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EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral

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LA SILLA OBSERVATORY

LED / Optics

FEROS on 2p2 Telescope

Conceptual Design

Technical Report

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1 Purpose.

Within the frame of the La Silla scientific plan for the coming years, the Feros spectrograph actually in use on the 1m52 telescope will be moved to the 2m20. This document propose a solution for this transfer. A conceptual design of the Feros adaptation on the 2m20 is presented. The document will serve as basic information for the conceptual design review to be held in April 23, 2002.

2 Proposal

2.1 Present situation

The Feros spectrograph is a bench instrument using a fiber link from the 1m52 Cassegrain focus. A fiber head with two inputs (star and sky or calibration) was attached on the Boller and Chivens spectrograph to reduce the instrument exchange operation. By sliding the slit unit it is possible to select either B&C or Feros.
A new calibration unit was implemented to cover the required field (long slit from the B&C) knowing the incorrect beam illumination for the two fiber inputs. The calibration unit was done within a compromise between the two modes. A flat field and Thorium lamps were compulsory for the Feros instrument to allow a proper internal flat fielding and wavelength calibration (at this resolving power).
The F/ratio of the 1m52 telescope is F/15 with a scale of 9.2 Arcsec/mm.
The fiber diameter is 100 microns and a micro-lens is used at the fiber entrance to adapt the F/ratio from the telescope to the fiber one.The fiber head hole is 290 micron corresponding to 2.6 arcsec on the sky.

On the 2m20 the WFI is permanently mounted and used on the period outside full moon.

2.2 General concept

The translation of the Instrument can be foreseen according to three possibilities:

- A new complete adapter requiring the WFI removal from the telescope.
- An integration of the fiber head on the WFI allowing easy instrument change without dismounting
- An integration of the fiber head on the WFI allowing simultaneous observations

The first solution gave more freedom for the fiber adapter manufacturing but will require instrument change from WFI to Feros and vice versa; certainly a too heavy and always risky operation.
The second and third solutions will require an integration of the Feros fiber head on the WFI area. The feasibility to include the fiber head within WFI is not possible at the detector area (back focal distance too short). A fiber head viewer is required to check the proper location of the star over the fiber hole. Space is not enough and modifications of the instrument will be compulsory and will have to be authorized by MaxPlanck. The illumination of the star and sky fibers with the calibration light as flat field and thorium will be very difficult to install in such a reduced space without glowing onto the WFI CCD.
Are simultaneous observations of Feros and WFI compulsory, certainly not in fact !

The only available space to integrate the Feros fiber head with the WFI is above the instrument in the Cassegrain hole of the telescope. Then no modifications will be required on the WFI instrument.

The operation of Feros at the 1m52 telescope as well as the new design of Harps instrument for the 3m60 were great sources of experience on the fiber feed spectrographs. Consequently, some recommendations for the integration design could be made:

- The fiber head is a very delicate part with very small holes sensitive to cleanliness. An orientation of the head to avoid dust deposition will be preferable if possible.

- The matching of the fiber input hole with the telescope Image Quality (IQ) in average must be very well defined
- The calibration illumination must be as close as possible of a star simulation with a proper M2 shadow simulation. Tungsten lamps must be in current control mode to obtain a good stability.
- Interchangeability between star and sky fiber in science and calibration exposures.
- Calibration lamps can be moved away from the telescope area to avoid thermal perturbation on a Cassegrain instrument. Fibers can be used to feed the lamp and the fiber head.

2.3 Proposed Concept.

In this chapter we will present the project following the optical path for science and then calibration exposures.

2.3.1 Fiber head design

The same design as it is now can be used. Of course a new smaller head should be designed to fit with the 2m20 optical parameters.

- Holes in front of the micro-lens must be around 1.2 arcsec and 0.8 minimum. With a scale of 11.7arcsec/mm the holes range from 100 microns to 70 microns. These value correspond to the best achievable image quality of the telescope including the local seeing perturbations.

  Of course it will be easier to manufacture the fiber head with a 100 micron hole or larger
- The fiber head must be on the telescope axis to avoid uncorrected field astigmatism of 1.4 arcsec at 0.38 deg field angle (corner of the WFI CCD).
- The star and sky fibers separation is not a critical parameter and depends more on manufacturing issues. Scattered light from the star image should not contaminate the sky fiber.
- A new micro lens should be designed to image the pupil of the 2m20 over the 100 micron fiber (a safer value of 90 micron for the fiber core must be considered)

After an excellent suggestion raised by Andrea Kaufer, an improved design of the fiber coupling is presented delivering for sure more efficient throughput.
A rod-lens type design is used. A special small lens must be designed (not off the shelf) with 0.75 mm diameter and 1.08mm thick with a entrance radius of 0.375mm, of course a more costly solution but offering better performances with less glass-air interfaces.
The figure 1 illustrates the lens design.

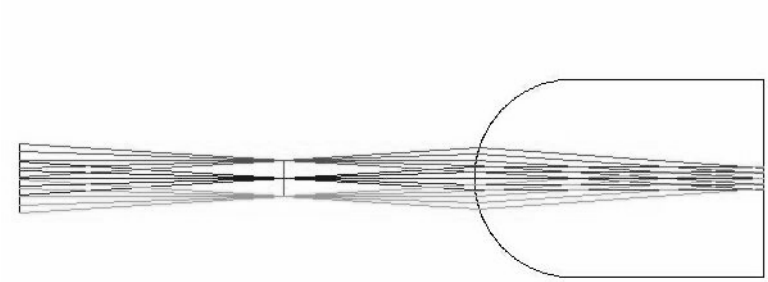


Figure 1. FiberFeed Rod lens

From a dummy surface the beams covering the 140 micron hole go through the rod lens and the telescope pupil is formed on the fiber input face-with a diameter of 90 micron.

2.3.2 The Fiber head location

According the requirement above listed, the possible solution consists in bending the telescope beam above the WFI to deflect the light toward the fiber head keeping the on axis telescope alignment.
This arrangement presents the advantage of a proper fiber head orientation insensitive to dust deposition.
The deflecting mirror can be foreseen exchangeable and must be mounted on a support arm to be moved in and out the telescope beam. The direction of the movement in/out should be designed in such a way to be insensitive on the image position (flexion influence minimized).
Of course simultaneous observations could not be possible on axis. The park position of the support arm must not produce vignetting for the WFI mode. The grism space must be kept in front of the WFI instrument.

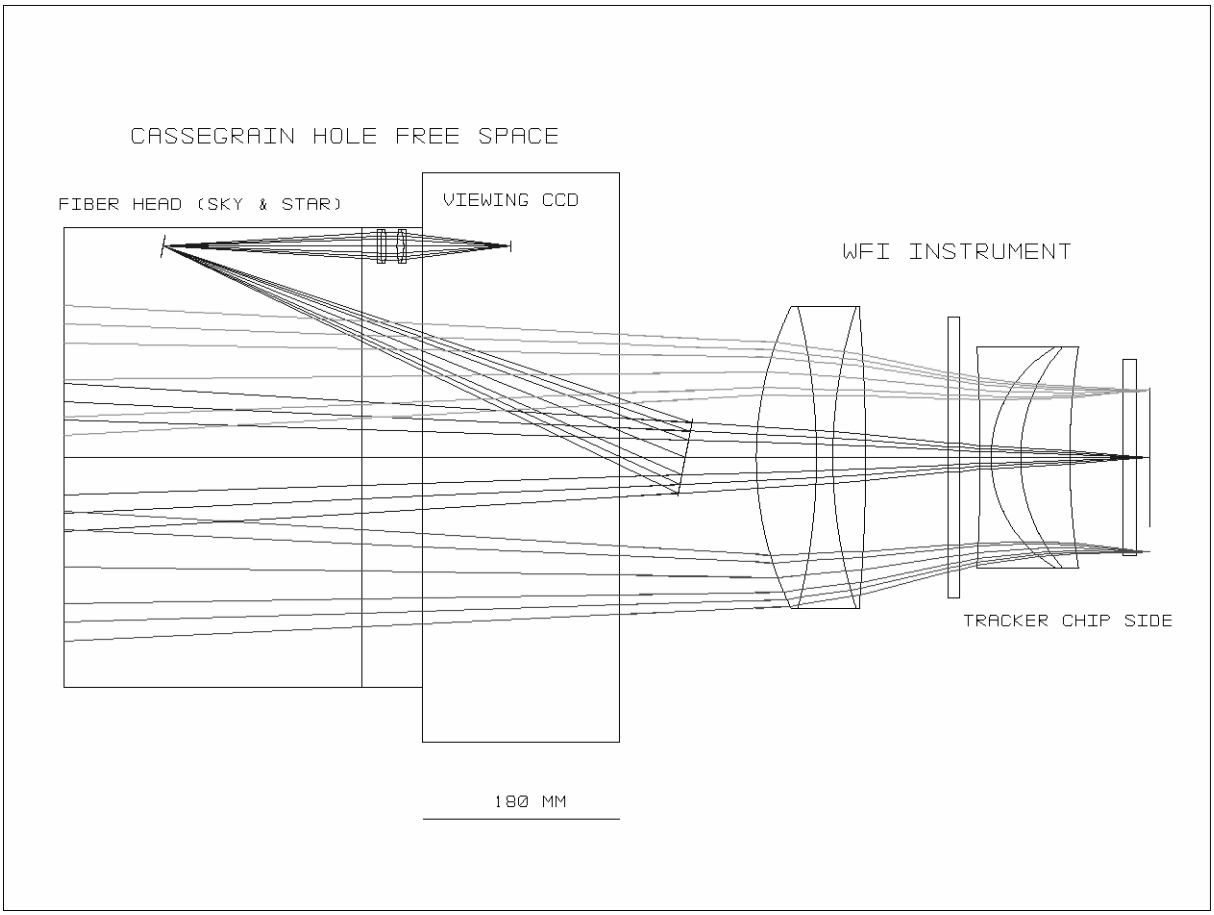


Figure 2.: Fiber head with WFI.

On the figure above we can see:

- on the right part the complete WFI instrument. The beam coming to the top part corresponds at the side of the mosaic CCD. The lower one corresponds to the outer side of the tracker chip.
- on the left part we simulated the Cassegrain free space with dummy surfaces
- the two instrument modes are presented together, WFI and Feros
- The new fiber head for Feros is oriented down with the advantage of an easier maintenance.
- by reflection on the fiber head the light goes through standard lenses to form an image on a viewer camera. It could be a technical CCD or a scientific CCD like Sbig. The design is done to match the full field of the two fibers holes having an image quality of 15 micron 80% Encircled Energy. This CCD could be used for telescope guiding if it decided in this way.

- WFI could be used simultaneously but with center vignetting as well as the deflecting mirror support arm shadowing.
- It is foreseen in a first approach to guide the telescope with the WFI tracker chip unvignetted. This solution is of course retained to simplify the Feros adaptation in software terms. Anyway a verification of the star location on the fiber hole input is required. The fiber head could not be not seen.
- The field recognition could be performed with WFI. The need of a larger field of view on the fiber head is then not mandatory.

In the next figure we present a view along the optical axis from the deflective mirror towards the M2.

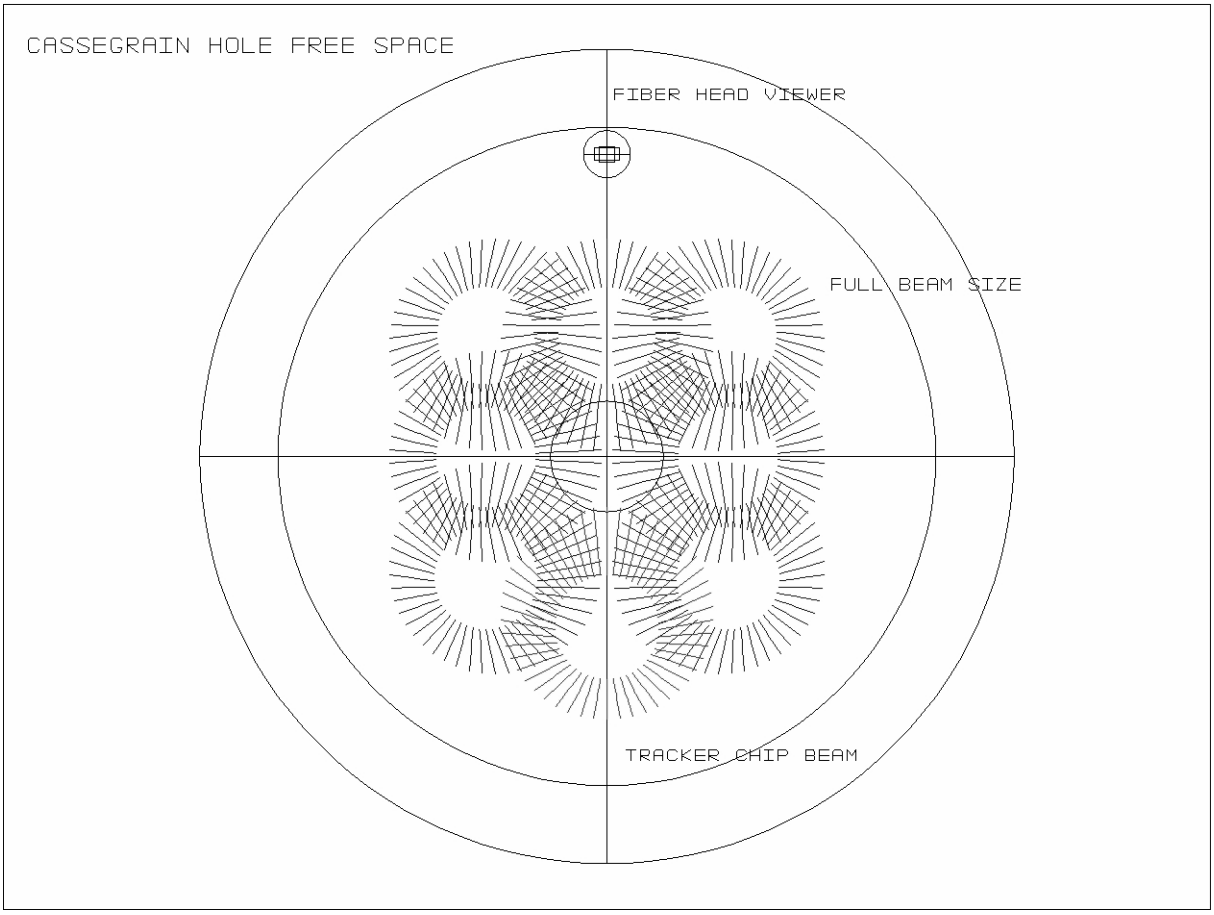


Figure 3.: Beam space requirement for the WFI unvignetted.

The two outer circles correspond to the Cassegrain free space.
The radial segments correspond to the optical beam propagation on the Cassegrain area. A ring beam mode is selected on this figure
The space used by the beams presents the un-vignetted area of the WFI, with beam positions corresponding to the four corners of the Mosaic CCD.
The lower centered beam corresponds to the outer edge of the tracker chip. (almost the mosaic CCD corner circle).
On the top part figures the fiber head with the viewer optical device. The position here allows some space to install the Feros head as well as the calibration source device without producing vignetting on the WFI mode. Of course lamps should not be installed on this area to avoid heat sources. A calibration lamp fiber fed seems a better approach as done on Harps.

At this stage of the Feros installation we have:

- two fibers (object, sky) will have to exit the Cassegrain hole area. The only possibility is to add an intermediate flange of 15mm thickness between the telescope and WFI to allow free space for the fibers. The final image quality will degrade by a very small amount still within the quality requirement as it is now. The simulation gave a negligible degradation all over the WFI field by 0.1 arcsec only
- The Feros “unit” will be installed on a cylinder support fixed on the Cassegrain hole above the WFI and fully independent (flange from the direct camera can be used). Feros mode could be used without dismounting the WFI. It will be anyway compulsory to perform the first alignment of the full unit (free access without WFI mounted). This new unit should not produce an increase of the scattering or ghost image for the WFI.
- The use of a cooled CCD within the Cassegrain could be critical in term of thermal contribution for image quality degradation and also in term of water contamination. A solution to move out the viewer focal plane is possible with imaging fiber bundle or periscopic optics.
- The deflective mirror unit must be:
    - designed to allow easy mirror exchange (maintenance aspect)
    - the mirror must have lambda/10 surface quality with unprotected aluminum coating
    - in park position, no vignetting should be seen on the WFI
    - in position the stability of the mirror could be insensitive if the mechanical design solution is appropriate.

In the following figure we present the fiber head viewer in a more detailed way.

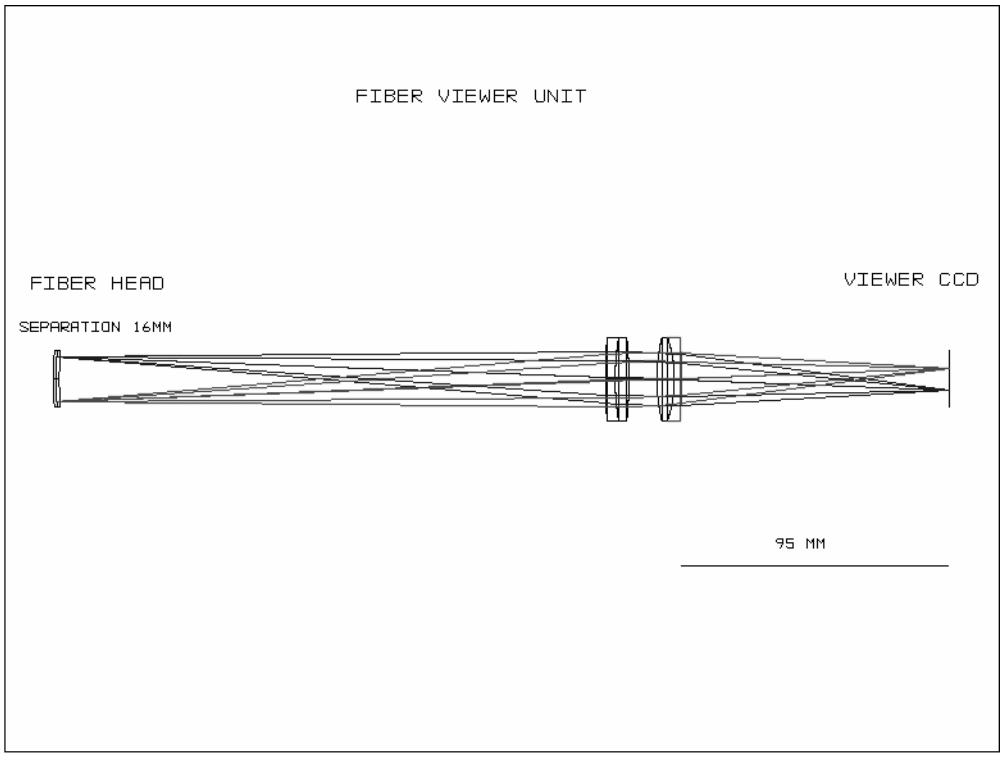


Figure 4.: Fiber Viewer Unit

2.3.3 The Calibration Source Devices.

The present calibration lamp unit used on the Boller & Chivens is not what we really need for Feros in terms of illumination mode. The best solution is to project with the same aperture ratio of the telescope a simulated star. A pupil mask will also simulate the right beam aperture type with the M2 and spider occultations.
The presence of warm source underneath the telescope must be also avoided.
According to these considerations the best fiber illumination design corresponds to the actual design of the Harps calibration unit.
A scaling of this design will be presented as a good solution for the new illumination device for Feros.

On the following figure the layout of the calibration projector is presented together with the Fiber head viewer.

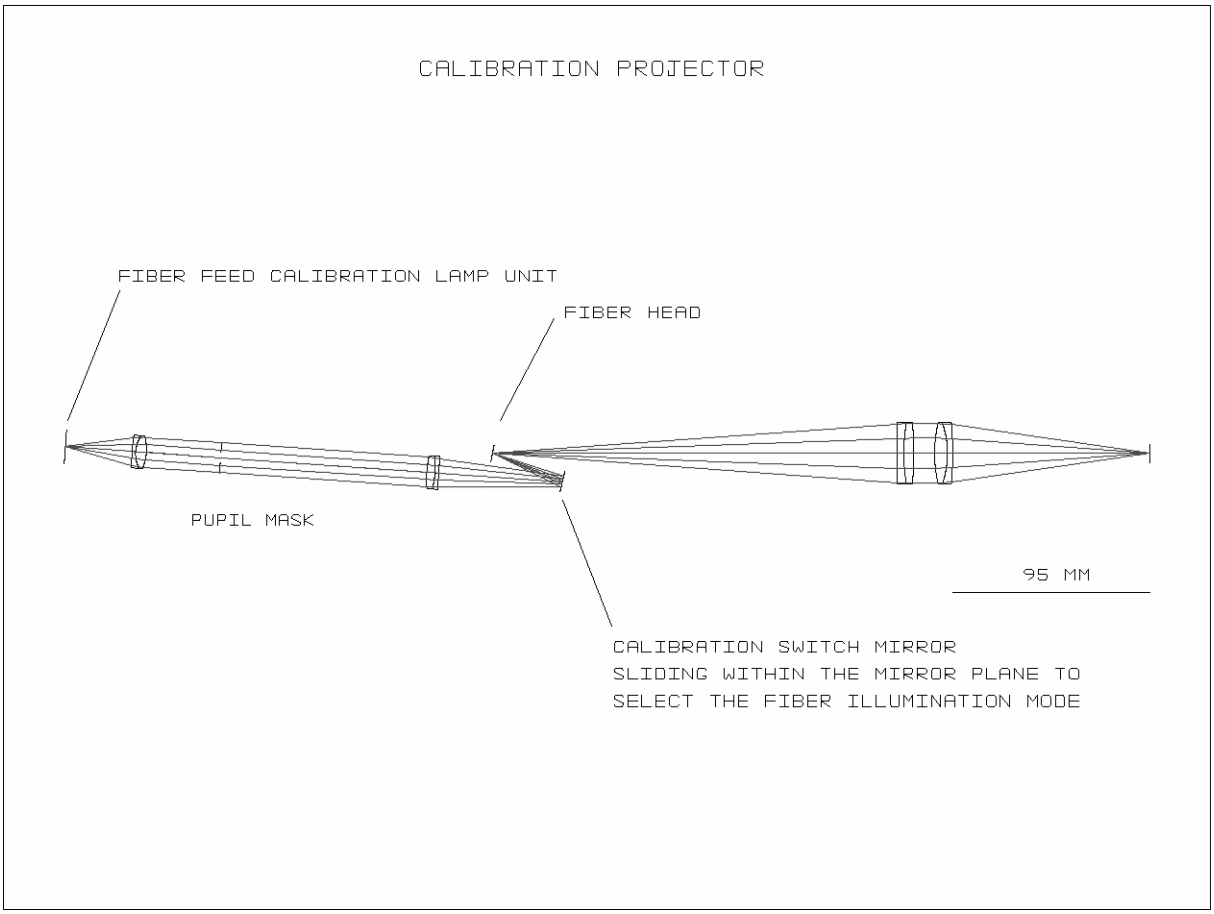


Figure 5.: Calibration Projector Unit

The right part has been already presented and corresponds to the Fiber head viewer unit.
The left unit is the calibration projector. A fiber coming from the calibration lamp unit illuminate the left doublet. A mask simulates the pupil position located after the first doublet as the exit pupil of the telescope.
The folding calibration switch mirror will by translation along the Z axis (perpendicular to the paper) select science or calibration exposures. The axis of the unit is inclined parallel to the WFI optical beam and no produce vignetting. As it is designed for Harps the mirror may have a diaphragm plate to occult the optical beam towards the viewer camera (avoiding blinding effects with calibration lamp used with star exposure).
Of course the projector is doubled, one for each fiber of the fiber head, the star and sky ones.

Then all combinations of observing modes are possible (as it is for Harps).

- Star fiber A with sky fiber B
- Star fiber A with calibration fiber B (either Tungsten or Thorium)
- Calibration fiber A with star or sky fiber B
- Both fibers A/B with calibration source either Tungsten or Thorium

On the next figure on the following page a view rotated by 90deg along the axis is presented.

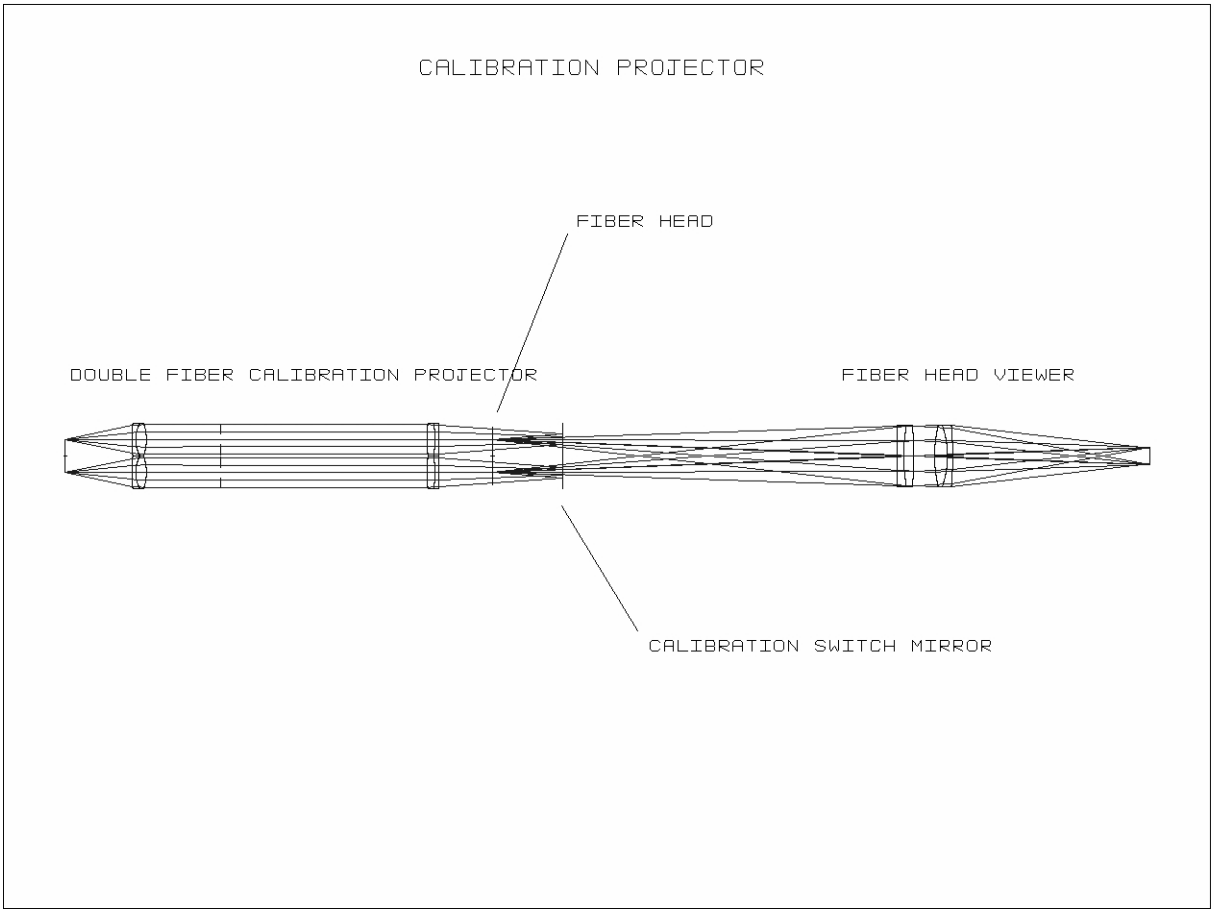


Figure 6.: Rotated by 90deg view of the calibration projector

The fiber head must be curved to image the telescope pupil over the viewer doublet lenses. The full fiber head field will have no vignetting.
According the possible observational modes the calibration switch mirror should have four axial positions.

The calibration lamp unit will be a copy of the Harps one with only three lamps position instead of 5.
The lamp will by mean of two doublets project light on the two calibration fibers.
This unit could be installed not close to the telescope.

On the next figure, the calibration lamp unit is presented with the Thorium lamp.

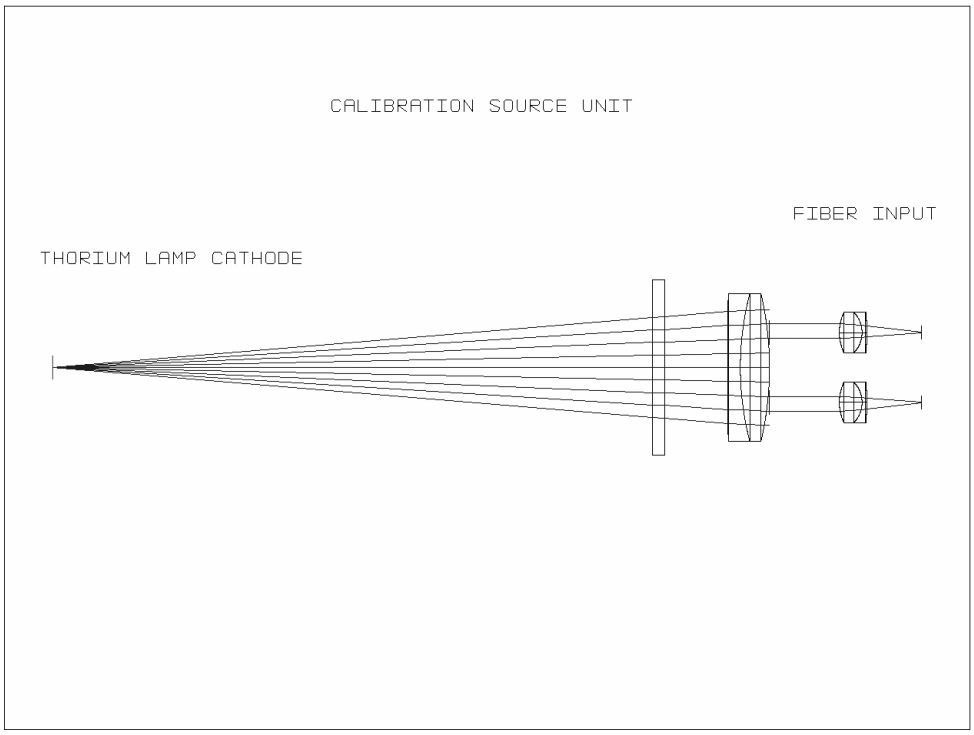


Figure 7.: Calibration Source Unit

The thorium lamp is represented optically with its cathod and the window. The first doublet generates a parallel beam. Then each calibration fiber has a small doublet to form the cathod image over the fiber entrance hole.

As an alternative solution, but far to be the most suitable one, the calibration unit of the Boller & Chivens could be use as a fix illumination device for the two calibration fibers. Replacing in fact the illumination system as it is presented on the fig.7. The Optics will have to be scaled on the above presented solution.
Of course this solution will freeze the lamps option selection for each fiber.

2.3.4 Feros installation

A suitable room must be designed to receive the optical bench of Feros. To shorter the fiber, the proper location will be as close as possible of the telescope. The present double room on the left side of the telescope could be upgraded for that purpose after a proper vibration analysis. Of course a floating floor should be considered already to minimize the dome rotation vibration perturbations.
The room should be thermally controlled within half degree.
The calibration lamp source unit could be mounted at the room side in an cooled rack for example.

2.4 Implications

- Off the shelf optics have to be ordered meanwhile the mechanical design exists for Harps and requires only a scaling.
- A new fiber head must be manufactured with a curved face (Feasible because already done for Harps)
- The full adaptation unit should be mounted without WFI for alignment and tests.
- Four fibers must access the instrument area:
    - 2 calibration input fibers
    - 2 science fibers (star and sky ones)
- An additional imaging fiber bundle could be required for the viewer camera location outside the Cassegrain hole. Alternatively periscopic optics could be used.
- An additional flange is required to mount the WFI allowing space for the above mentioned fibers
- Involved functions:
    - Feros switch mirror (in/out) to allow beam reflection towards the Feros head
    - Calibration switch mirror (sliding unit with four positions)
    - Calibration source selection for the fiber A
    - Calibration source selection for the fiber B
    - Tungsten lamp on/off and Thorium lamp on/off
- Functions to be computer controlled ?
- Telescope guiding with the WFI tracker chip or with the viewer camera ?
    - Type of camera ?
- The full instrument unit should not produce vignetting on the WFI field.

3 Conclusion.

The document presents a transfert project of the Feros instrument from the 1m52 to the 2m20 telescope. It has been prepared with the intention to inform the people who will participate on the conceptual design review.

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