stitut für Physikalische Sensorik at the Fachhochschule Offenburg (FHO), Germany, started with a theoretical investigation of this concept in view of the specific requirements in astronomical telescopes and came up with a proposal for a fibre/laser gyro combination in order to cover the pointing as well as tracking phase in telescope operation.

A first prototype for the fibre gyro part has recently been completed at the FHO (see Fig. 1) which would already meet the VLT requirements for tracking with an accuracy of better than 0.1 arcsec over 30 seconds, and a resolution higher than 0.02 arcsec. Commercially available systems currently do not provide this accuracy and resolution. The construction for an improved version which will be delivered to ESO (3) and tested on the NTT next year has just started. This fibre gyro will be combined with a commercially available laser gyro covering the faster slewing and pointing operations of the telescope. A Litton LTN-90 laser gyro system has been considered for this.

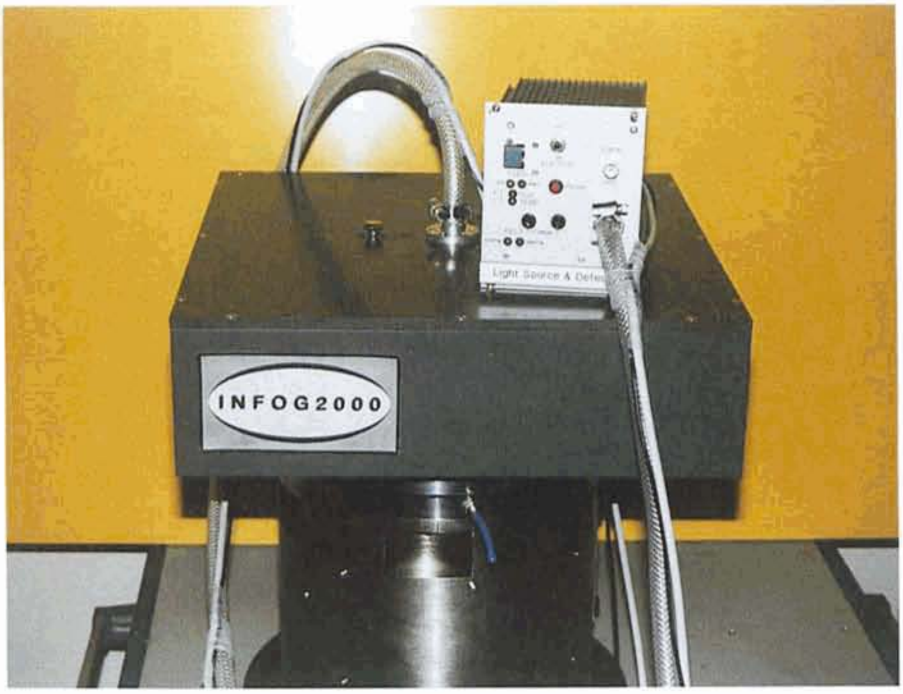

Figure 1: *View of the fibre gyro system (INFOG 2000) developed by Prof. Schröder at the FH Offenburg. The coil with 1100 m polarization maintaining fibre has 26 cm diameter and is inside the thermally stabilized and magnetically shielded square box (gyro head) mounted for test purposes on a rotation table. The small control box, which can be separated more than 15 metres from the gyro head, contains the light source (ELED at 1280 nm) and the detector and delivers the conditioned gyro output signal. (Photo: FH Offenburg).*

References

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(2) H.W. Babcock (1991), *PASP*, Vol. **103**, 468.
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Multi-Object Spectroscopy with an Automatic Fibre Positioning System in a One-Degree Field

First Technical Run of MEFOS at the Prime Focus of the 3.6-m Telescope

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1. Introduction

Several scientific programmes require the acquisition of a large number of spectra to build up a statistically significant sample of data. Typical examples of this category are studies of galaxies in clusters or in the field and surveys of QSO candidates and peculiar stars in selected galactic regions or in nearby galaxies. In the last decade, optical fibres have been successfully used in gathering the light of different targets spread over the field of a telescope to a common spectrograph slit and thus to speed up the process of data collection.

In the first generation of instruments of this type, the fibres – typically between 40 an 100 – are manually inserted in predrilled plates mounted at the focal plane of the telescopes. The ESO facility OPTOPUS (1986, *ESO Operating Manual* No. **6**) is based on this principle and is successfully in operation at the La Silla 3.6-m telescope since 1986 as a common user instrument. Its performance has recently been upgraded with the introduction of two new fibre bundles and of a new F/6 collimator (Avila and D'Odorico, 1991, preprint). The plate drilling operation has recently been transferred to the ESO workshop at La Silla. In the second generation of fibre instruments, which came into use more recently, the positioning of the fibres in the field is done automatically at the telescope in order to skip the need of the predrilled plates and to retain real-time control of the fibre position. Systems of this type have been prototyped by Hill and Lesser at the Steward Observatory (1988, Proceedings of the 9th Santa Cruz Workshop, ed. S. C. Barden, p. 233), by Parry and Gray at the Anglo-Australian Telescope (1986, *SPIE* **627**, 118) and by Ingerson et al. at Cerro Tololo (1991, in preparation).

In 1989 ESO concluded an agreement

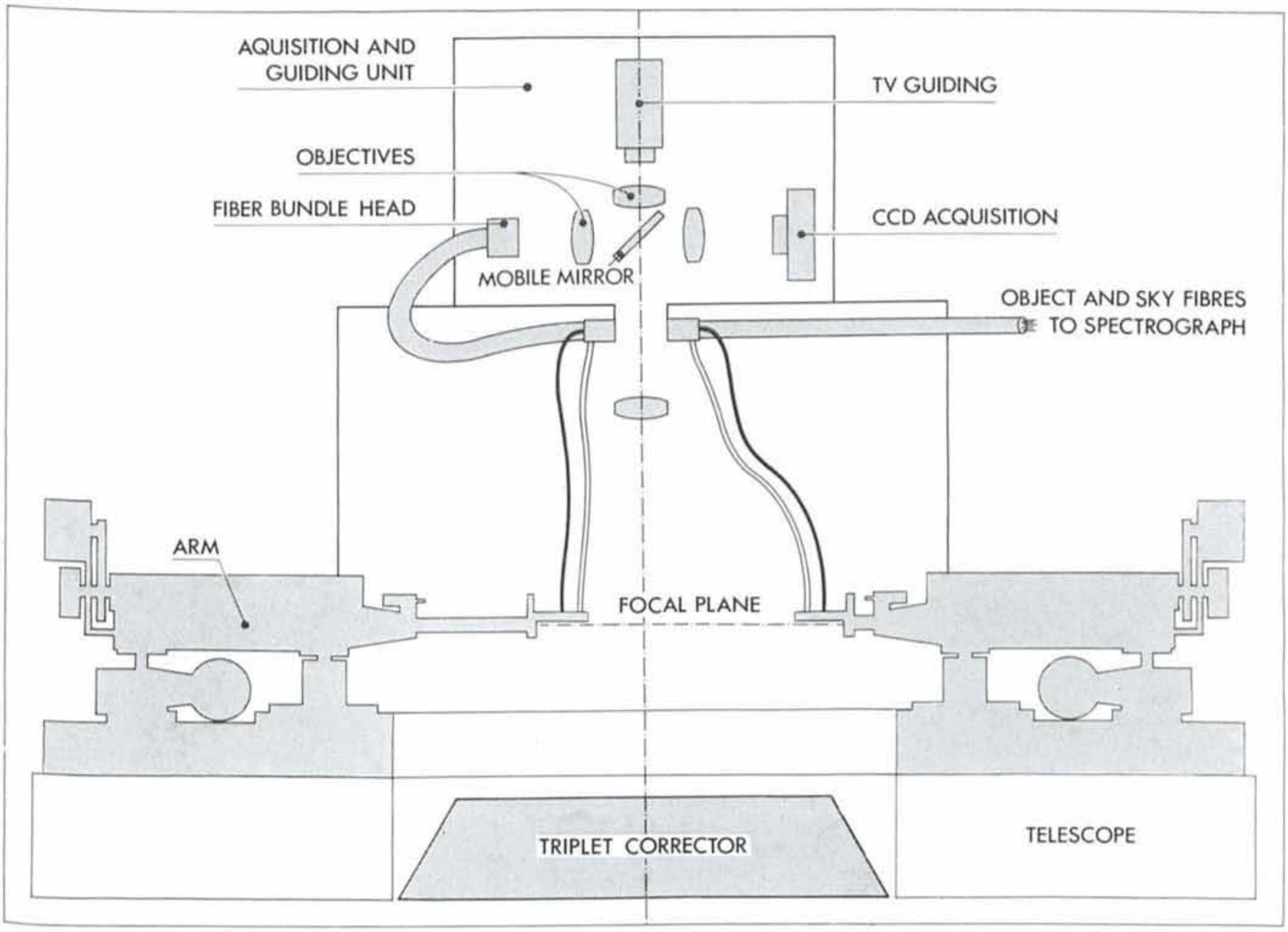


Figure 1: *General scheme of MEFOS showing its main modules and attachment at the prime focus of the ESO 3.6-m telescope.*

with the Observatoire de Paris, then led by the late Pierre Charvin, to have an automatic fibre positioning device built for the prime focus of the 3.6-m telescope. The concept of the instrument was inspired by the systems built at the Steward Observatory and at Cerro Tololo, but it includes some original features. It has the advantage of shorter setting time – the arms can move in parallel – and it gives the possibility to easily correct for atmospheric diffraction and to improve the sky subtraction by switching between object and sky fibres during the exposures. The agreement foresees that the group led by Paul Felenbok at the DAEC department in Meudon will design and build the fibre positioning and target acquisition/guiding units while ESO will deliver the fibre optics bundle and take care of the interface to the telescope and the existing grating spectrograph. The instrument schedule foresees the final installation at the telescope by the last quarter of 1992. In January 1991, a prototype version of the instrument named MEFOS (Meudon-ESO Fibre Optics Spectrograph), was tested at La Silla. This article gives an overall view of the instrument and briefly reports on the results of the first telescope test.

2. The MEFOS Project

At the ESO 3.6-m telescope prime focus, using the triplet corrector, a flat, corrected field of one degree diameter is available for faint-object spectroscopy. MEFOS is designed to pick up targets over this field. Figure 1 shows its overall structure. Four main subsystems can be identified: *the positioning arms, the fibre optics, the acquisition and guiding system* and *the spectrograph*. There are 30 positioning arms arranged in a circle at the edge of the field, each of them carrying two spectroscopic fibres and one image fibre bundle. The F/3 input aperture of the beam at the prime focus is well suited for the best performance of the fibres as far as the focal ratio degradation is concerned. No front lenses are needed at the fibre top ends. The bundle of spectroscopic fibres is guided to the Cassegrain cage where it is interfaced to a modified Boller and Chivens spectrograph. This could be substituted in the future by a dedicated bench spectrograph mounted in a stationary configuration in one of the coudé rooms of the telescope.

The output ends of the image fibre bundles are projected onto a CCD viewing camera fixed to the structure of MEFOS and used for target recognition and centring.

2.1 Positioning Arms

Figure 2 shows the 30 positioning arms – without the tips carrying the fibres – during the integration on their support flange. This flange is interfaced to the top of the prime focus triple corrector unit. It can be tilted in order to match the plane of motion of the fibres to the telescope focal plane. Figure 3 illustrates the design of one positioning arm. Each arm sweeps a triangular zone by rotation and translation. It is activated by DC motors coupled to optical encoders. The distance between the two spectroscopic fibres is 3 mm or 59 arcsec on the sky.

2.2 Optical Fibres

The two single fibres used for spectroscopy have the same projected aper-

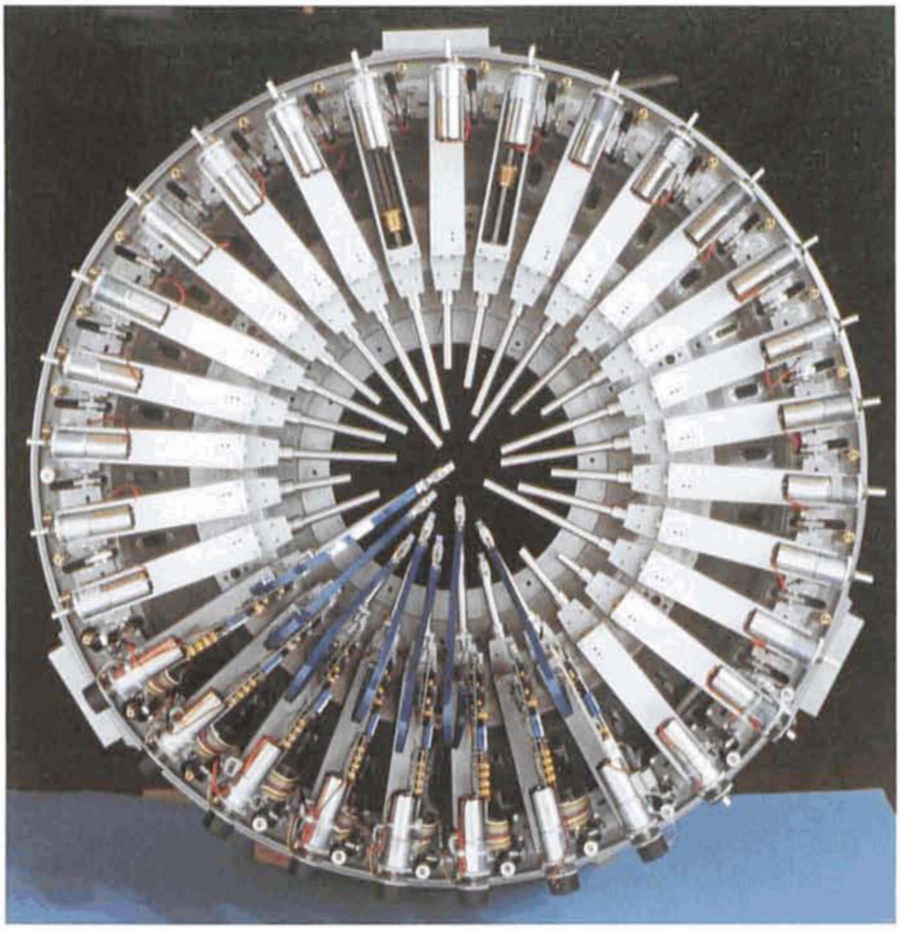


Figure 2: *MEFOS top view with all 30 positioners. 8 arms are shown with their drive cards. The fibres are not installed.*

The polished input fibre ends directly pick up the F/3.1 beams at the prime focus. The output ends, arranged on a line to form the slit of the spectrograph, feed a F/3 dioptric collimator fitted to an existing B&C spectrograph. With these apertures, the focal ratio degradation along the fibre is minimal: an average of 90% of the light is recovered by the collimator. The fibre absorption and the reflection losses at the fibre ends are not included, but they are estimated to be of the order of 10% at visual-red wavelengths. By the process of degradation of the focal ratio at the fibre output the central obscuration shadow of the Cassegrain telescope is partially filled in. For this reason, we have avoided the use of camera optics with central obscurations in the spectrograph.

The image fibre bundles have a surface of 1.9×1.9 mm, i.e. 36×36 arcsec on the sky.

2.3 Acquisition and Guiding System (AGIS)

Figure 1 shows the scheme of the unit which is mounted on a plate above the arms. All the output ends of the image fibre bundles are packed together and projected onto a CCD by two photo-objectives, giving a scale of 50.8 μm/arcsec. Before the beginning of an observation each arm moves the image fibre bundle to the calculated position of

ture on the sky: 2.6 arcsec (135 μm). The fibre length needed to link MEFOS to the spectrograph located in the Cassegrain cage is 21 m. For the first run at La Silla we used Polymicro FBP fibres. This type of fibre shows a flat transmission between 500 and 1200 nm, as illustrated by the continuous line in Figure 4. To increase the efficiency in the blue wavelength region (350–450 nm) we will use in the future the so-called "wet" fibres. As shown by the dashed line in Figure 4, this kind of fibre is much more transparent in the blue but exhibits water absorption bands in the near-infrared region.

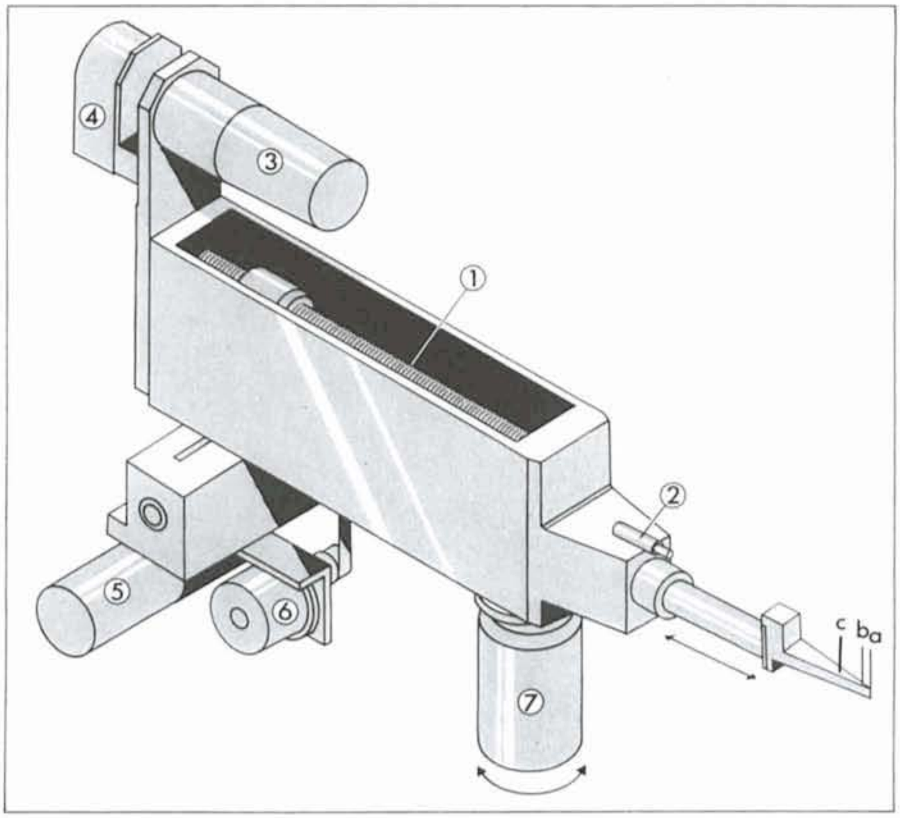


Figure 3: *Detailed view of one positioner. A high-precision screw (1) with a 0.5-mm pitch is used for the radial movement of the arm. A switch (2) provides the definition of the zero reference point with a precision of 1 μm. A DC motor (3) is coupled to an optical encoder (4) for the radial movement, (5) and (6) are the motor and the encoder for the rotation of the arm around the pivot (7). The spectroscopic fibres are labelled by (a) and (b), the image fibre bundle by (c).*

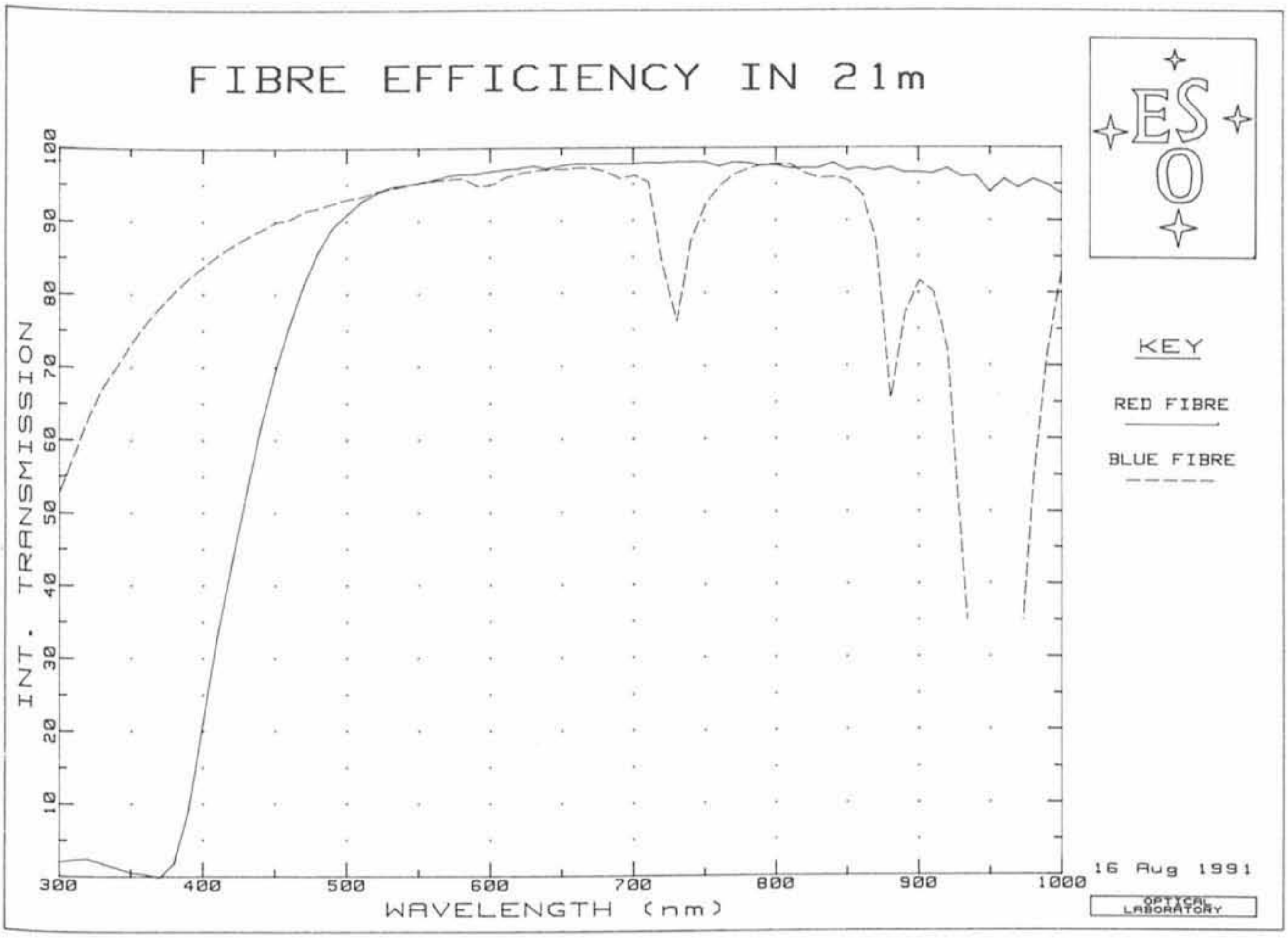


Figure 4: *Internal transmission of 21-m fibres in the 300- to 1000-nm wavelength range. Continuous curve: fibre optimized for the visible-red wavelengths. Dashed curve: fibre optimized for the blue spectral region.*

its assigned target. A short CCD integration then gives subimages of all 30 targets. These are processed to compute the exact object positions with respect to the single spectroscopic fibres on the corresponding arms. Finally the arms are moved by the computed offsets and the integration of the spectra can be started.

The acquisition camera uses a Thomson CCD with 1024×1024 pixels of 19 μm, cooled with a two-stage Peltier device to about −60°C. Lower temperatures are not needed because the exposure time will never exceed a few minutes and the read-out noise is small compared to the sky photon noise. A 12-bit A/D converter is used in the commercial CCD control camera leading to a sufficient dynamical range and to a fast read-out.

As shown in Figure 1, the acquisition system is placed in such a way that a separate TV camera can monitor the centre of the field by means of a third photo-objective. A movable 45° mirror may be inserted to project the image fibres on this TV camera. In this position, the automatic guiding of the telescope

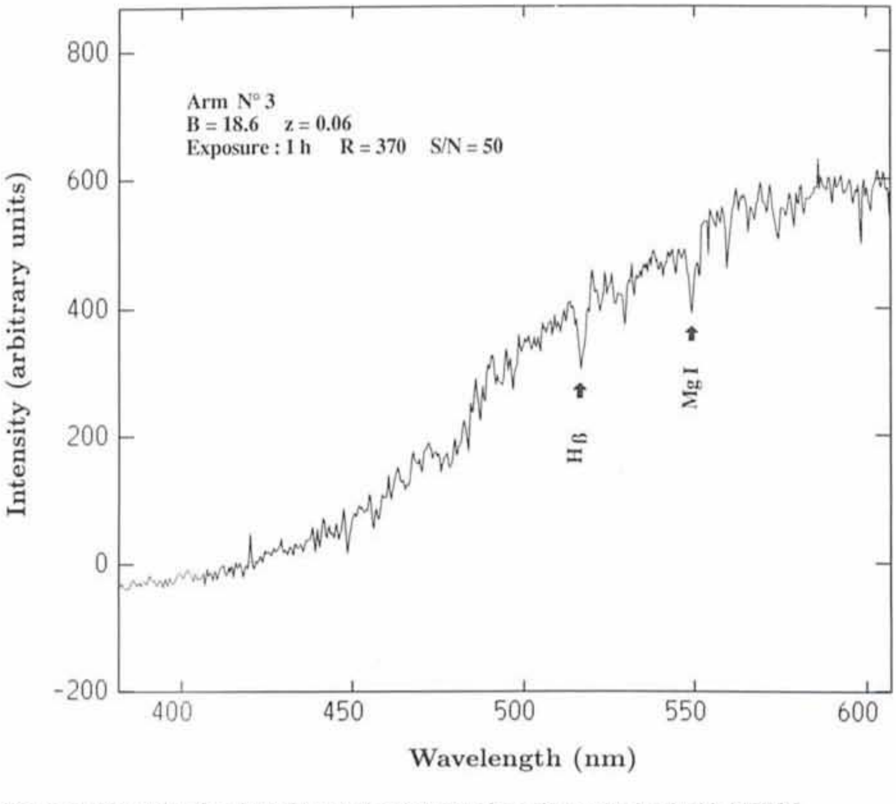


Figure 5: *Example of a sky subtracted spectrum of a galaxy, obtained with MEFOS.*

can be achieved with one image fibre pointing to a conveniently bright star in the field. If such a star cannot be seen on any of the image fibre bundles, one of the arms must be moved to find it.

2.4 Control of the Instrument

An Olivetti M300 PC/AT is used for the general control of the positioners and the Acquisition and Guiding module. The arms are driven by a central master card located in the PC. This card is connected through two optical fibers to slave cards located on each positioner. Both cards, master and slaves, are based on 8 bit 80451 and 80535 microprocessors, respectively.

The coordinates of the arm positions are stored in the master card. The latter questions and sends commands to all the arms; once well received and acknowledged, these commands are executed by the arms. The arms move therefore simultaneously and the maximum time to set up a field configuration from the "parking" position is less than 5 minutes with a repeatability of 10 μm (0.19 arcsec). The master microcontroller continuously scans the whole system. By questioning the master card, the user can observe in "real time" the dynamic state of the system.

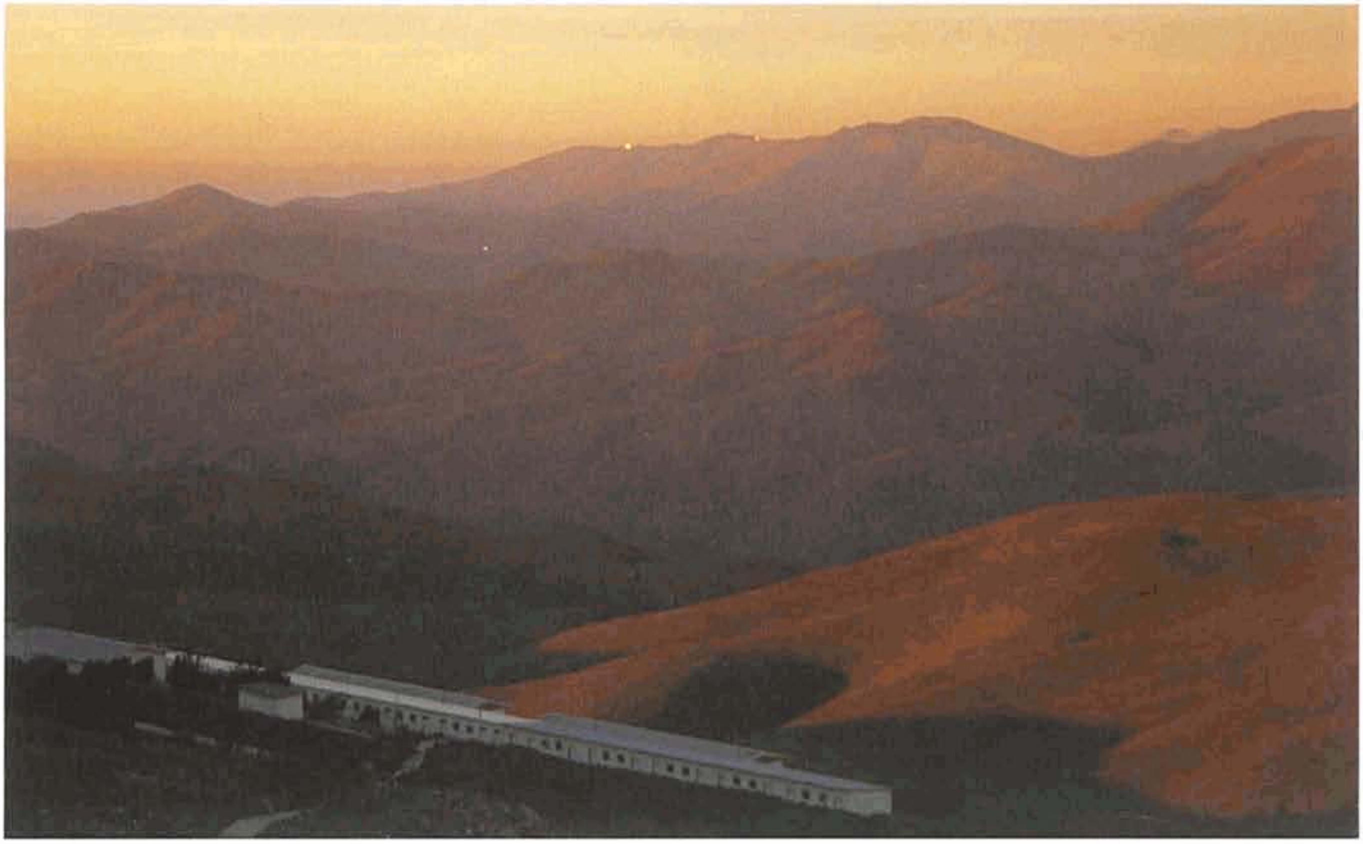
Communications between the master and the slaves are done in serial at a data rate of 375 Kbaud. The two optical fibres (transmit and receive) have a length of 75 m and are provided with an error-detection procedure.

The software that drives the whole instrument is written in C. The user provides files stored on floppy disks with the object coordinates α and δ in the fields of interest. These coordinates are converted in r, θ coordinates in the telescope focal plane. The object-to-arm assignment is made by software using the Hungarian algorithm for the best match and to avoid collisions. The coordinates stored in the master card are then distributed to the assigned arms, which first move the image fibres to the objects. The programme eventually takes care of moving the arms to set the spectroscopic fibres on the targets as explained in section 2.3.

2.5 Spectrograph

The Boller & Chivens spectrograph has been adapted to the use with MEFOS. The standard F/8 parabolic mirror used as collimator and the Schmidt camera have been replaced by two fully dioptric elements, an F/3 collimator and an F/2 camera, respectively. With this new configuration the fibre-spectrograph matching is optimal. As was mentioned above, the light losses at the central obscuration of the camera are avoided and the focal ratio degradation at F/3 is minimal. During the first test observation in January 1991, the spectrograph detector was a Tektronix CCD with 512×512 pixels of 27 μm. The fibre output ends project a diameter of 86 μm or about 3 pixels on the detector. The usual complement of gratings and corresponding dispersions of the B & C spectrograph in the OPTOPUS configuration is available to the observers.

A Distant View of . . . Las Campanas



With reference to the article by W.C. Keel in an earlier issue of the *Messenger* (**55**, p. 29) in which a distant view of La Silla was reproduced, I should like to inform the readers that spectacular views of an observatory are also available to visiting astronomers at La Silla itself.

This photo was taken during my last visit to La Silla on May 2, 1991, around 18.00 from the 1-m telescope. From my experience as a long-time La Silla resident astronomer, the most favourable epochs of the year are are around one and a half months before and after the June solstice.

TH. LE BERTRE (DEMIRM, Observatoire de Paris, France)

3. First Technical Run at the 3.6-m Telescope

The first test run of MEFOS at La Silla took place from January 30 to February 7, 1991. The final instrument structure was used but with nine positioning arms only. The goal of the observing run was to check the telescope interfaces and to practise all instrument mounting and adjustment procedures. The fibre output slit could be mounted either at the spectrograph collimator or at a photomultiplier to verify the accuracy of the fibre centring. The whole system (including the read-out of the photomultiplier) was controlled by the instrument PC in the Control Room.

The spectral calibrations and flat-fields were performed using the Optopus flange mounted, as usual, on the Cassegrain adapter. The lamps sent the beams directly to the prime focus through the central hole of the main mirror. They were controlled together with the spectrograph CCD by the OPTOPUS software package running on the HP 1000 telescope computer.

Apart from minor difficulties in the mechanical installation and in the control software, the main problems were encountered in the object acquisition: at the beginning the arms were not able to reach the correct positions. This was traced down to a slightly erroneous value of the scale we were using. After this correction, the final position of the arms was still not fully satisfactory because the programme did not yet include the field distortion. Nevertheless, once the objects were brought inside the image fibres and analysed with the acquisition programme, the arms could send the spectral fibres to the objects with relatively good accuracy: better than 0.4 arcsec. Two factors contributed to this uncertainty: the spherical aberration produced by the non-perfect alignment of the triplet corrector, and small drifts in the tracking of the telescope during the acquisition exposure time. In the laboratory the procedure of target acquisition and displacement of the arms to put the spectral fibre in front of the object yields an accuracy of better than 10 μm or 0.17″.

In the last three nights of the run, a number of scientific exposures were obtained. The most important exposure was on a field of galaxies with magnitudes between 17.5 and 18.6. This field had been observed before with OPTOPUS by C. Balkowsky and R. Kraan-Korteweg. The field acquisition exposure time of 5 min and the spectral exposure time of 1 hour proved to be sufficient for the purpose. The spectrum displayed in Figure 5 is from a galaxy of $m_B = 18.6$, $z = 0.06$ and reaches a signal-to-noise ratio of 50. An actual measurement of the relative efficiency of MEFOS and OPTOPUS is almost impossible because of the strong dependence on seeing. A computation which takes into account telescope, fibre and spectrograph effects indicates that MEFOS should be approximately 25% more efficient than OPTOPUS.

Acknowledgements

The design and construction of this instrument was done under the responsibility of André Collin and the mechanical workshop of the CNRS at Bellevue. We are grateful to Daniel Hofstadt for his continuous support of the project, to all colleagues who helped us during the test in Chile – in particular A. Gilliotte, M. Maugis and O. Lavin – and to P. Focardi for her help in the data reduction.

News on ESO Instrumentation

S. D'ODORICO, ESO

1. EMMI

EMMI, the ESO Multi-Mode Instrument, is in regular operation at the Nasmyth B focus of the NTT since November 1990 (see *The Messenger* **61**, p. 51). In March and April of 1991 part of the EMMI team (H. Dekker as project coordinator and optical engineer, J.L. Lizon for opto-mechanical integration and testing, A. Longinotti and G. Raffi for the control software, R. Reiss for the CCD and the author for the astronomical tests) was again on the mountain for a number of upgrades on the instrument. These are shortly summarized below.

1.1 Multi-Object Spectroscopy

The operation and the first results of the MOS mode of EMMI have been described in the *Messenger* No. **63**. Further work was needed to refine the object selection software, for slight modifications of the hardware and to prepare a user interface. The work is now completed and the mode is in operation. Figure 1 shows one MOS observing sequence. Table 1 lists the main parameters and compares them with the equivalent facility in EFOSC1 at the 3.6-m.

1.2 Medium-Dispersion Spectroscopy with the Dichroic

The DIMD mode is now also in operation. In this configuration the slit is fed by a wide-band mirror instead of the blue- or red-optimized mirrors and the blue and red beamsplitter prism below the slit is replaced by a dichroic prism. All types of coatings represent state-of-the-art coating technology. The absolute efficiencies as measured in the ESO optical laboratory are shown in Figure 2. The EMMI control software fully supports the DIMD mode and allows parallel exposures (but sequential read-out) of the two CCDs.

TABLE 1: *MOS in EMMI and (for comparison) EFOSC1*

	EMMI	EFOSC1
Wavelength range (A)	4200–10000	3600–10000
Field (arcmin)	10×10	3.6×5.8
Punch field (arcmin)	5×8	3.6×~4
Aperture shape	slit	circ. hole
Hole size (arcsec)	1.3×8.6 1.9×8.6*	2.1 3.6
No. objects per field (typical)	10–30	5–15
Punching machine	on line (on EMMI)	off line (control room)

* Available October 1991.