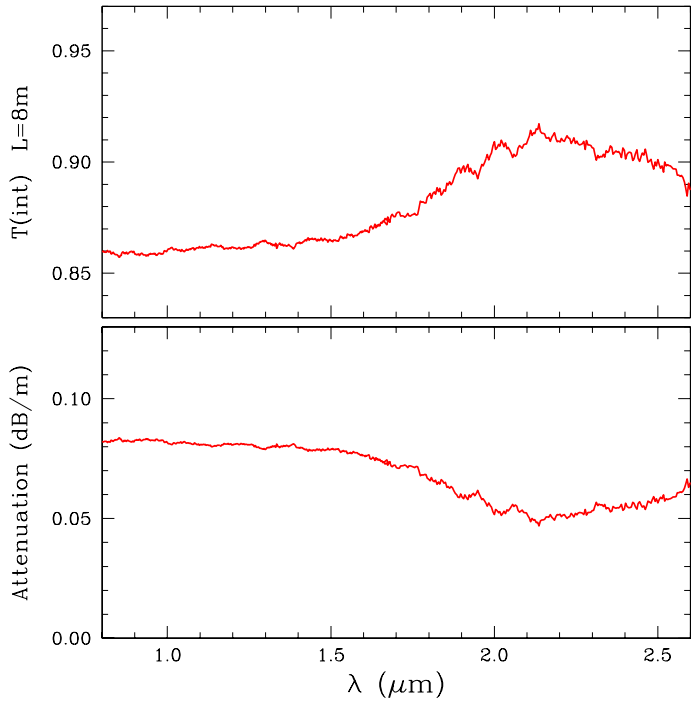

Figure 4.2: Lower panel: measured attenuation of the ZBLAN glass used to manufacture the GIANO fibers (from IRphotonics). Upper panel: derived internal transmission of the 8m-long fiber bundles purchased for GIANO.

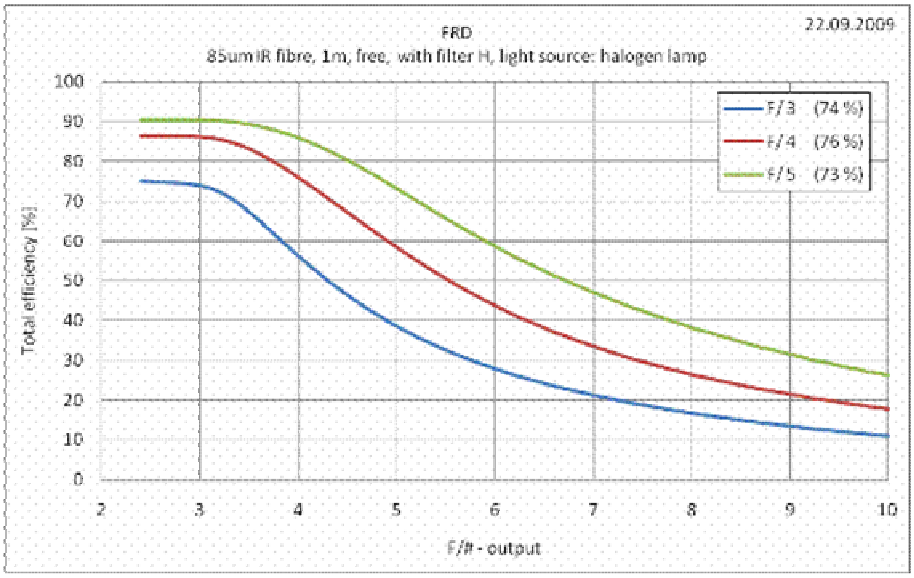

Figure 4.3: Measurements of efficiency and focal ratio degradation on the commercial ZBLAN fibers for the GIANO-fiber interface. The data displayed are the *absolute efficiency* of the fiber, i.e. the ratio between the light measured within a given F/# at the fiber output, and the total light entering the fiber from the opposite side. The numbers in the upper-right panel are the absolute efficiency of the fiber for F/# output = F/# input.

The two fibers are aligned and mounted by the company inside a custom connector. The fiber centers are at a distance of 0.25mm, equivalent to a sky projected angle of 3". The bundle is inside a steel jacket, in order to protect these fragile fibers from bending and breaking. The drawings of the bundle, jacket and connectors are displayed in Figure 4.4.

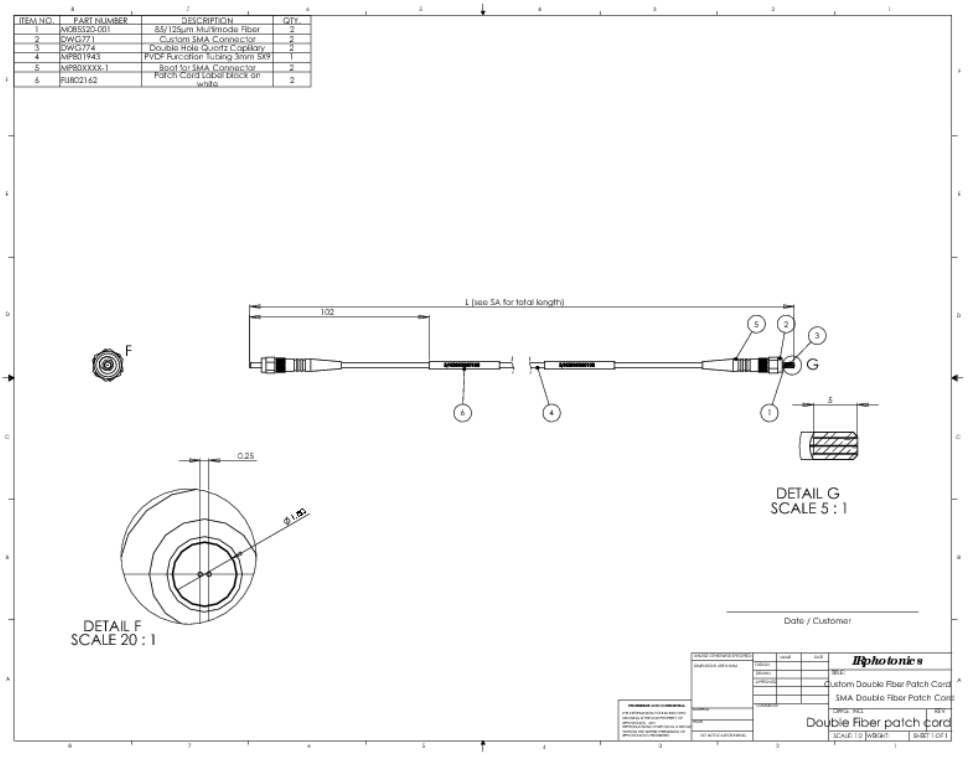

Figure 4.4: Design of the ZBLAN fiber bundle for GIANO.

Since the fiber steel jacket has a very limited flexibility, the optimal length and path of the fiber can only be determined by testing/positioning an empty jacket at the telescope. To this purpose we also ordered two empty jackets of 10m length. These were positioned at the Nas-A to determine the optimal length of the fiber: 8m. The contract with the company also included a pre-selection of the ZBLAN batch to achieve the highest possible transparency around 0.9µm. The selected batch has superb transmission (Fig. 4.2). Four bundles were already delivered to the TNG.

The fiber can be conveniently connected to the TNG through the hole/flange previously used for OIG. The optical elements are listed in Table 4.1. All the elements are already in hand. The mechanical structure is shown in Fig. 4.5. It was tested at the TNG in July 2010 (see Fig. 4.6). It fulfills the specifications for visiting instruments (TNG-SPE-TEC-001-0001-V1.0, March 10 2010).

To avoid mechanical stress on the fiber and simplify telescope operations when GIANO is not observing, the fiber pre-slit module is mounted on a GECO-like bearing structure which maintains a fixed orientation relative to gravity, independently of the position of the Nasmyth de-rotator.
The mounting tolerance in the Z direction (focusing) is ±0.1 mm. The mounting tolerances in the X-Y direction depend on the adopted system for auto-guiding. If the IR camera is used then the tolerances are lax, i.e. ±1 mm, because the auto-guider is fixed relative to the fibers. If the off-axis guider of the TNG is used, instead, the tolerances are tight, i.e. better than ±0.01 mm, because the guiding precision depends on the positioning of the fiber relative to the mechanical axis of the de-rotator.

Table 4.1: Optical elements of the TNG-NasA GIANO fiber interface.

Element	Surface parameters	Position relative to TNG focus					Size (mm)	Note
		X (mm)	Y (mm)	Z (mm)	α (deg)	β (deg)		
TNG M1		0.00	1200.00	4100.6	90.00	0.00		
TNG M2		0.00	-4733.3	4100.60	90.00	0.00		
TNG M3		0.00	0.00	4100.60	45.00	0.00		
Beam splitter	Flat pellicle	0.00	0.00	65.00	-45.00	0.00	Ø 25.4	(1)
F/11-F/5 focal adapter lens	CaF_2 Convex-plano R=-21.7	0.00	0.00	58.50	0.00	0.00	Ø 12.7 thick=2.5	
Fibers	F/5 focal plane	0.00	0.00	30.60	0.00	0.00	2 x Ø 0.085 dist=0.25	(2)
Acquisition and guiding system, fed by reflected light from beam-splitter								
Folder	Flat mirror	0.00	-70.00	65.00	-45.00	0.00	Ø 25.4	
Guider lens #1	TK23 Meniscus R1=76.76 R2=35.51	0.00	-70.00	25.00	0.00	0.00	Ø 40.0 thick=15.0	(3)
Guider lens #2	CaF_2 Biconvex R1=35.51 R2=-116.42	0.00	-70.00	10.00	0.00	0.00	Ø 40.0 thick=25.0	(3)
Guider lens #3	CaF_2 Biconvex R1=45.08 R2=-14.454	0.00	-70.00	-73.60	0.00	0.00	Ø 24.0 thick=20.0	(4)
Guider lens #4	NBK7 meniscus R1=-14.454 R2=-35.51	0.00	-70.00	-93.60	0.00	0.00	Ø 24.0 thick=8.0	(4)
IR camera	F/8.9 focus f.o.v. 1 arcmin	0.00	-70.00	-181.60	0.00	0.00	320x256 pix 30 μm pix	
Fiber viewer and aligning system, fed by reflected light from fibers and beam-splitter								
Folder	Flat mirror	0.00	70.00	65.00	-45.00	0.00	Ø 25.4	
View lens #1	TK23 Meniscus R1=108.90 R2=42.46	0.00	70.00	-15.00	0.00	0.00	Ø 36.0 thick=6.0	(5)
View lens #2	CaF_2 Biconvex R1=42.46 R2=-127.35	0.00	70.00	-21.00	0.00	0.00	Ø 36.0 thick=12.0	(5)
View lens #3	CaF_2 Biconvex R1=52.00 R2=-67.61	0.00	70.00	-35.00	0.00	0.00	Ø 36.0 thick=10.0	(6)
View lens #4	NBK7 meniscus R1=-67.61 R2=-522.40	0.00	70.00	-45.00	0.00	0.00	Ø 28.0 thick=6.0	(6)
CCD camera	F/5.6 focus	0.00	70.00	-157.70	0.00	0.00	256x256 30 μm pix	

Notes
(1) Commercial (Thorlabs), uncoated pellicle, reflects ~8% of light to guider optics.
(2) Bundle of 2 fibers.
(3,4,5,6) Glued doublet.

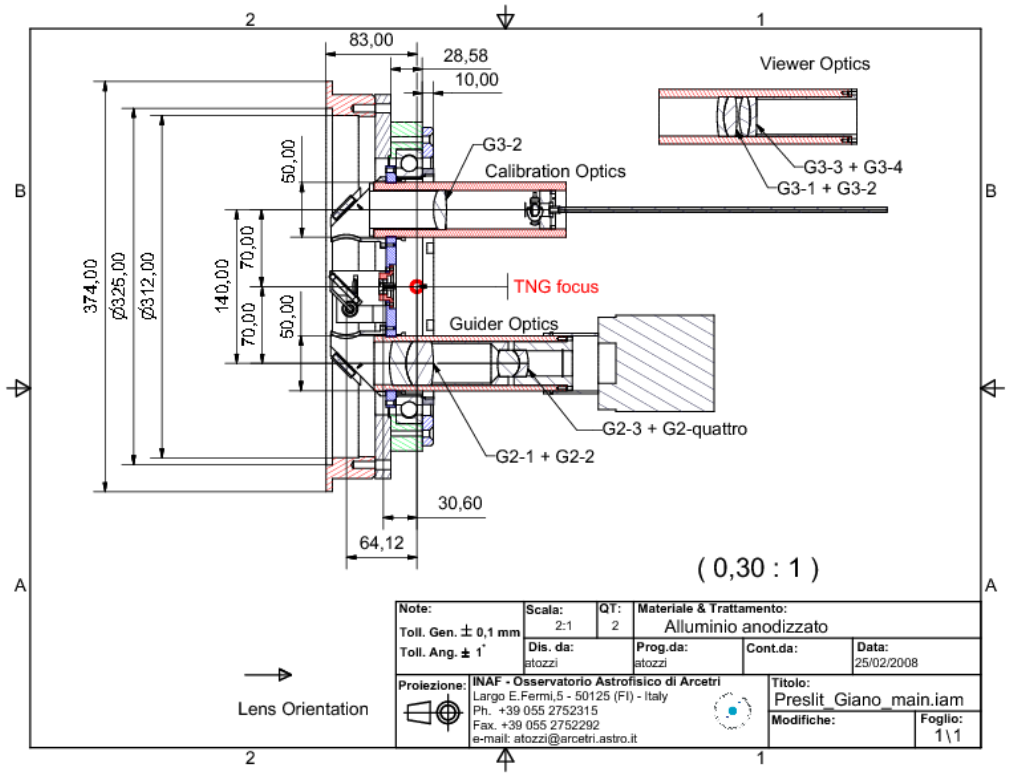

Figure 4.5. Mechanical drawing of the fiber-GIANO interface.

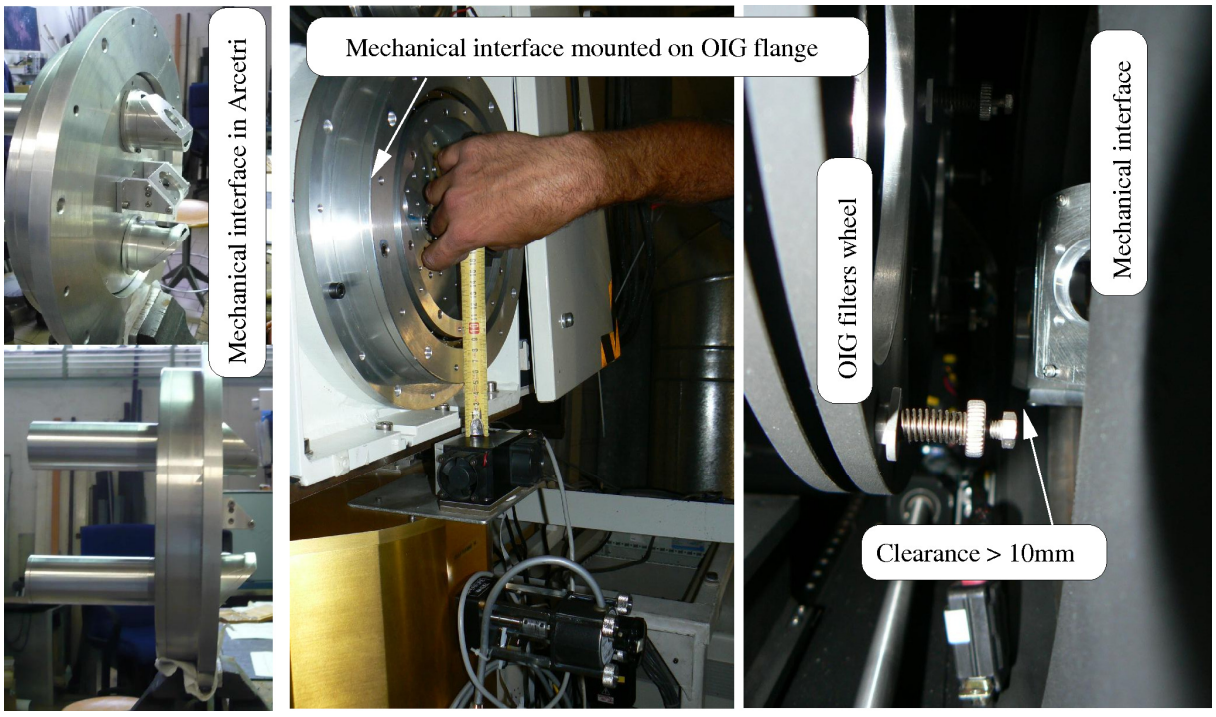

Figure 4.6. Pictures of the mechanical interface assembled in Arcetri and during the tests at the TNG in July 2010.

4.1 Implementation at the Nasmyth A

The fiber pre-slit system can be mounted, aligned and tested independently of the GIANO spectrometer.
The focusing and positioning of the image on the fiber can be measured using the viewing channel/CCD while pointing at a bright star.
Since the relative positions of the fiber and the image on the guiding camera is fixed, acquisition and guiding will simply consist of centring and maintaining the image at a given (fixed) X,Y position on the guiding camera.
The program used for guiding will be a simplified version of that currently used for SARG. The communications between the auto-guide PC and the camera will be similar to that used for the other technical cameras at TNG. A preliminary version of the software was already developed and tested at TNG by Marcello Lodi.
Off-axis guiding using the standard TNG guiding system is also possible by observing with the de-rotator tracking the object. This mode requires an accurate measurement of the position of the fibers relative to the de-rotator mechanical axis. This shift will be compensated and corrected using the compensation algorithm already existing in the program for auto-guiding.

5 Pre-slit optics at the Nasmyth B

The pre-slit system for the Nasmyth B is detailed in the SPIE paper by Bruno et al. 2006, SPIE 6269, 129. The optical elements, described in Table 5.1, were specifically designed to be mounted using the available space between SARG and DOLORES. It is unlikely that the same design could provide a convenient solution for mounting the spectrometer at a different focal station or position. Nonetheless, the optical elements could be re-arranged and/or re-designed to adapt the pre-slit system to the current (or future) mechanical layout of the Nas-A interface. For example, using a first doublet with a longer focal length we can position GIANO farther from the TNG focus, on a platform attached to the telescope fork leaving the clearance necessary to the rotation of NICS.
The optical elements and mechanical mounts are already in hand, except for the second lens of the first doublet which was damaged by the manufacturer during the last phases of polishing (Fig. 5.1). M4 should be mounted on the first slide of DOLORES (Fig. 5.2). The first doublet should be mounted on a flange of DOLORES (Fig. 5.3). Positioning tolerances are lax, i.e. ±1 mm.

Table 5.1: Optical elements of the TNG-Nasmyth B GIANO pre-slit system.

Element	Surface parameters	Position relative to Nasmyth B flange						Size (mm)
		X (mm)	Y (mm)	Z (mm)	α (deg)	β (deg)	γ (deg)	
TNG M1		0.00	1200.00	3600.60	90.00	0.00	0.00	
TNG M2		0.00	-4733.3	3600.60	90.00	0.00	0.00	
TNG M3		0.00	0.00	3600.60	45.00	0.00	0.00	
M4	Flat mirror	0.00	0.00	-200.00	45.00	0.00	0.00	Ø 76.2
Focal plane	dummy surface	0.00	300.00	-200.00	90.00	0.00	0.00	
First doublet lens #1	NPH2 meniscus R1=230.930 R2=184.801	0.00	988.70	-200.00	90.00	0.00	0.00	Ø 120.0 thick=10.0
First doublet lens #2	BaF_2 Biconvex R1=251.226 R2=-361.461	0.00	1014.39	-200.00	90.00	0.00	0.00	Ø 120.0 thick=21.0
M5	Flat mirror	0.00	1102.00	-200.00	90.00	45.00	5.00	Ø 158.4
F/17.7 focus	focal plane	976.28	1102.00	-285.41	0.00	85.00	0.00	

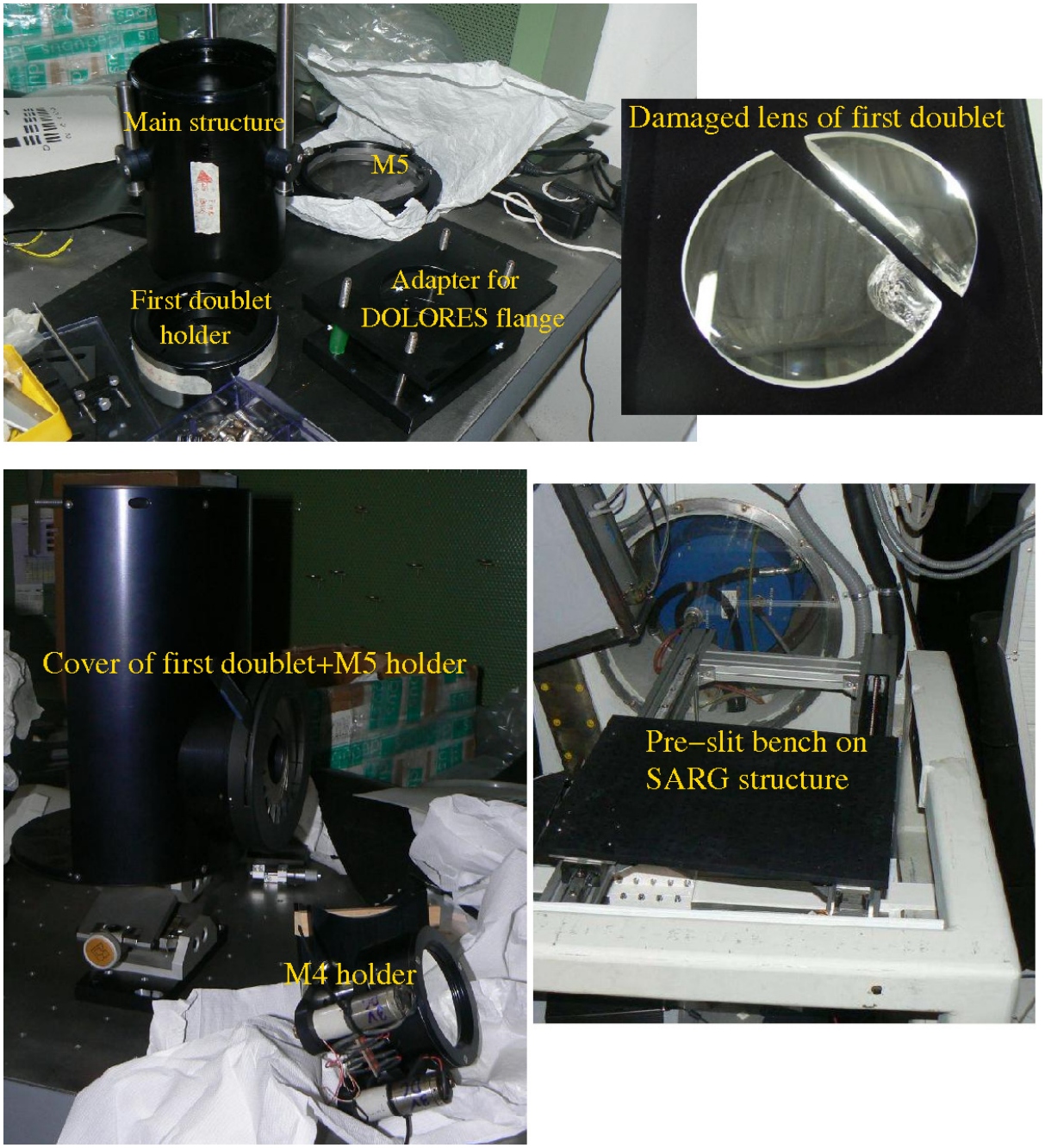

Figure 5.1: Pictures of the mechanical holder of M4, of the mechanical holder of M5+first-doublet, of the damaged lens of the first doublet, and of the optical bench mounted onto the SARG structure.

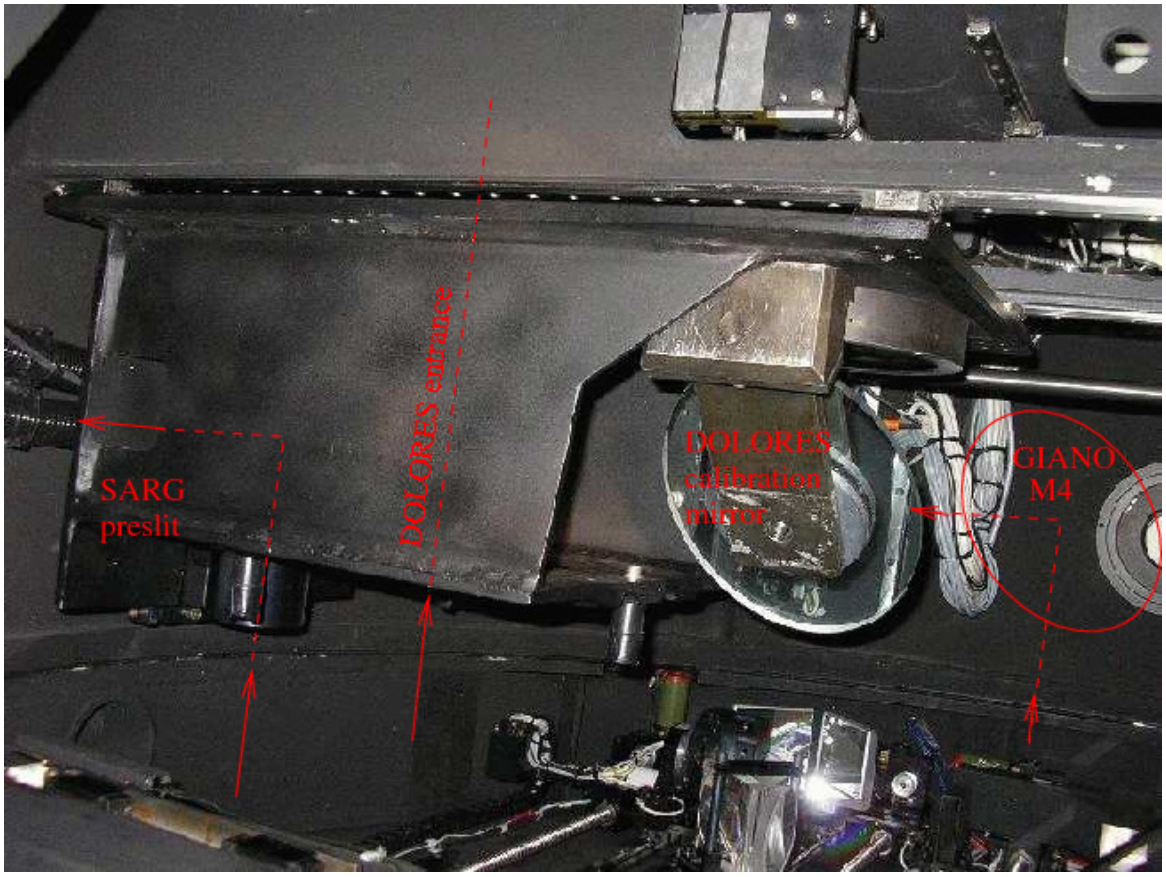

Figure 5.2: Picture of the first slide in DOLORES, the position where to mount M4 is marked .

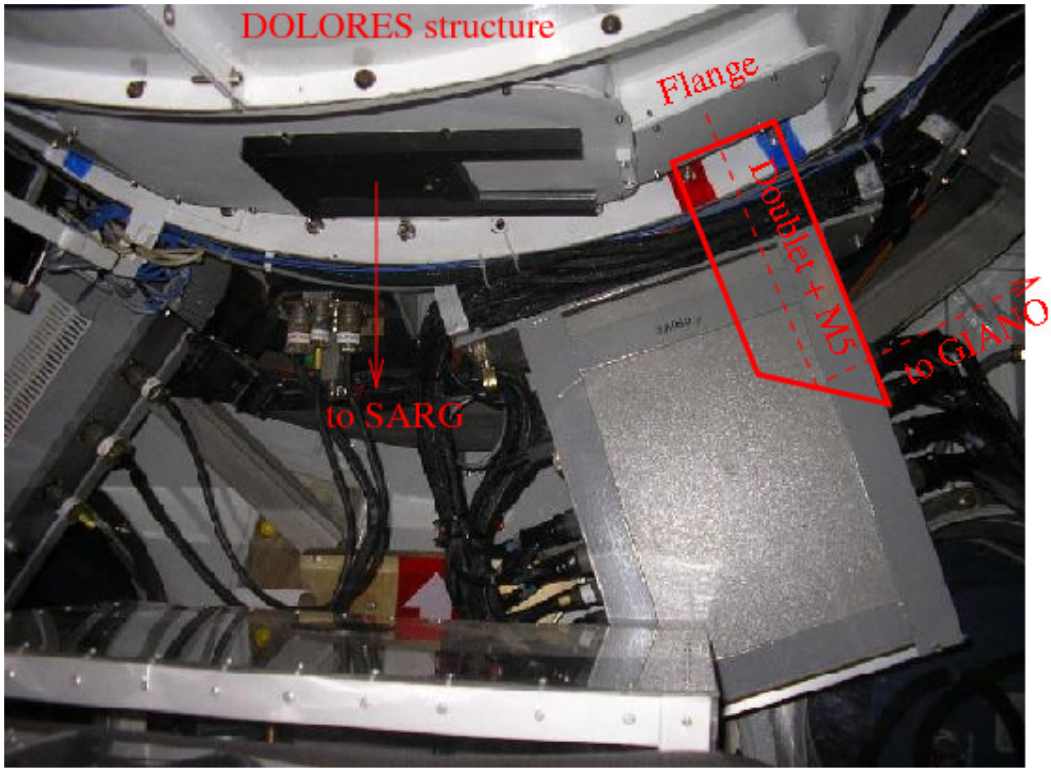

Figure 5.3: Picture of the DOLORES flange foreseen for the mount of the first doublet and M5.

5.1 Implementation at the Nasmyth B

The fine alignment of the M4 mirror will be performed using the 2-angles motorized system on the mechanical mount. The alignment of the structure holding the first doublet and M5 will be performed using the manual adjustment screws included in the mechanical systems.
These operations must be performed by TNG staff-members and/or outside persons with a good knowledge of the DOLORES instrument. The scheduling for installation depends on the available manpower.

The platform holding the GIANO spectrometer was designed and delivered by Tomelleri. The company is available to assist to the installation for 2-3 days, at a cost of 5000 Euros.

The guider system is mounted after the intermediate F/17.7 focus as described in the SPIE paper (Bruno et al. 2006). Auto-guiding is only possible using the GIANO camera, i.e. there is less flexibility than in the Nas-A configuration. The image acquisition protocol is the same as in Nasmyth A fiber interface.

6 Conclusions

In order to evaluate the best achievable interface solution for the commissioning and first light, the following actions have been undertaken

- Procurements of the fibers and steel jackets. IR-Photonics selected for us a particularly transparent batch of ZBLAN glass. The bundles were already tested in the laboratory of the company. Four bundles were already delivered to TNG.
- The optimal length and path of the fiber-bundle was determined by testing/positioning an empty jacket at the telescope.
- The opto-mechanical interface for the OIG flange was built and partially tested at the telescope.

We plan to test the fibers in combination with GIANO in Arcetri. The measurements will also include spectra of the scattered light of sun from the day-sky, of the airglow emission of the night-sky and, possibly, of the sun and/or a few bright stars.

If the procurement and tests of the fiber bundles proceed without problems, we strongly support the fiber-fed solution for the high resolution mode commissioning and first science operations. This interface is scientifically valid, technically easier and it could be largely tested and characterized in Arcetri, thus minimizing the overall impact on the TNG schedule.

Parallel to the work with the fibers, we are also available to study and design the opto-mechanical components necessary to directly feed the light from the Nas-A focus, with the spectrometer attached to the telescope fork. However, this requires updated information on the new mechanical layout of the Nas-A.