A collimator (COL) lens generates a parallel beam and produces a pupil image near the pupil plane assembly (PPA). The collimator will be used for the entire wavelength range covered by CONICA. Two mirrors fold the light path, which result in a compact cryostat. The pupil plane assembly consists of five wheels carrying a selection of Lyót stops, filters, grisms, and polarization analysers. An additional wheel carries camera lenses (CAM) which provide a selection of five magnifications in order to use efficiently the accepted field of view and the angular resolution throughout the 1 μm . . . 5 μm range. There will be two sets of camera lenses, optimized in optical performance and throughput for the 1 μm . . . 2 μm and the 2 μm . . . 5 μm spectral ranges.

Two 256×256 pixel detectors (DET), cooled to their optimum operation temperature between 20°K and 70°K, will be included in the camera in order to cover the wavelength range efficiently. A SBRC InSb detector is foreseen to be used mainly for the long wavelength region, a Rockwell NICMOS 3 HgCdTe detector is baselined for direct imaging and speckle applications at short wavelengths. Detectors are selected by rotating the folding mirror assembly; it will not be possible to observe with both detectors simultaneously. The field subtended by a detector will range from 3 arcsec for diffraction-limited resolution at 1 μm to 33 arcsec for full field viewing. The optical design of the camera is such that CONICA can be upgraded with larger (512×512 pixels) detectors as soon as these become available.

The optics, mechanics and cryogenics, as well as the control electronics will be constructed by MPIA, who also host the principal investigator of the project. The detector electronics will be built jointly by MPIE and OATo. MPIE will also supply the data analysis software and a cold fast shutter unit. CONICA is scheduled for commissioning at the VLT in December 1997.

FORS – The Focal Reducer for the VLT

I. APPENZELLER, Landessternwarte Heidelberg, Germany, and
G. RUPPRECHT, ESO

Introduction

On February 6, 1992 at the ESO Headquarters in Garching the FORS instrument project for the ESO Very Large Telescope was publicly started with a kickoff meeting. FORS, the FOcal Reducer/low dispersion Spectrograph, will be the first instrument built outside ESO to be installed at the VLT observatory.

The idea for a set of general-purpose focal reducers for the VLT can be traced back to the recommendations of the ESO Working Group on Imaging and Low-Resolution Spectroscopy, published in VLT Report No. 52 (1986).

The experience gained with EFOSC-type instruments at the 3.6-m telescope and at the NTT then led ESO to propose in the VLT Instrumentation Plan of June 1989 the construction of two dioptric focal reducer/low dispersion spectrographs for deep-imaging, low-resolution and multi-object spectroscopy. The Cassegrain foci were chosen for the instruments because of their high throughput, to minimize the amount of scattered light and to make them suitable for polarimetric observations.

Following a Call for Proposals issued in 1990 a consortium composed of three German astronomical institutes (the Landessternwarte in Heidelberg and the University Observatories of Göttingen and München) was chosen in 1991 for the realization of the project.

The Plan

It is expected that the demand for observing time with a focal reducer at the VLT will be comparable to or larger than on the existing large ESO telescopes. FORS I and II will therefore be something like the workhorses of the VLT, and their duplication will save construction costs and later simplify operation and maintenance. The two identical instruments will be installed on Unit Telescopes 1 and 3 in 1996 and 1998, respectively.

Their basic observing modes will be
(1) direct imaging,
(2) low-dispersion grism spectroscopy,
(3) multi-object spectroscopy,
(4) polarimetry.

These modes can be combined e.g. to allow imaging polarimetry or spectropolarimetry.

The instruments are specified to work over the wide wavelength range 330 to 1100 nm. Their efficiency (excluding the detector) should be better than 50% at wavelengths greater than 350 nm and peak near 450 nm with approximately 78%. The detector will probably be a large CCD with 2048 × 2048 pixels and a 24 μm pixel size.

The Implementation

The fundamental parameters of the optical design are the image scale at the VLT Cassegrain focus, which is 528 μm/arcsec, and the intended final image on the detector. Combining the expected image quality of the VLT telescopes with the pixel size of available large CCDs, a scale of 0.2″/pixel was specified for the standard observing mode.

In order to obtain a large field of view and to allow accurate polarimetry, an all-dioptric design was chosen. Its principal layout was derived by ESO optician B. Delabre on the basis of the experience gained with EFOSC.

Figure 1 gives the optical paths of the light passing from three different positions in the focal plane of the telescope (situated to the left of Figure 1) to CCD detector (on the right). The first group of lenses (the collimator) produces a parallel beam and also forms an image of the telescope's entrance pupil (i.e. of the main mirror). The second group of lenses (the camera) then focuses the parallel beam onto the CCD detector, thus re-imaging the large image in the telescope focal plane on a smaller scale in the detector plane. The standard "wide-angle" collimator will have a focal length f of 1230 mm and a collimated beam diameter of 90 mm. During periods of excellent seeing it will be possible to double the image scale by exchanging the standard collimator by a second, high-resolution collimator (f = 615 mm, collimated beam diameter 45 mm) using a remotely controlled internal exchange mechanism.

The parallel beam section is tightly filled with various optical components. There are rotatable phase retarder plates and a Wollaston prism for polarimetric observations, grism, and broad-band colour filters. All these components can be moved in and out of the beam by means of rotating wheels or a swing arm. The grism presently

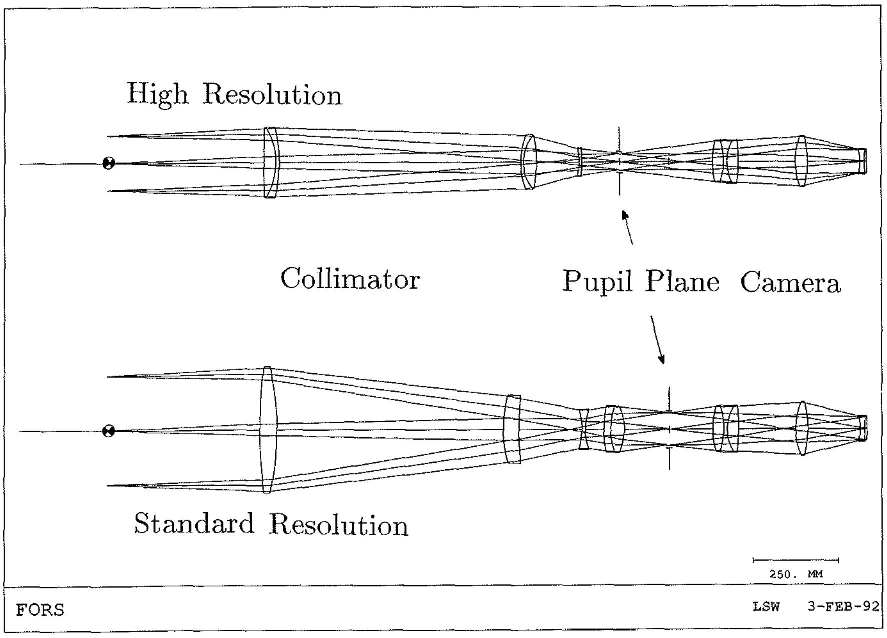

Figure 1: *Schematic drawing of the optical layout of the focal reducers showing the standard (bottom) and high-resolution (top) configurations. Since the camera sections are identical, the changeover will be accomplished by an exchange of the collimators.*

foreseen will allow spectroscopy with resolutions up to ≈ 2000.

The camera has a fixed focal length of 280 mm. It includes the focusing mechanism and two additional wheels for interference filters. (Note that in order to avoid position-dependent differences of the filter band pass over the image, interference filters have to be inserted outside the parallel beam.) When the standard collimator is used, the final focal ratio is 3.1; with the high-resolution collimator this changes to 6.2 and the image scale accordingly becomes 0.1″/pixel. The available field of view in the two modes will be 6.8′ × 6.8′ (square) and (at least) 2′ diameter (circular), respectively.

To get an impression about the dimensions of the optics involved in FORS one should notice that the standard collimator field lens is 36 cm in diameter and therefore of a similar size as the objective of what would have been a medium-sized refracting telescope at an observatory 100 years ago!

Mechanically, the instrument will consist of three main units. The first one contains the multi-object spectroscopy unit, described below in more detail. The second one houses the collimators and carries the instrument control electronics, and the third one contains the optics in the collimated beam and the camera. The detector cryostat will be fixed to the camera unit. The whole instrument will be attached to the Cassegrain focus rotator by means of its top flange.

Without the electronics racks (the sizes of which have not yet been finally determined) each FORS will have a diameter of about 1.7 m and a length of approximately 2.5 m. This does not include the detector cryostat which will be delivered by ESO. The weight of the whole instrument will be about 2 tons.

Figure 2 shows schematically the outside appearance of the instrument. Figure 3 is a cut through the instrument indicating the location of its major components.

Of fundamental importance for the performance of the instrument is a minimization of the image motion resulting from mechanical flexure during extended integration times, when the gravity vector changes with respect to the instrument axis. To suppress this effect the housing of FORS has been designed in such a way that the effect of the movement of the collimator is exactly compensated by the flexure related movement of the camera. Computer simulations show that as a result of this flexure compensation it will be possible to keep image shifts well below 1/4 of a pixel even during exposures of several hours duration.

One of the crucial components of the instrument is the multi-object spectroscopy (MOS) unit, located in the focal plane common to the telescope and the instrument. It will consist of 19 pairs of slitlets, each of them individually driven by a motor and controlled by a highly precise position encoder. This device will allow simultaneous spectroscopy of up to 19 objects, distributed over the field of view. The projected slit length on the sky will be 22.5″. By aligning the slitlets properly, it will also be possible to form a long slit of arbitrary width. Finally, by alternatively opening and

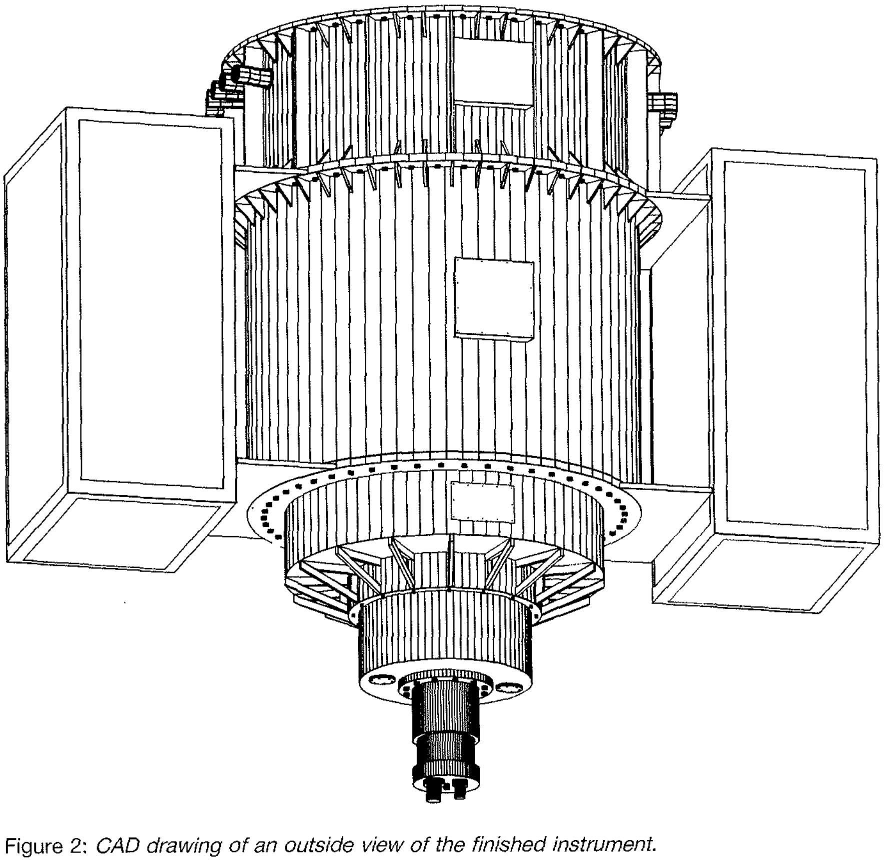

Figure 2: *CAD drawing of an outside view of the finished instrument.*

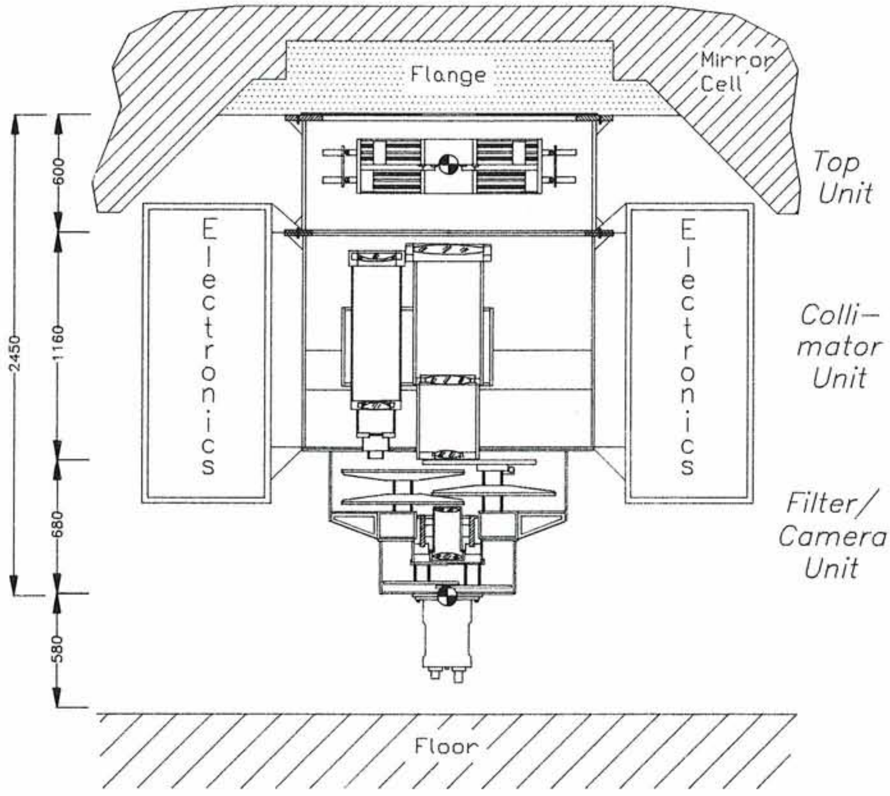

Figure 3: *Cut through the instrument including its major sub-units (MOS unit in the focal plane, the exchangeable collimators, collimated beam space with the components mentioned in the text, and the camera.*

closing adjacent slitlets completely, a focal plane mask for differential imaging polarimetry of extended objects can be produced.

Figure 4 shows a prototype of the slitlets. This prototype has been built to test critical properties of the slitlets like their sensitivity to flexure, guiding precision and positioning accuracy. The basic components visible here are the slitlet arm that will carry the polished slit blade (top right), the DC motor (left), the two linear ball bearings and the high precision spindle drive (centre), and the linear position encoder (bottom). This and similar setups are also used to test the electromechanical accuracy, the drive controls and the long term reliability of these devices.

The approach chosen here for the MOS unit illustrates the emphasis on maximal operational flexibility common to all functions of the instrument. It will be possible to switch between different instrument setups in a matter of seconds. Changing from spectroscopy to imaging or vice versa, e.g., is accomplished in less then 15 seconds by moving all slitlets simultaneously. Changing filters, grisms or Wollaston prisms is done by rotating the appropriate wheels, and the switch between the high and standard resolution collimators or the insertion of the retarder plates for polarimetry will also take a few seconds only.

As specified for all VLT instruments, the focal reducers will be designed for fully remotely controlled operation. All functions are motorized, and numerous safety features are included.

Building the two copies of FORS in the relatively short time dictated by the progress of the VLT project requires a major manpower effort at the three participating institutes. According to the present estimates, about 150 man-years will be needed to complete the two instruments. Among the key persons presently involved in the project are K. Fricke and R.-P. Kudritzki, who head, respectively, the Göttingen and München task groups of the three-institute consortium. I. Appenzeller of the Landessternwarte Heidelberg is the Principal Investigator of this project. All optical design and development work is being carried out in Heidelberg under the responsibility of R. Östreicher and W. Seifert. H. Nicklas, K.-H. Duensing, S. Gong, and R. Harke of the Göttingen observatory lead the complex effort of designing and producing the sophisticated mechanical system of the instruments. B. Muschielok, H. Geus, H.J. Hess, and S. Kiesewetter at the University Observatory of München are responsible for developing the electronic system and the instrument related software, while O. Stahl and S. Möhler are designing the science support software at the LSW Heidelberg. A particularly important member of the team is also H. Böhnhardt who will be in charge of managing the whole cooperative effort from his office at the USW München.

Scientific Opportunities

The use of the FORS instruments on the 8-m VLT unit telescopes, located at one of the astronomically best places on earth promises outstanding new results in many different fields. Based on the anticipated transmission of the instrument, the efficiency of the detector and the quality of the atmosphere on Cerro Paranal, we have calculated that it will be possible to detect – in imaging mode – objects fainter than 30^m with integration times of the order of an hour.

Among the exciting new possibilities of the new instruments will be the quantitative spectroscopy of individual early-type stars up to distances of about 4 Mpc, i.e. well outside our local group. Primary distance indicators such as δ Cephei stars and Planetary Nebulae will become observable to unpre-

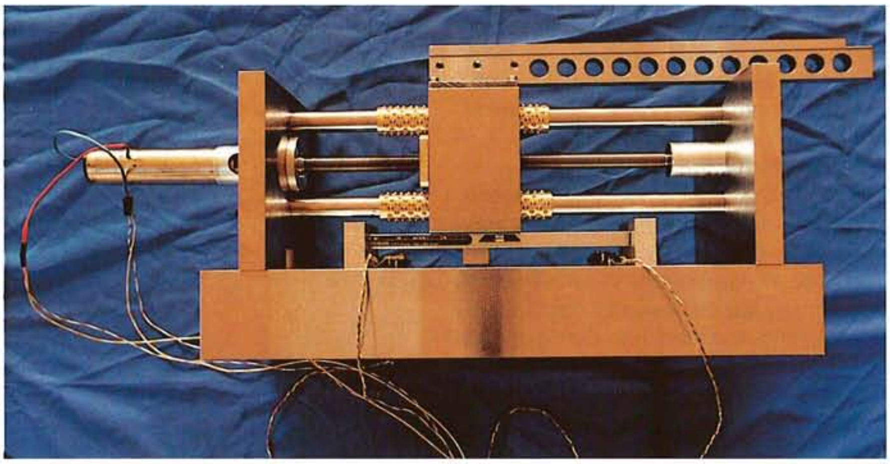

Figure 4: *Prototype of a single slitlet for the MOS unit. The whole assembly is about 35 cm long, the slitlet arm can be extended another 25 cm. See text for details.*

cedented distances, promising real progress in clarifying the extragalactic distance scale. As an example we note that Planetary Nebulae should be observable with FORS not only in the Virgo and Centaurus clusters but also at the distance of the "Great Attractor" region of enhanced galaxy densities.

The FORSes will also be excellent instruments for spectroscopic surveys of (field) galaxies down to B-magnitudes fainter than 24^m. They will serve to constrain the basic cosmological parameters and the scenarios for the evolution of galaxies as well as to investigate the clustering of galaxies in redshift.

With their superb imaging capabilities the FORSes will be particularly valuable for investigating the galaxy environment of QSOs, for probing the large-scale structure of the distant universe in selected fields and, perhaps, for finding very young or still forming galaxies.

Finally we note that in astronomy new and more powerful instruments almost always resulted in the discovery of new and often completely unexpected types of objects. Not the least for this reason are we looking forward with great excitement to the year 1996 when, if everything goes well, FORS I will see its first light at the VLT on Paranal.

Delay Lines of the VLT Interferometer: Current Status

M. FAUCHERRE and B. KOEHLER, ESO

The four 8-m telescopes of the VLT, located at fixed positions, as well as the movable auxiliary telescopes, need delay lines between them to cancel out the optical path difference (OPD) due to sidereal motion. The ESO design comprises 60 metre delay lines using cat's eye optics of 80 cm diameter to transmit an 8 arcsec field-of-view.

An exceptionally high dimensional stability is required both for longitudinal and lateral positioning. A feasibility study was performed by MBB (Ottobrunn) between October 1990 and September 1991 to find solutions for both requirements. The goal was to reach the requirements with a straightforward single-stage approach based on state-of-the-art air bearings (passive solution) or magnetic suspension (active solution).

Six commercially available air bearings were found to be inadequate due to excessive acoustic noise exciting cat's eye eigenmodes. The magnetic suspension option is an elegant solution to actively control vibrations. However, to eliminate uncertainty with regard to stability performance, a prototype is needed to assess the performance at the unusual manometer level.

Following this, tests were performed by ESO and OCA in September 1991 in Limoges (Ateliers Maître, Microcontrôle) and in October 1991 at the TU München on air bearings using different technologies. The test carried out at the TU München on sintered bronze air pads, patented by Prof. Heinzl's group, revealed a level of acoustic noise more than an order of magnitude lower than air bearings previously measured. This shows that air bearings exist which meet our OPD requirement, and that air bearings are still potential candidates for VLTI delay lines.

In conclusion, the main driver to select a solution for VLTI delay lines remains the cost for the design, manufacturing and installation on the site.

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IRAC 2 – ESO's New Large Format Infrared Array Camera

IRAC 2 has been developed to exploit the new generation of large array detectors for broad and narrow band infrared imaging and to gain experience with these devices of relevance for the VLT. It is equipped with a Rockwell 256×256 pixel Hg:Cd:Te NICMOS 3 array; broad and narrow band filters between 1 and 2.5 µm; a scanning Fabry Perot etalon covering the range ~ 2–2.5 µm at R ~1000 and five selectable objectives providing for image scales from 0.15 to 1.1 arcsec/pixel (at the 2.2-m telescope). At present IRAC 2 is in the integration and test phase in Garching with installation and tests on the ESO/MPIA 2.2-m telescope scheduled for May 1992. An HP workstation will be used for instrument control, with MIDAS available on-line for image display/handling, in line with the current ESO policy of phasing out the HP 1000 computers on La Silla. The final user interface and control software as well as new VME based motor controllers are being developed on La Silla and are planned to be installed in October 1992. In the meantime, the instrument will be used with software developed in Garching for laboratory testing. The accompanying photographs show the instrument mounted on the telescope simulator in Garching and the cryogenically cooled optical assembly.

Observational Capabilities

IRAC 2 will be installed initially at the 2.2-m telescope where it will be mounted on the F/35 infrared adapter. Its main characteristics are summarized in Table 1. It should be noted that the five objectives have been provided not only to allow optimization of the image scale for particular scientific programmes and seeing conditions but also to foresee use of this camera with different array detectors and possibly at the 3.6-m telescope in future. For most applications and average seeing conditions it is expected that the 0.53 and 0.28″/pixel scales will be the most ap-