GIANO: report on 2012 commissioning and design of the new fiber interface

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Content

1 Scope

This document briefly summarizes the results obtained during the first technical commissioning of GIANO at the TNG, in July 2012. We describe, identify and discuss in some details the only important problem which we encountered, namely the very low overall efficiency of the system when observing the sky and astronomical targets. We also present the design of the new fore-optics and fiber-feed system which should solve this problem.

2 The spectrometer at the telescope

The container with the GIANO spectrometer and its accessories arrived at the TNG on Jul 12th 2012. The instrument was unpacked, re-assembled, positioned in the Nas-A room, cooled and ready for operations in only 9 days, i.e. half of the foreseen time. The first on-sky technical light was obtained on the night Jul 20th, though clouds and wind made it impossible to observe astronomical targets. More appropriate measurements, including science-grade spectra of cold super-giants, were obtained on the nights of Jul 27th to Jul 30th. The performances of the spectrometer optics and mechanics were equally good to those measured in laboratory before shipping, while the cryogenics were found to behave even better, thanks to the lower ambient pressure at the altitude of the TNG. In other words, we confirmed the values in the compliance matrices reported in Table 2.1 and Table 3.2 of our pre-commissioning report (v2, dated Apr 23th 2012). The only parameters out of specifications were the overall efficiency and the flat-field accuracy limit. These are most probably related to a bad optical coupling between the fiber and the telescope, as discussed in the next sections.

3 On-sky results

The left panel of figure 3.1 shows the cross-dispersed spectral format of GIANO. The spectrum has resolving power R=45,000 and extends over the 0.95-2.43μm range with complete spectral coverage up to 1.8μm, and 75% spectral coverage at the longest wavelengths.

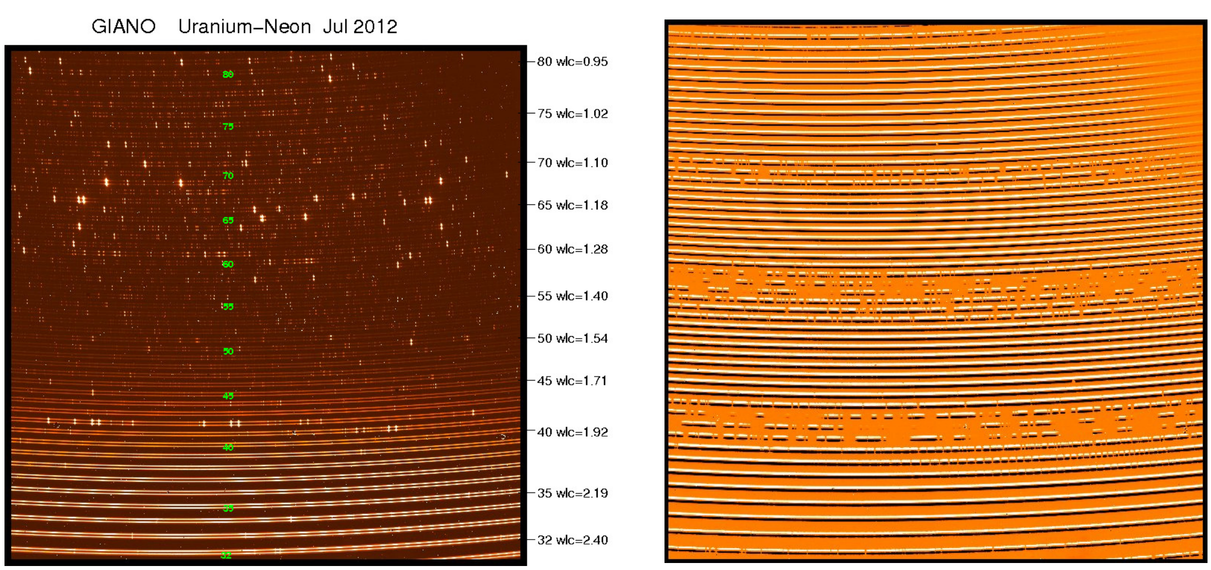

Figure 3.1. Calibration spectrum (left) and A-B subtracted spectrum of a star (right-hand panel).

The cryogenic slit of GIANO, originally built to directly look at a 0.5” x 6” portion of the sky, is illuminated by two fibers with projected diameter of 1” and spaced by 3”. In a science observation the target is first positioned on the upper fiber (“A”), then moved to the lower fiber (“B”). The positioning and tracking of the telescope are controlled by a guider camera (CCD with Z filter) fed by a beam-splitter before the fibers which reflects ~7% of the object light to the CCD. The A and B frames are subtracted to eliminate sky emission and warm pixels. An example of an A-B frame is shown in the right-hand panel of figure 3.1. The echelle orders are then rectified, extracted, flat-fielded and wavelength calibrated to obtain the required spectrum of the science target. As an example, figure 3.2 (left-hand panel) shows a portion of the extracted spectrum of four M super-giants belonging to a very young and massive star-cluster. The quality of the spectrum, which spans from 2.326μm (4300cm^{-1}) and 2.339μm (4275cm^{-1}), is of comparable S/N as the reference, highest-quality spectra of bright stars available in the literature (right-hand panel of figure 3.2).

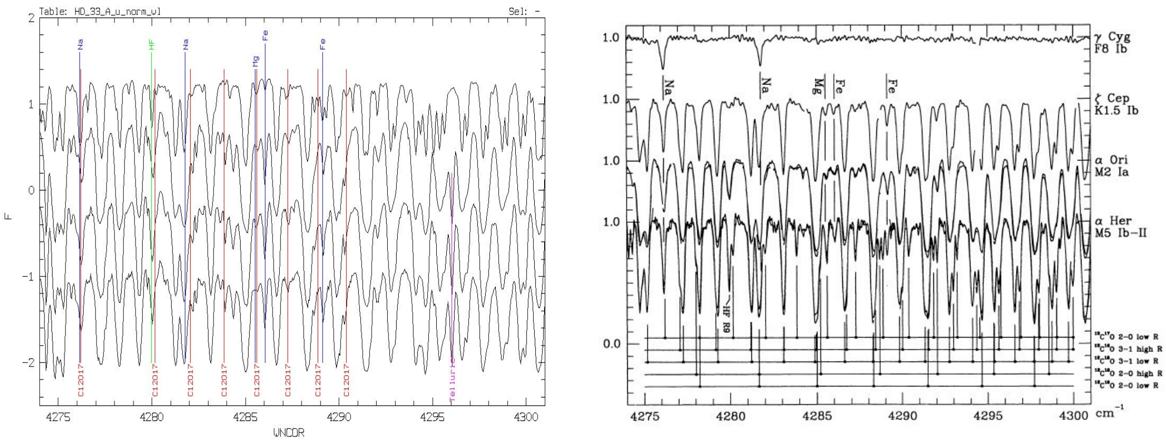

Figure 3.2. Spectra of M super-giants (left panel) compared to reference spectra of bright stars (right-hand panel)

All the system, including the target acquisition and auto-guiding, worked flawlessly. The only problems which were encountered were the very low overall system efficiency and a non-gaussian extra-noise in the spectra of bright objects. The measurements of efficiency are summarized in Table 3.1. The efficiency of the spectrometer alone, using the thermal background, was measured both in Arcetri (before shipping) and at the telescope; the two numbers are equal. We could not repeat at the telescope the direct measurements of the Sun-light performed in Arcetri, because the fibers are too short. We also performed comparative measurements with the other bundles and with commercial low-OH silica fibers. The relative efficiencies were found to be similar except, of course, in the K-band where the silica fibers become opaque.

Table 3.1 Measured efficiencies of GIANO

K(2.2μm)	H(1.65μm)	J(1.25μm)	Y(1.05μm)	Comment
0.9%	0.7%	0.4%	0.3%	GIANO+fiber+TNG, standard star, Jul 2012
13%	12%	10%	8.5%	GIANO+fiber, Sun, Apr 2012
24%				GIANO alone, thermal background

The extra-noise appears as wiggles in the spectrum with relative amplitude varying between 1% and 10% of the continuum level. The amplitude of these wiggles does not decrease when averaging several frames, i.e. they limit the S/N limit achievable with the spectrograph. The effect is attributable to fiber modal-noise, whose amplitude increases when the fiber is badly illuminated, an effect which we clearly noticed when observing bright stars with the defocused telescope. We therefore suspect that the extra-noise is produced by a bad illumination of the fiber from the telescope. The modal-noise can be cured by shaking the fiber during the integration, for which we developed an emergency human-driven system (see figure 3.3). We plan to include an automatic device in the new pre-slit system.

Figure 3.3 Human-driven fiber-shaker, used to decrease the fiber modal-noise during the observations.

4 The telescope interface

GIANO was originally designed to be located at the Nasmyth B, fixed to the telescope fork and directly fed from the telescope light (i.e. similar to SARG). Following the requests of TNG, we studied the possibility of positioning the spectrograph in the Nas-A room. This resulted in the design of a new interface where the spectrograph is positioned on the floor of the rotating building, detached from the telescope and fed via special fibers with extended transmission to the infrared wavelengths which are interfaced to the telescope at the ex-OIG focus. Following the requirements set by TNG for visiting instruments, the fiber-telescope interface of GIANO was designed with minimal size and to be easily dismounted. The resulting mechanical and optical designs are shown in Figure 4.1-4.2. The interface is mounted on a quasi-gravity-invariant structure consisting of a horizontal bench fixed to a vertical bearing attached to the ex-OIG flange. The fiber-feed optical system consists of a commercial (Thorlabs) CaF_2 plano-convex lens with focal length of 50mm. To fit into the very tight space available before TNG focus, the fiber is fixed at the centre of the mechanical structure, while the lens is mounted on a wheel which is used to switch between the science and the calibration mode. The relative fiber-lens positions cannot be adjusted. We suspect that the low efficiency is due to a misalignment between the lens and the fiber.

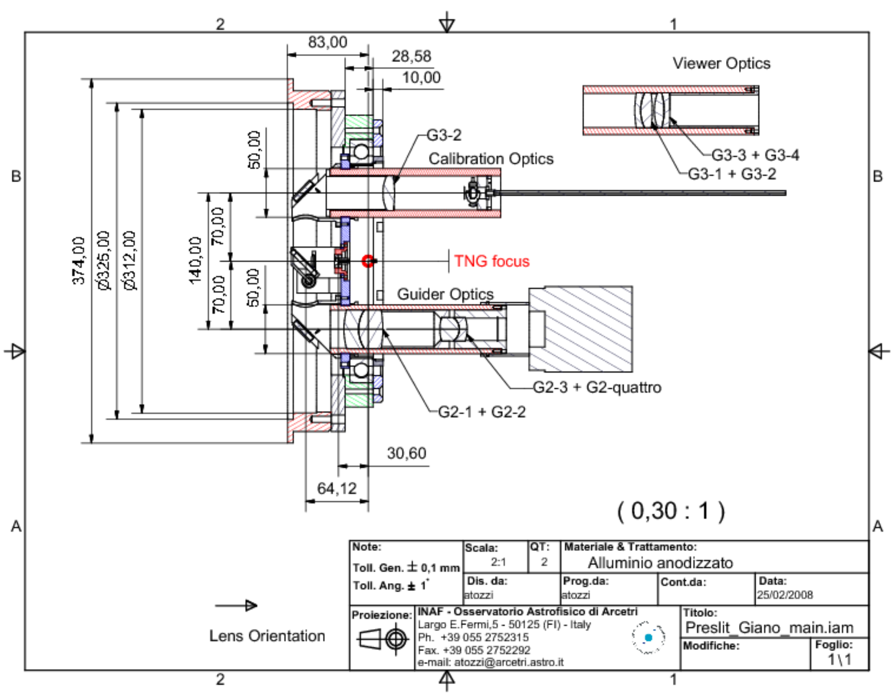

Figure 4.1. Mechanical drawing of the fiber-telescope interface of GIANO

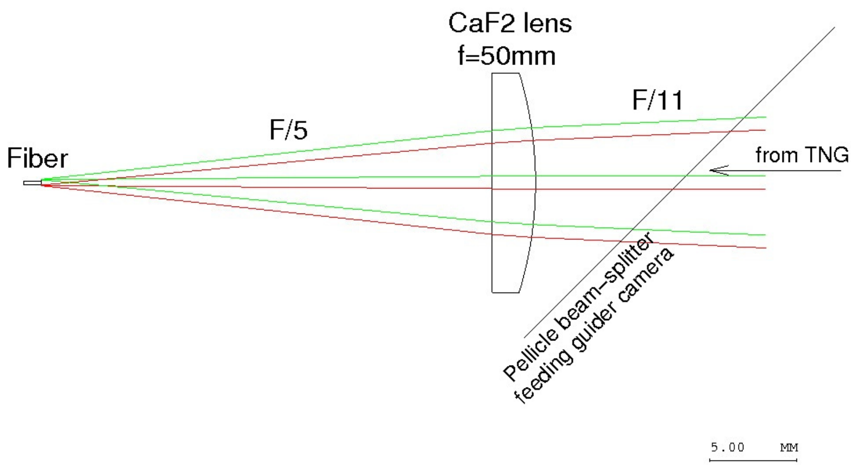

Figure 4.2 Optical layout of the fiber-feed system.

5 The fibers

The GIANO fiber bundle, made of $ZrBaLaNaF_2$ glass (ZBLAN), was designed and manufactured by IR-photonics (Montreal, Canada). It consists of a pair of commercial D_{core}=0.085mm fibers inserted, by means of custom adapters, into standard SMA connectors. The two fibers are mounted with a centre-to-centre distance of 0.25mm. The bundle is 8m long and sealed into a flexible steel jacket which protects the fibers from mechanical shocks and accidental bending. We purchased four identical devices. Figures 5.1 shows the drawings and pictures of one of these bundles.

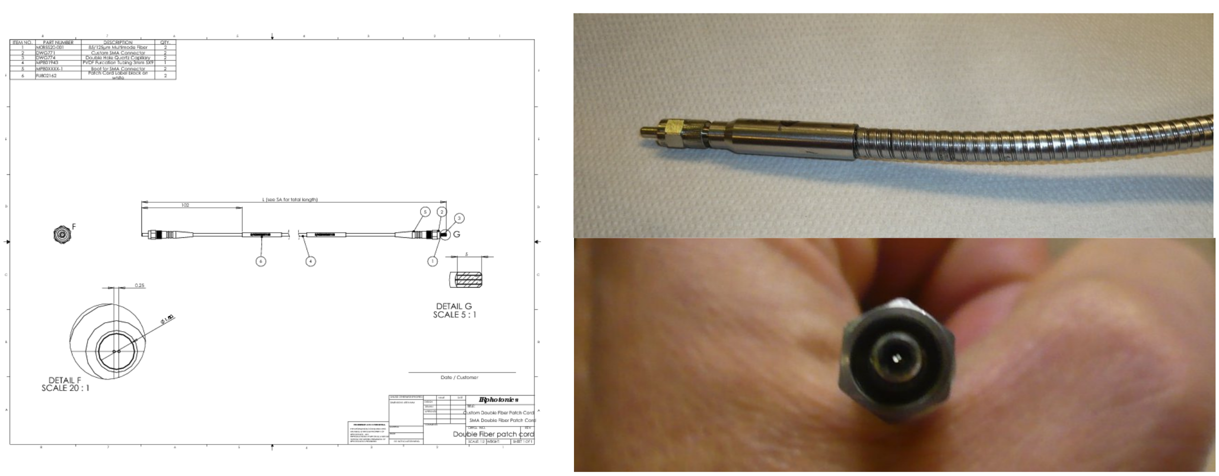

Figure 5.1: Drawing and pictures of the ZBLAN fiber bundle for GIANO.

The internal transmission of the fibers, measured by the manufacturer, is displayed in Figure 5.2. Measurements of relative focal-ratio degradation of one fiber of a bundle were performed in Arcetri in May 2011, the resulting curves are displayed in figure 5.3 (left-panel). These yield a 61% relative FRD efficiency for an F/5-F/5 coupling. This is somewhat lower than the 81% relative efficiency for a nude fiber of the same type, prepared and measured by G. Avila at ESO in October 2009 (see curves on the right-hand panel of figure 5.3). The difference can be attributed to micro-fractures in the glass produced during the assembling of the fibers into the SMA connector. We plan to measure relative and absolute FRDs for all the fiber-bundles of GIANO and, if necessary, to dismount and re-assemble one bundle to improve the overall fibers efficiency. This work will be performed at the beginning of 2013, in direct collaboration with G. Avila.

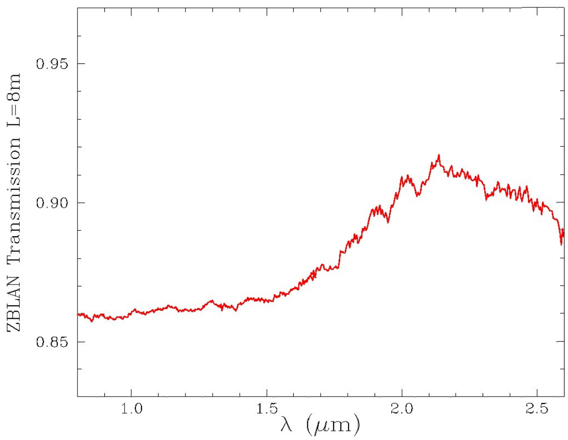

Figure 5.2: Internal transmission of the 8m-long fiber bundles purchased for GIANO.

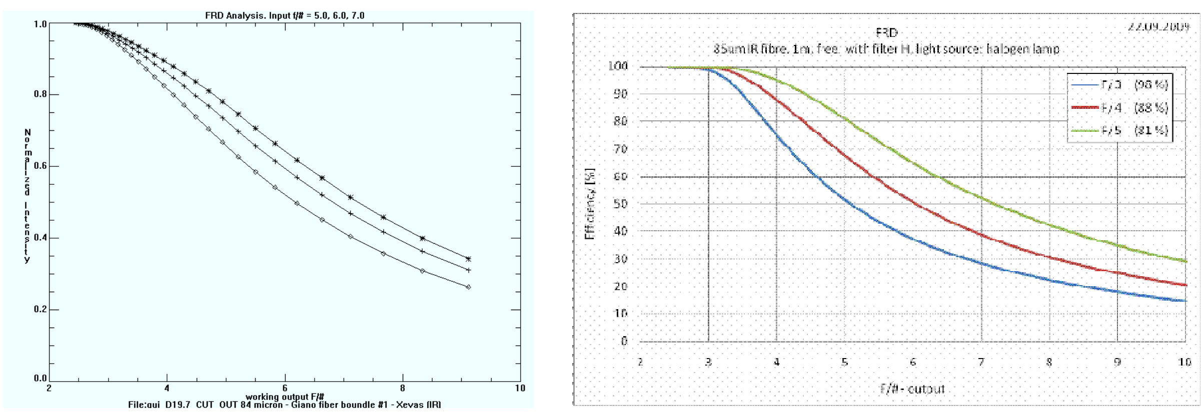

Figure 5.3: Measurements of focal ratio degradation of one GIANO bundle (left) and a nude ZBLAN fiber (right-hand panel)

6 The new fibers-telescope interface

A new fibers-telescope interface was designed taking advantage of the much larger and more stable physical space which was recently made available by TNG. The new system includes a pupil-viewer and the necessary mechanics to accurately align the axis of the fibers with the optical axis of the telescope. Once aligned, the system will remain permanently mounted at its dedicated focus. It will be removed and re-mounted, with the assistance of the GIANO team, only for special maintenance works on the de-rotator. Figures 6.1 and 6.2 show the opto-mechanical design, which is based on commercial elements including, in particular, off-axis parabolic mirrors which only recently became available as standard, off-the-shelf optical elements.

The F/11 beam from the telescope passes through a pellicle beam-splitter which reflects ~7% of the light to the guider optics and camera which are used for target acquisition and guiding. The remaining light is collimated and re-imaged at the intermediate F/11 focus using two off-axis parabolae (P1, P2) and two bending mirrors (M1,M2). The light is then collimated and re-focused onto the fibers using two off-axis parabolae (P3, P4) and flat mirrors (M3, M4). The output F/4.9 beam is telecentric with diffraction-limit optical quality. An image of the TNG pupil is accessible between M3 and M4. The pupil image is particularly useful for aligning the optical axis of the preslit optics with the optical axis of the telescope.

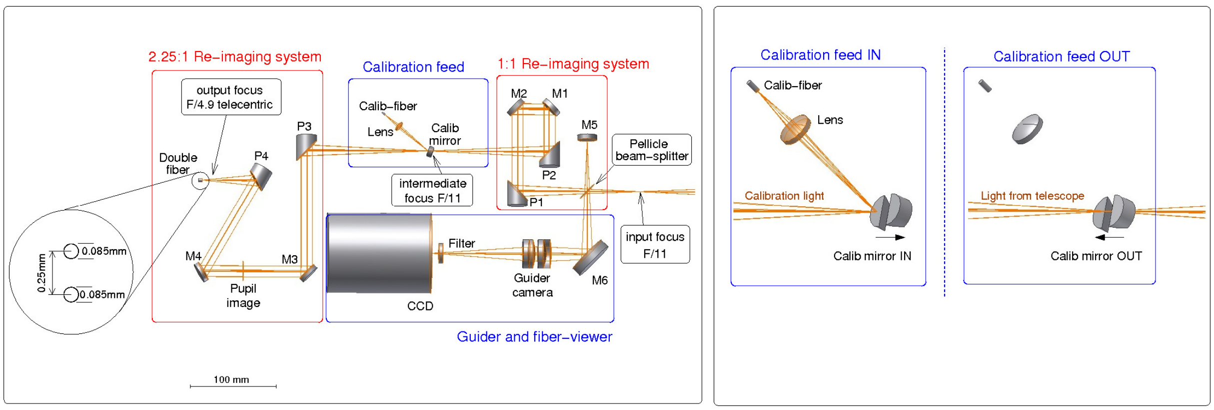

Figure 6.1 Optical layout of the new fibers-telescope interface. The right-hand panel is a zoom of the calibration feed.

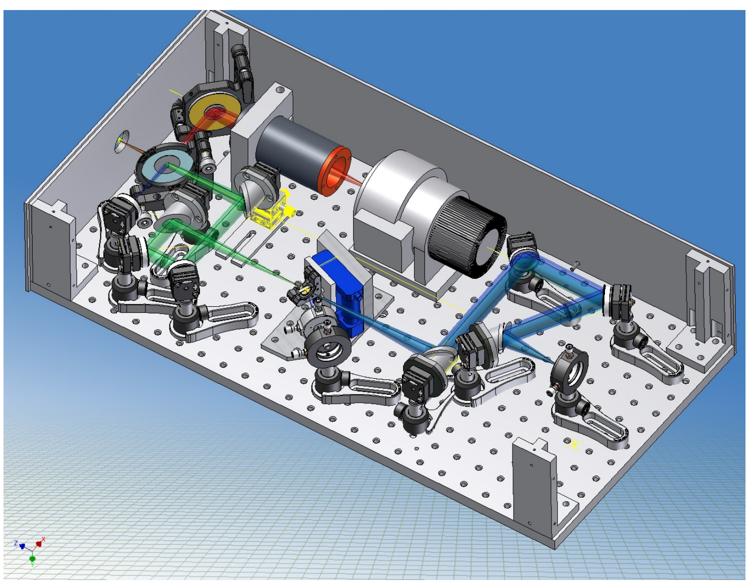

Figure 6.2 Mechanical layout of the new fibers-telescope interface.

6.1 Acquisition and guiding

The new system is identical to the one successfully tested at the telescope. The guider optics and CCD are fixed onto the same optical bench, together with all the other optics and the fibers. Therefore, the positions of the CCD pixels conjugated with the fibers are fixed. The main advantage of the new layout is that the fiber-positions on the CCD can be determined, and periodically checked, by back-illuminating the fibers and using the light reflected from M5, without using night-time.

6.2 Calibration modes

The light from the calibration unit (λ-cal and flat) is fed to the telescope interface via a separate ZBLAN fiber with core diameter of 0.4mm. The calibration light is injected at the intermediate F/11 focus through a focal-reducer (CaF_2 lens f=15mm) and a reflective slit mounted on a vertical slide (see right-hand panel of figure 6.1). With this set-up we can implement new observing modes where one of the fibers is looking at the astronomical target, while the other is illuminated by the calibration light. The available observing modes are listed in Table 6.2.1. It should be noted that the calibration light is switched off in the A+B mode.

Table 6.2.1 Observation and calibration modes

Mode	Description	Vertical slide position
A + B	Light from the telescope goes freely to both fibers	Center
A + c	Telescope light to “A” fiber, calibration light to “B” fiber	0.5mm up
c + B	Calibration light to “A” fiber, telescope light to “B” fiber	0.5mm down
c + c	Both fibers are illuminated with calibration light	2.0mm down

7 New fibers-GIANO interface

We designed a new fibers-GIANO interface, which also includes the possibility to insert an image-slicer (modified Bowen-Wallraven prism) similar to the device employed with great success in the FEROS spectrograph. This element became recently available on the market, thanks also to the work of the CARMENES team. The most important differences between the previous (figure 7.1) and the new design (figure 7.2) are as follows

- The new design includes an intermediate focus where the image slicer can be inserted.
- The new design accepts a larger focal aperture, taking advantage of an (already existing) oversized cold stop in the spectrograph.
- The new design includes a collimated beam (after the parabola P1) which can be conveniently used to measure the light distribution in the pupil plane.
- The new mechanical design includes a fiber-shaking device, to eliminate the problem of modal-noise.

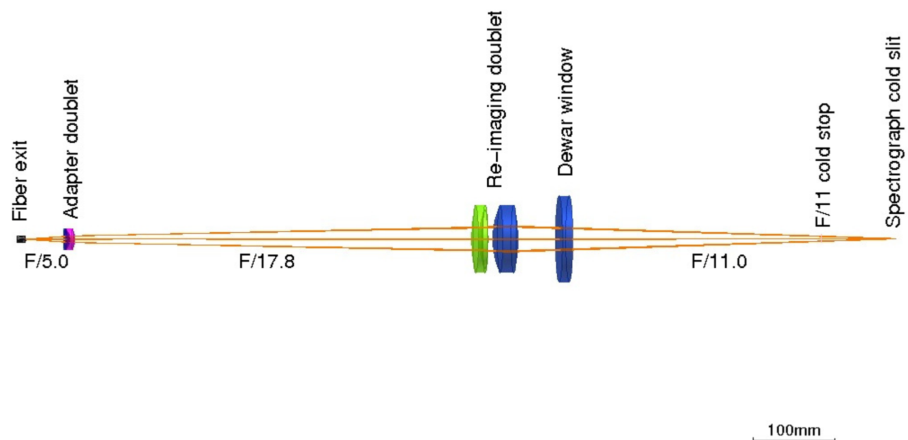

Figure 7.1 Optical layout of the previous fibers-GIANO interface.

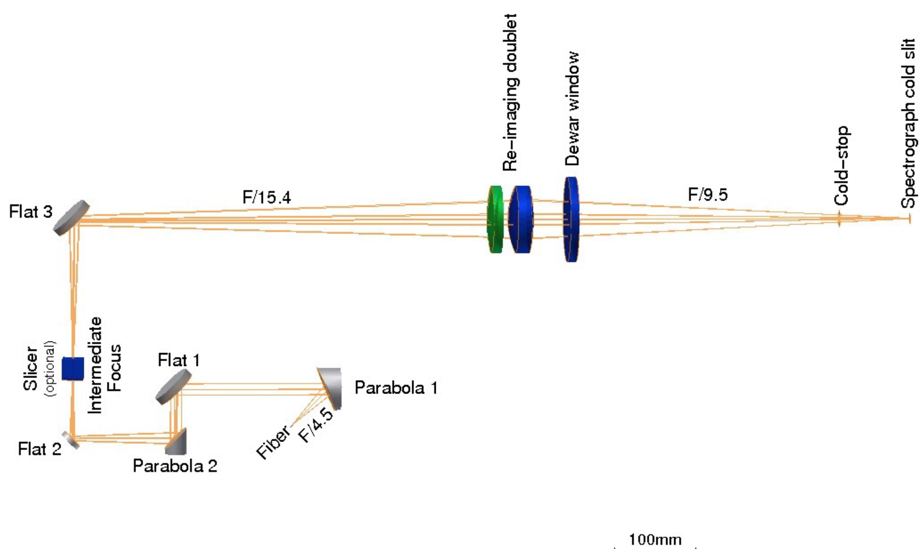

Figure 7.2 Optical layout of the new fibers-GIANO interface.