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Science Operations

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FEROS-II User Manual

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Contents

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Chapter 1

Introduction

This is the FEROS User's Manual. It is primarily intended as the main reference for observers who wish to use or have been awarded time to use FEROS in either visitor or service mode.

1.1 On the contents of the FEROS User Manual

The current version of the FEROS User Manual is available as retrievable postscript and PDF files from the ESO home page on the World Wide Web:
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS`
Before the observing proposal application deadlines, the User Manual is normally updated; any significant changes are announced on the FEROS webpages. If you have no access to the WWW, a printed copy can be requested from ESO's Visiting Astronomers Section (on Internet: `visas@eso.org`) in Garching, Germany. Paper copies of a new version of the FEROS User Manual are printed out only after a major revision of the document. The reader is referred to the web version of this document for the best quality of the included (color) figures.

The **first Chapter** of this manual is addressed to users who are not familiar with the FEROS instrument and who are interested in a **quick overview** of its capabilities, in comparison with other similar ESO instruments. This should enable a potential user to select the best instrument for a given observing program. It also includes information on how to access FITS files of reference FEROS spectra and a glossary of terms used in the Manual. The **second Chapter** provides the **description of the instrument**: the instrument layout (§ 2.1), its components (§ 2.2), the properties of the CCD Fibrehead Viewer and of the scientific CCD detector (§ 2.3, 2.4), the Calibration Unit and the FEROS/WFI Adpater (§ 2.5, 2.6), the spectral coverage, resolving power and overall efficiency (§ 2.7) and reference to instrument features and known problems to be kept in mind while planning the observations or reducing the data (§ 2.8). It can be consulted by users who want to prepare an Observing Proposal (Phase I), but should definitely be read by those who have been granted observing time and have to prepare their observations (Phase II).

The **third Chapter** provides the basic information needed to **prepare an observing program**: the identification of the instrument observing modes (§ 3.2) and a description of the Exposure Time Calculator (§ 3.4). The **fourth Chapter** deals with **calibration** strategy (wavelength, flat-fielding, relative and absolute calibrations) of data obtained in standard operation. The **fifth Chapter** provides information for the visiting astronomers who come to the La Silla Observatory to use FEROS. The **sixth Chapter** summarizes the properties of the **pipeline reduction** carried out for data obtained using the standard set-ups of the instrument.

1.2   Information available outside this manual

If you cannot find a specific piece of information in the FEROS User Manual or in case you have remaining questions, please contact: `http://www.eso.org/observing/support.html`, or more specifically:

- For information on the instrument performance and Phase I and Phase II proposal preparation, please contact the User Support Group (`usd-help@eso.org`).

- For questions directly related to your granted observing run in Visitor Mode, please contact La Silla Science Operations (`lasilla@eso.org`).

- For Phase II preparation of Observation Blocks (OBs) follow the instructions given in the FEROS Template Reference Guide: `http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS`

- For checking on possible recent changes in the instrument not yet recorded in the current version of the User Manual consult the FEROS web page at
  `http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS`

- Information on the current instrument performance can be found on the FEROS Quality Control pages at
  `http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/InstrumentCharacteristics/InstrumentEfficiency.html`

1.3   Capabilities of the Instrument

ESO's Fibre-fed, Extended Range Échelle Spectrograph (FEROS) is a bench-mounted, thermally controlled, prism-crossdispersed échelle spectrograph now installed at the MPG/ESO 2.20-m telescope at ESO La Silla. It is designed to be a high resolution, high efficiency, versatile spectrograph providing in a single spectrogram almost complete[1] spectral coverage from ~ 350–920 nm. Precise radial velocity work (accuracies of ~ 25 m/s or better) is also possible, especially via the Object-Calibration mode.

The spectrograph is fed by two fibres providing simultaneous spectra of object plus either sky or one of the two calibration lamps (wavelength calibration and flat-field). The fibres are illuminated via 2.0 arcsec apertures on the sky separated by 2.9 arcmins. A small amount of rotation of the telescope adapter is possible in the rare case that a field star by chance falls on the sky fibre. The resolving power is 48,000 achieved with a two-slice image slicer over the spectral range of ~ 350–920 nm spread over 39 ećhelle orders. The detector is an EEV 2k×4k CCD.

The instrument is built for maximum mechanical stability and for accurate calibration of the wavelength scale down to an accuracy of at least 50 m/s. Wavelength calibration spectra can be obtained simultaneous with the science exposure for observations requiring higher accuracy.

FEROS was first installed at the ESO-1.52m telescope in late 1998. In October of 2002 FEROS was transferred from the ESO 1.52-m telescope to the MPG/ESO 2.2-m telescope. In October-November of 2003 it was upgraded to full VLT-compliance (i.e. OB controlled observing).

The main capabilities of FEROS are summarized in Table 1.1.

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[1]The two spectral ranges 853.4–854.1 nm and 886.2–887.5 nm are lost due to non overlap of the spectral orders.

Table 1.1: FEROS characteristics and observing capabilities

Wavelength range in one exposure (object + sky)	356 - 920 nm (39 orders, 2 fibres)
Resolving Power (with 2-slice image slicer)	$R = 48000$
Entrance Aperture	2.0 arcsec
Fibre Input/Output Focal Ratio	F/4.6
Spectrograph Beam Size	136 mm diameter
Off-axis Collimators	F/11, cut from one parent paraboloid
Echelle	R2, 79 lines/mm, 154 mm by 306 mm
Crossdisperser Prism	LF5 glass, 55°: apex angle
Dioptric Camera	
Wavelength Range	350 - 900 nm
$F/\#$	$F/3.0$
Focal Length	410 nm
Field Diameter	69 mm
Image Quality (E80)	$< 25~\mu m$
Efficiency	$> 85~\%$
CCD	2048 x 4096, 15 μm, thinned
Detection Efficiency (without telescope)	7% (3 700 Å), 27% (5 000 Å), 8% (9 000 Å)
Radial-Velocity Accuracy	< 30 m/s

1.4   FEROS within ESO

A detailed overview of the different ESO instruments is given on the ESO homepage under Instrumentation (`http://www.eso.org/instruments/`). In the choice of the best instrument for a given observing program, the following trade-offs have to be taken into consideration:

1.4.1   La Silla

Spectroscopy in the UV-Visual-Red regions (300-1100 nm)

- **EMMI** at the NTT.
  TBD... See `http://www.ls.eso.org/lasilla/sciops/ntt/emmi`.

- **EFOSC** at the ESO 3.6-m.
  TBD... See `http://www.ls.eso.org/lasilla/sciops/3p6/efosc`.

- **HARPS** at the ESO 3.6-m.
  TBD... See `http://www.ls.eso.org/lasilla/sciops/3p6/harps`.

- **CES** at the ESO 3.6-m.
  TBD... See `http://www.ls.eso.org/lasilla/sciops/3p6/ces`.

Spectroscopy at infrared wavelengths (1-5 μm)

- **SofI** at the NTT.
  TBD... See `http://www.ls.eso.org/lasilla/sciops/ntt/sofi`.
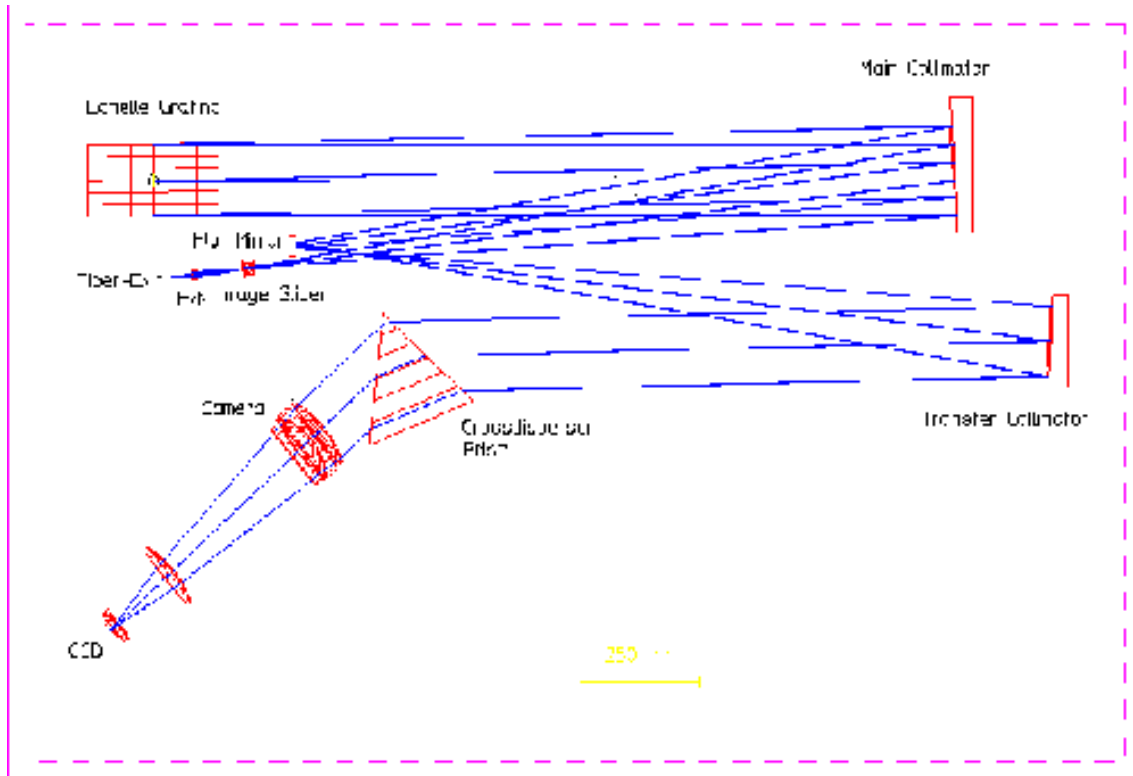
Figure 1.1: FEROS optical system from fibre exits to detector.

- **TIMMI2** at the ESO 3.6-m.
  TBD... See `http://www.ls.eso.org/lasilla/sciops/3p6/timmi`.

1.4.2   Paranal

Spectroscopy in the UV-Visual-Red regions (300-1100 nm)

- **UVES** is the high-resolution optical spectrograph of the VLT located at the Nasmyth B focus of UT2. It is a cross-dispersed echelle spectrograph designed to operate with high efficiency from the atmospheric cut-off at 300 nm to the long wavelength limit of the CCD detectors (about 1100 nm). To this aim, the light beam from the telescope is split in two arms (UV to Blue, and Visual to Red) within the instrument. The two arms can be operated separately, or in parallel via a dichroic beam splitter. The resolving power is about 40,000 when a 1-arcsec slit is used. The maximum (two-pixel) resolution is 80,000 or 110,000 in the Blue- and the Red Arm, respectively. Three image slicers are also available to obtain high resolving power without excessive slit loss. The instrument is built for maximum mechanical stability and allows for accurate wavelength calibration. An iodine cell can be inserted in the light beam for observations requiring extremely high accuracy for radial velocity measurements.

- **FORS1** at UT2 since June 2004 can be used for spectroscopy in the spectral range 360-1100 nm. Its overall efficiency is on average 2 times higher than UVES (one reflection less in the telescope and simpler instrument optics) but the maximum resolving power to be obtained with a 0.5 arcsec slit is 2,500 only.

- **FORS2** at UT1 is a replica of FORS1 but it will eventually include two transmission echelle gratings which, when used in conjunction with a grism cross disperser, will provide a resolving power of up to 6,000 and a wider spectral coverage comparable to that of UVES.

- **GIRAFFE**, which is part of the FLAMES instrument at the opposite Nasmyth platform of UT2, is the instrument which approaches UVES in resolution. An automatic fibre-positioning unit is installed at the Nasmyth focal plane. It can use up to 132 fibers in the field of view of 25 arcminutes in diameter. The fibers feed the GIRAFFE long-slit spectrograph mounted on the Nasmyth platform. The data are collected by a 2048×4096 pixels CCD. One CCD frame contains the linear spectra of up to 132 objects observed in parallel with a limiting resolving power of $\sim 20{,}000$ and a spectral coverage in a single exposure of 26-60 nm depending on the wavelength. GIRAFFE is on average 30% less efficient than UVES, but the multiplexing gain can make it the best choice if the observing program includes many objects in a single field at intermediate spectral resolution.

Spectroscopy at infrared wavelengths (1-5 μm)
Complementary spectroscopic observations at infrared wavelengths can be obtained with two other VLT instruments:

- The infrared imager-spectrometer **ISAAC** can be used to obtain spectra in the 1-5 μm spectral region. Two separate cameras in the same cryogenic/vacuum vessel are optimized separately for the 1-2.5 μm and 2.5-5 μm spectral ranges with resolving power up to 10,000 if a 0.5 arcsec slit is used.

- A high-resolution infrared spectrometer, **CRIRES**, is currently under study. It is intended to be the counterpart of UVES in the 1-5 micron spectral region providing a resolution up to 40,000 (0.5 arcsec slit) in a single order or cross-dispersed format.

1.5   How to access FEROS sample calibrations and observations

Scientific observations of selected of targets and the associated calibrations have been obtained during the FEROS Commissionings in October and November 2003 and in March 2005. They are available as public data from the ESO archive. Moreover all calibrations since October 2003 are public domain, as are all SCIENCE data more than one year old and all are obtainable from the ESO Archive.

1.6   Bibliography

[1] *FEROS-II Template Manual*, 2p2-TRE-ESO-22400-0001, version 1.0, 09/07/2004, J. Pritchard

[2] *P2PP User's Manual*, VLT-MAN-ESO-19200-1644, Version 2.7, 12/01/04, F. Comerón, D. Silva

1.7   Glossary

Acquisition: Accurate positioning of the telescope in order to center the target on the spectrograph fibre aperture.

Atmospheric Dispersion Correction (ADC) unit: This unit can be inserted in the pre-fibrehead area of FEROS to correct for atmospheric dispersion.

BIAS frame: Read-out of the CCD detector of zero integration time with shutter closed. The registered number of electrons per pixel has to be subtracted from a science exposure, because these were not created by photons from the source.

Calibration: Procedures to remove the instrumental signature from the scientific data (e.g. by subtracting BIAS frames and by dividing through the flatfield).

Camera: FEROS has a dioptric camera imaging the dispersed parallel beam on one CCD detector.

Charge-Coupled Device (CCD): Electronic 2D-array detector converting photons into electrons.

Cross-disperser prism: An echelle spectrograph contains two dispersive elements, in the case of FEROS one grating and one prism. The grating is the echelle grating, the prism is called the cross-disperser prism. The cross-disperser prism determines the distance between the echelle orders.

Fibrehead Viewer: Simple optics which focus the light reflected by the fibrehead onto a technical CCD detector. They are used to center the targets on the fibre and for guiding.

Flatfield: Spectrum obtained from light source with a flat (i.e. without spectral features) energy distribution, e.g. a tungsten lamp. The registered signal provides information about the response of the detector, allowing a determination of the variation in sensitivity from pixel to pixel, the echelle order shape, the presence of bad columns on the detector, etc.

Grating: One of the main light dispersing elements of FEROS is the echelle grating.

Guide star: A point source used for accurate tracking (and active control of the telescope mirrors).

Image slicer: This device converts a two-dimensional image (e.g. of a star) in the focal plane of the telescope into a one-dimensional slit. In this way, the light that normally would fall outside the slit (especially when using a narrow slit for high spectral resolution) is fed to the spectrograph.

Maintenance: Technical procedures developed to control and maintain the quality of telescope, instrument, and detector.

Mode Selector: Unit in the pre-fibrehead area of FEROS which can direct calibration light into one of the fibres.

Observation Block: A logical unit of exposures needed to obtain a coherent set of data. Encompasses all relevant information for a successful data acquisition on a target. It consists of target information, a set of templates, parameter files for the templates, conditions, requirements and comments concerning the specified observations. It represents the entity the short-term scheduler deals with. Constructing Observation Blocks is part of the Phase II Proposal Preparation Process.

Phase II Proposal Preparation (P2PP): During this phase the successful applicant (whose Phase I proposal has been accepted based on the scientific rationale and technical feasibility) prepares the Observation Blocks to carry out the observing program.

Standard Setting: A pre-defined setting of the instrument facilitating the preparation of the observations. The Observatory keeps an updated database of the relevant calibration files for all Standard Settings of the instrument.

Template: A set of instructions for the performance of a standard operation on an instrument, typically an instrument and detector setups. The templates represent specially devised sequences for all instrument operations and calibrations.

Template Signature File: This is a description of a Template and its parameters. It contains information about the type and allowed ranges of the parameters; some of the parameters have to be set by the observer.

Wavelength calibration: Spectrum obtained from a reference emission-line lamp. The wavelengths of the (many) emission lines are accurately known and are used to transform pixel space into wavelength space.

1.8   Abbreviations and Acronyms

AT	Acquisition Template
BOB	Broker for Observations Blocks
CAL	Calibration exposure
CCD	Charge-Coupled Device
CD	Crossdisperser
ESO	European Southern Observatory
ETC	Exposure Time Calculator
EM	Exposure Meter
FCU	FEROS Calibration Unit
FEROS	Fibre-fed, Extended Range Échelle Spectrograph
FV	Fibrehead Viewer
FWA	FEROS/WFI Adapter
IS	Image Slicer
LSO	La Silla Observatory
OB	Observation Block
OS	Observation Software
OBS	Observation Template for a scientific target
P2PP	Phase II Proposal Preparation
RTD	Real Time Display
SCSM	Sliding Calibration Selection Mirror
STD	Standard star
SM	Service Mode
TSF	Template Signature File
VLT	Very Large Telescope
VM	Visitor Mode

Chapter 2

Instrument Characteristics

2.1 Opto-mechanical layout

Figure 1.1 gives the optical layout of FEROS.

The complete instrument consists of three main parts:

- The FEROS/WFI Adapter

- The Spectrograph

- The FEROS Calibration Unit

The FEROS/WFI Adapter (FWA) is mounted at the Cassegrain focus of the MPG/ESO 2.20-m telescope. It includes a mirror (M3) mounted on an arm which moves in and out of the beam to select between FEROS (mirror IN beam) and WFI (mirror OUT of beam). With M3 in the telescope beam is reflected onto the downward facing fibrehead which is a polished, solid aluminium block. The SCIENCE fibres are mounted into the back of the fibrehead and are illuminated via the fibrehead apertures, holes 2.0 arcsec in diameter on the sky separated by 2.9 arcmins, oriented EW of each other in the default orientation of the telescope rotator. The FWA also includes the Sliding Calibration Selector Mirror (SCSM), which is used to control which of the SCIENCE fibres is illuminated by light from the CALIBRATION fibres whose exit is also mounted in the Adapter, and the Atmospheric Dispersion Corrector which was installed and commissioned during March 2005. A new ADC was later installed in April 2006.

The Spectrograph itself is installed in a thermally stabilised room[1], the FEROS Climate Controlled Room (CCR), located on the level below the observing floor in the 2.20-m telescope building, within the so-called FEROS Room. The optical components are mounted on an $2400 \times 1500 \times 200$ mm^3 Newport M-RPR-58-8 optical table. There are no movable or remotely controlled components on the optical table except the CCD shutter and the LED CCDTest light ring (which can be moved manually and whose three sets of LEDS (Red, Green & Blue) can be remotely turned on and off). Therefore, FEROS works in a fixed configuration in order to guarantee the best possible long-term stability of the spectrograph.

The FEROS Calibration Unit (FCU) is located in the FEROS room. It provides flat-field and wavelength calibration lamp sources to the spectrograph. Light is delivered from the FCU via the CALIBRATION fibres to the FWA where optics image the light onto the fibrehead reproducing the illumination of the pupil of the telescope. From the fibrehead the light is then delivered to the spectrograph via the SCIENCE fibres (see figure 2.1).

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[1]Temperature stability of ± 0.5 degree celcius is maintained.
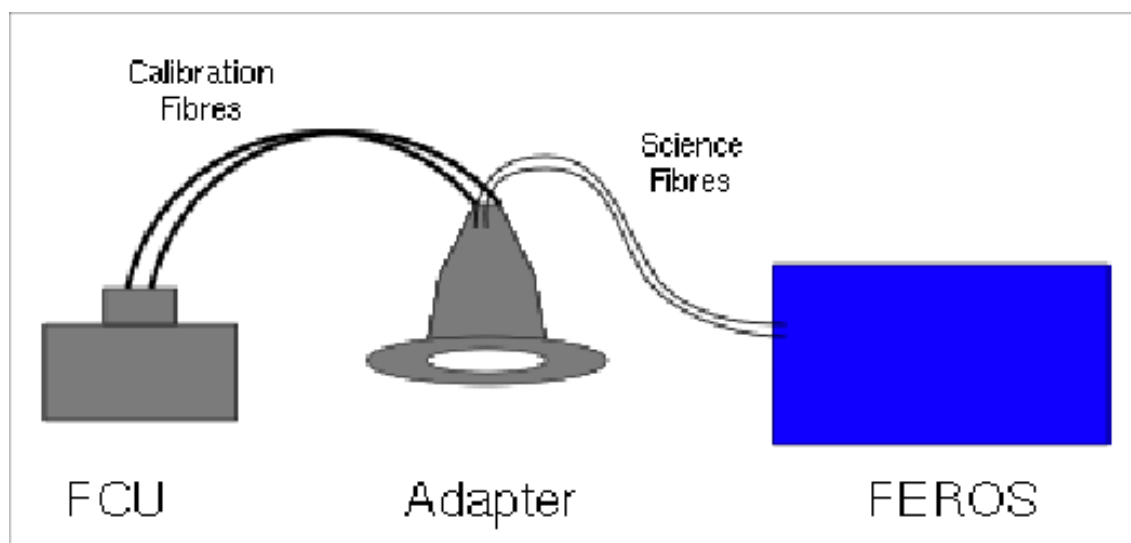
Figure 2.1: Light path of Calibrations.

All changes between the operational modes are carried out with/at the FCU and in the FWA.

The prism cross-dispersed, two-slice folded optical path results in a compact physical layout. The spectrograph operates in a quasi-Littrow mode [2] in a white-pupil configuration (Baranne, 1972, ESO-Cern Conference on Large Telescopes). The échelle grating is of type R2 with 79 lines/mm and a measured blaze angle of $63°24'$.

The camera is dioptric (no central obstruction) and provides an external focal plane for easy detector interfacing and upgrading during the lifetime of the instrument, together with a large field, good image quality and high optical transmission.

The CCD detector format is 2048×4096 pixels. The direction of the spectral dispersion (= echelle orders) is along the shorter dimension of the CCD. The instrument spectral format (wavelength coverage, etc.) is always computed for this fixed CCD window setting.

2.2 Instrument subsystems

This section describes the FEROS subsystems in the order they are encountered along the optical path going from the telescope to the instrument detector. The functionalities of the different subunits are explained and reference is made to their measured performance.

Efficiencies (e.g., in the form of tabulated data) of the main instrument components, including the CCD, are available from the FEROS Instrument Efficiency page from the FEROS Home page, or directly at:

`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/InstrumentCharacteristics/InstrumentEfficiency.html`

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[2]Quasi-Littrow mode, i.e. with the angle of incidence and diffraction equal but in a different plane, to maximize efficiency.

2.2.1   The pre-fibrehead system

The light path

Light from the telescope arrives at the FWA M3 where it is reflected upward passing through the ADC (if IN) to the fibrehead. The fibrehead viewing camera is located directly below the fibrehead.

Light from the FCU arrives at the FWA via the CALIBRATION fibres. It is reflected onto the fibrehead via the SCSM. The SCSM and the ADC can NOT be used simultaneously.

The pre-fibrehead functions

In the converging f/8 beam coming from the telescope, the first element is the **FWA M3** which allows switching between FEROS and WFI in approximately 8 seconds. When IN the M3 obscures the central approximately 40% of the WFI field of view.

Then follows the ADC which is moved IN and OUT of the beam via an arm. It consists of two sets of two counter rotating prisms each of 12mm diameter and 6mm thickness separated by 1 mm of air. One prism set is mounted in front of each of the two Fibrehead apertures. Each prism consists of a wedge of UBK7 glass cemented to a wedge of LLF6 glass with a 'ANTIREFLET' anti-reflection coating on the four prisms surface. From midday solar spectra[3] the measured total transmission of the TWO prims is above 90% for wavelengths above ∼3900Å thus achieving the design requirement of 90% or better transmission over the range 4000-9250Å(see figure 2.2). The overall modulation of the transmission curve is due to the antireflection coating.

2.2.2   The spectrograph

The light path

The two f/8 beams (OBJECT and SKY/CALIBRATION) either from the telescope and/or the calibration unit arrive at the fibrehead, where they enter the fibre apertures. The beams are focussed onto the SCIENCE fibres by rod-type microlenses. After exiting the SCIENCE fibres it traverses the F/N Adaption Lens System, the Image Slicer, the First Colimator, then the Échelle Grating, back to the first Collimator, then the Flat Folding Mirror, then the Second Collimator, the Cross-Dispersing Prism, through the Camera before finally arriving at the CCD.

The spectrograph functions and components

The **fibre head** consists of a polished block of Aluminium. The polished surface is curved in order to provide uniform focus across the field of view of the fibrehead in the fibrehead viewer. The fibres are mounted into the fibrehead via brass inserts which hold the microlenses and fibres in place.

The **microlenses** are rod-type lenses with a MgF Anti-Reflection coating. The microlenses re-focus the f/8 input beam to f/4.6 as required by the spectrograph design. The current microlenses were installed during October 2003. They replaced the former spherical lenses which were installed when FEROS was first moved from the ESO 1.52-m to the 2.20-m during October 2002. The microlenses used in the ESO 1.52-m fibrehead were rod-lenses and indeed rod-lenses were the preferred design for the 2.20-m fibrehead, but at the time of moving FEROS to the 2.20m, a manufacturer capable of fabricating lenses to the required specifications could not be found. A company capable of fabricating the required rod-lenses was subsequently discovered. As compared to the ball-lenses, the rod-lenses

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[3]Telescope pointed 30 degrees from the sun.
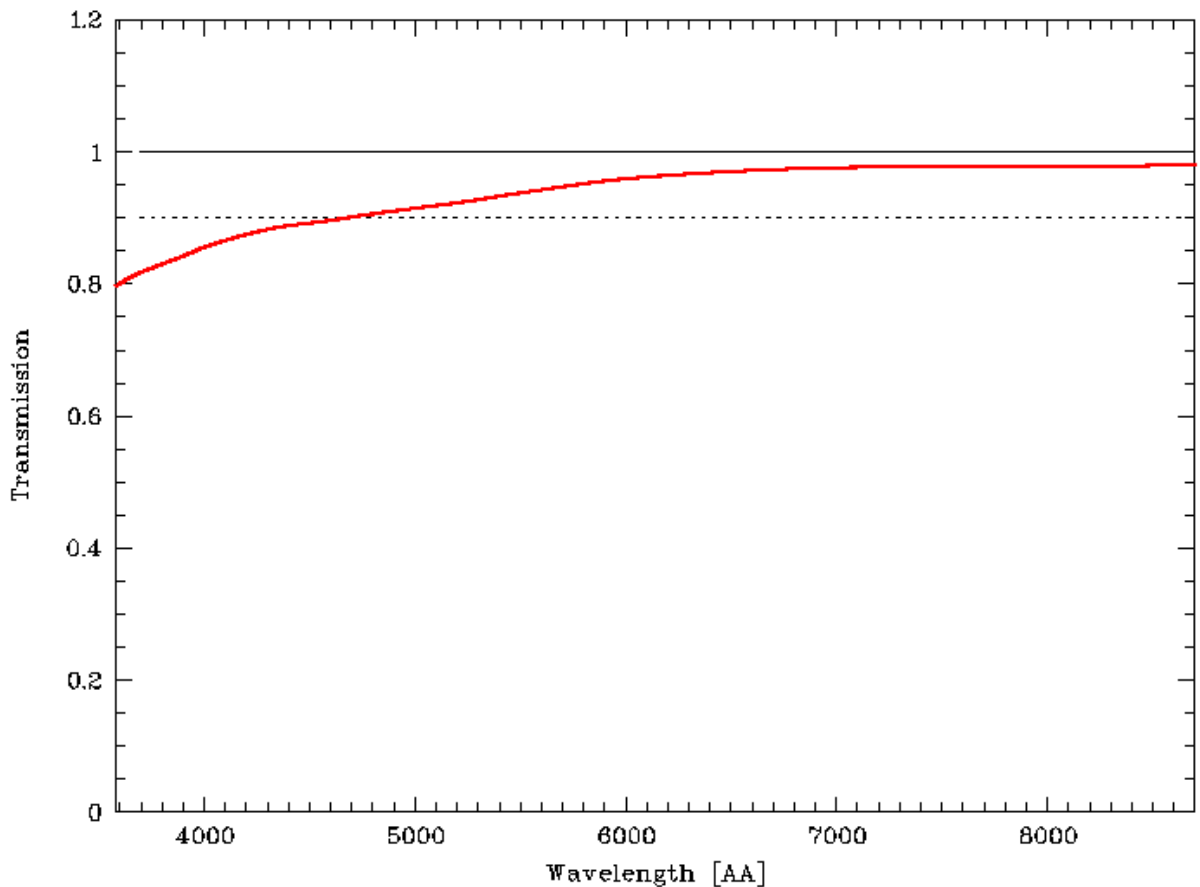
Figure 2.2: The red line represents the transmission curve of the new FEROS ADC commissionned in April 2006. The dashed line indicates the 90% transmission level.

provide a much improved optical matching between telescope and fibres. An important improvement being that the effective aperture with the new rod-lenses is restored to the design specification of 2.0 arcsec, as compared to 1.6 arcsec which was the case for the ball-lenses. The rod-lenses thus improve the overall efficiency as well as increasing the throughput as a function of seeing/image quality.

The **SCIENCE fibres** are of $100\,\mu$m diameter FV type, each measuring approximately 15 m in length. The current fibres were installed during October 2003 at the same time as the new microlenses, replacing the original fibres from the ESO 1.52-m which were also of type FV. The main reason for replacing the fibres was to increase the length in order to be able to reduce Focal Ratio Degradation due to stress on the fibres caused by small radius curves necessitated by the less than ideal length of the original fibres. The SCIENCE fibres are interfaced to the microlenses using optical glue. The intrinsic efficiency ratio between the designated OBJECT and SKY fibres is between ~ 1.6 (in the blue) and ~ 1.3 (in the red) varying smoothly between these two extreme values (see figure 2.3).

The **F/N Adaption Lens System**
TBD... See the original FEROS Final Design Report downloadable from
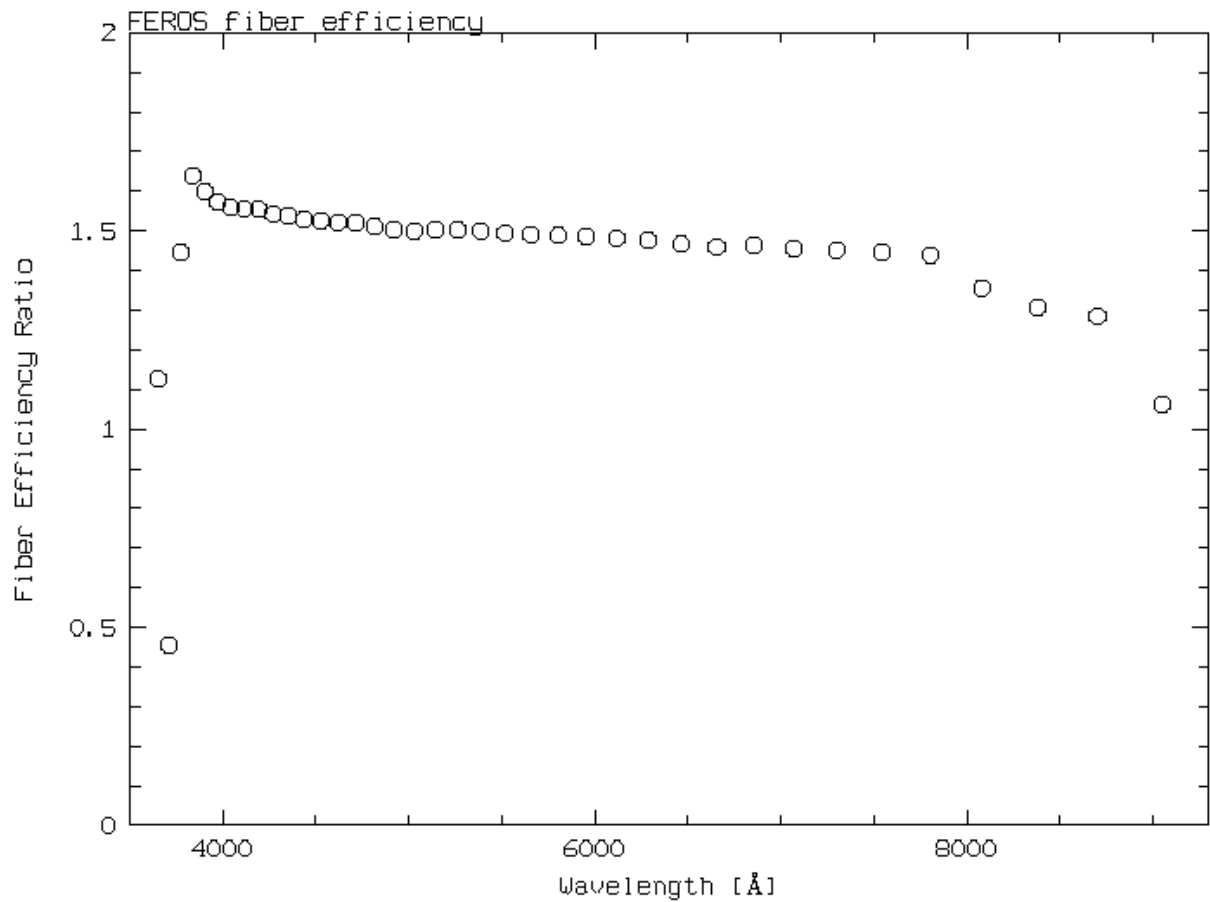
Figure 2.3: The relative fibre efficiency in the sense of OBJECT/SKY fibre. The raw frame is a solar spectrum. Each point represents one of the ećhelle orders.

http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/Documentation/fdr.ps.gz.

The **Image Slicer**
TBD... See the original FEROS Final Design Report downloadable from
http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/Documentation/fdr.ps.gz.

The **First Colimator**
TBD... See the original FEROS Final Design Report downloadable from
http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/Documentation/fdr.ps.gz.

The **Échelle Grating**
TBD... See the original FEROS Final Design Report downloadable from
http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/Documentation/fdr.ps.gz.

The **Flat Folding Mirror**
TBD... See the original FEROS Final Design Report downloadable from
http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/Documentation/fdr.ps.gz.

The **Second Collimator**

TBD... See the original FEROS Final Design Report downloadable from
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/Documentation/fdr.ps.gz`.

The **Cross-Dispersing Prism**
TBD... See the original FEROS Final Design Report downloadable from
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/Documentation/fdr.ps.gz`.

The **Camera**
TBD... See the original FEROS Final Design Report downloadable from
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/Documentation/fdr.ps.gz`.

2.3   The Fibrehead Viewer CCD

FEROS includes two CCD systems: the FEROS FibreHead Viewer (FFHV) technical CCD and the scientific CCD detector. The **fibrehead viewer** unit incorporates Peltier-cooled, 288×385, $22\mu m$ pixel frame-transfer, front illuminated CCDs on which an image of the fibrehead plane is focussed with a scale of approximately 0.5 arcsec/pixel. The unvignetted field is approximately 4×6 arcmin square (NS/EW). A Johnson V filter is permanently mounted between the fibrehead and the TCCD. The objective is focussed on the surface of the fibrehead. It is used to identify the target, to center it on the fibre aperture and for guiding, both on the object on the fibre (default) or on a field star (when not possible to guide on the object on the fibre, e.g. due to a close (i.e. within 5 arcsec) field star).

The limiting magnitudes of the FFHV cameras for target acquisition are a function of seeing, color of the target and sky brightness. As an example with a 5 sec integration, 1 arcsec FWHM seeing and dark sky, an object with $m(V) = 17$ is detected with adequate S/N for acquisition and guiding. The FFHV camera is generally able to acquire all objects for which spectroscopic observations can be made. If the target is too faint to be visible on the FFHV, blind offset procedures from a nearby star are provided (cf. Ref. [1]).

2.4   The Scientific CCDs and the associated shutters

A summary of the properties of the **scientific CCD** is given in Tab 2.1. The detector consists of one EEV CCD (EEV 44-82). Windowing of the CCD is not allowed.

Two fully supported read out modes of the CCD are available in both visitor and service mode:

1. Low gain, fast read-out – 225kHz,1,low 41 sec readout

2. High gain, slow read-out – 60kHz,1,high 148 sec readout

Both 1x1 and 2x2 binning are possible in both read out modes. The default readout mode is 225kHz,1,low,1x1.

A third **experimental** very fast read-out, medium gain readout mode (625kHz,1,med) is available in **visitor mode only** and only at 1x1 binning.

The second digit in binning applies to the direction of the spectral dispersion. The characteristics of these modes are given in Tab 2.1. The linearity of the CCDs is measured to be better than 1% over the range from $\sim$200 e$^-$ to the saturation limit. Note that counts per pixel above 50000 ADU should be avoided in the low gain readout mode because of non-linearity. The CCD parameters are periodically remeasured as part of the FEROS calibration plan
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/CalPlan/index.html`

Table 2.1: Measured properties of FEROS scientific CCD (July 2004 values). Where relevant the properties given are for the 1x1 readout mode only. Properties for the 2x2 mode are still pending.

	EEV
Quantum efficiency	50% at 350 nm 58% at 370 nm 72% at 400 nm 85% at 450 nm 85% at 500 nm 85% at 600 nm 78% at 700 nm 55% at 800 nm 28% at 900 nm
Number of pixels	2048×4096
Pixel size	15 μm
Gain	low: 3.2 e$^-$/ADU high: 1.0e$^-$/ADU
Read-out noise	fast readout, low gain: 5.1 e$^-$ = 16.3 ADU rms slow read-out, high gain: 3.0 e$^-$ = 3.0 ADU rms
Saturation	low gain: $\sim$40,000 ADU high gain $\sim$65,000 ADU
Full frame readout (s)	low gain, unbinned: 41 high gain, unbinned: 148
Dark current levels	*TBD*
Fringing amplitude	*TBD*
CTE	*TBD*
Read-out direction	in disp. dir.
Prescan, Overscan areas	Pix. -49-0 and 2049-2098
Flatness	*TBD*
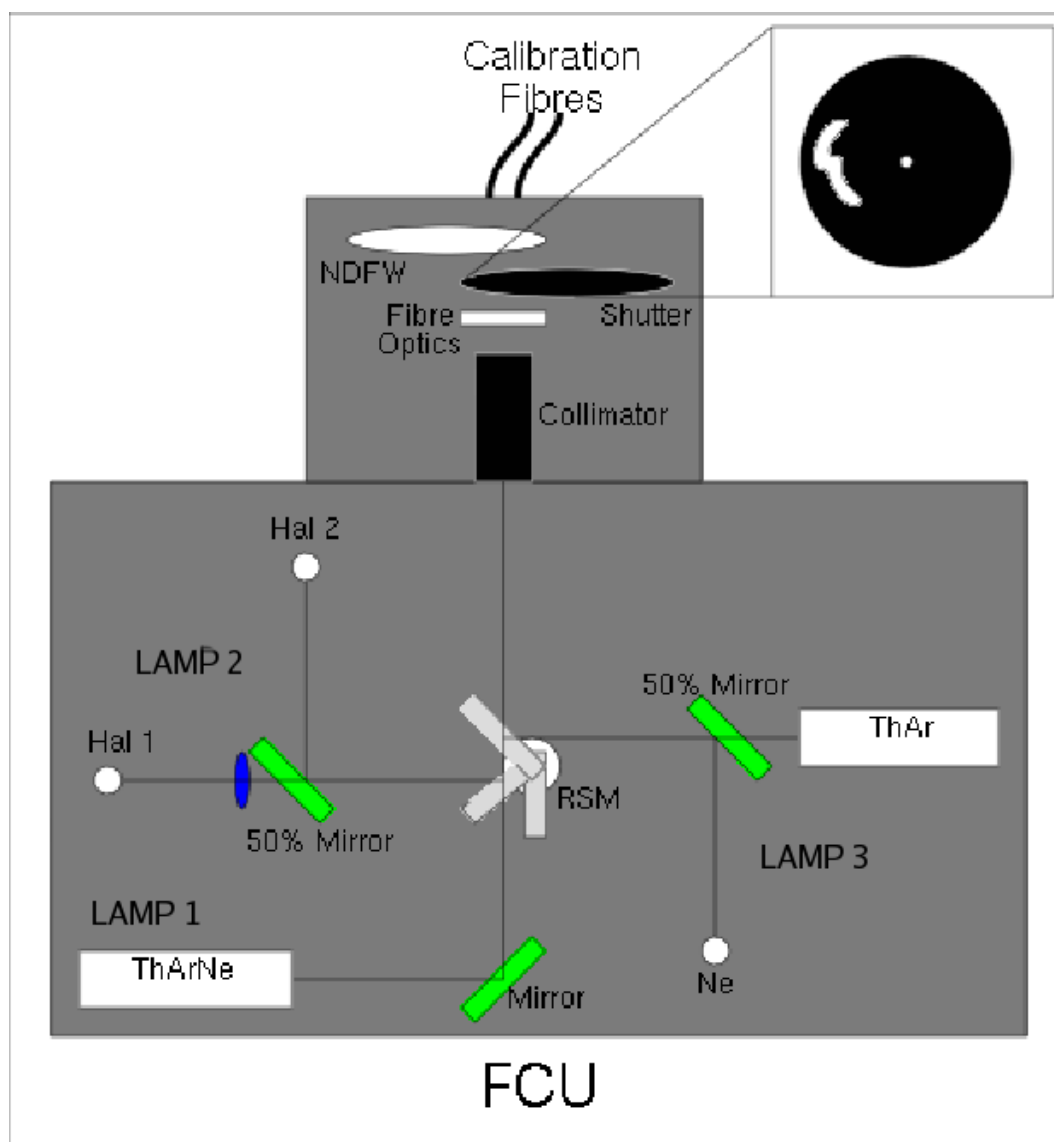
Figure 2.4: Schematic diagram of the FCU.

The cosmetic quality of the scientific CCD is good. Details are given in section 2.8.7.

The CCD cryostat is not attached to the dioptric camera, but is mounted independently of the camera directly onto the optical bench. A rubber seal between the shutter and the CCD provides light protection.

The CCD is operated at a temperature of ~ 139 K. $120 \, \mathrm{L}$ liquid-nitrogen tanks ensure continuous operation without manual intervention for ~ 2 weeks. The **shutter** is located between the cryostat window and the camera. It is actuated by a metallic cable with an open/close time of 50 ms. The illumination of the detectors is homogeneous within 50 ms but a **minimum exposure time of 0.5 sec** is recommended. The reader is referred to the CCD webpages of the ESO Optical Detector Team for additional general information on the CCDs and the Control System (FIERA): http://www.eso.org/odt/.

2.5   The FEROS Calibration Unit

The FEROS Calibration Unit (FCU) provides flat-field and wavelength calibration lamp sources to the spectrograph. Light is delivered from the FCU via the Calibration fibres to the adapter where optics image the light onto the fibrehead reproducing the illumination of the pupil of the telescope. From the fibrehead the light is then delivered to the spectrograph via the Science fibres (see figure 2.1).

The FCU currently houses three sources;

- **LAMP1=Wavelength Calibration=ThArNe**: This source consists of a single Thorium cathode, Argon (10%) and Neon (90%) filled Juniper lamp.

- **LAMP2=Flat-Field=Hal+Hal**: This source consists of two Halogen bulbs, one $6\,V$, $10\,W$ *Osram Halogen Halo Star* bulb providing the red part of the flatfield and one $12\,V$, $50\,W$ *Osram Halogen Xenophot* bulb behind a blue filter providing the blue part of the flatfield. Light from the two bulbs are combined via a 50% transmission, 50% reflection mirror.

- **LAMP3=Wavelength Calibration=ThAr+Ne**: This source consists of a Thorium cathode, Argon (100%) filled Juniper lamp and a $100\,k\Omega$, $220\,V$ Neon bulb. Light from the two bulbs are combined via a 50% transmission, 50% reflection mirror.

Prior to June 2003, only the ThAr+Ne source was available. Between June 2003 and December 2004 only the ThArNe source was available. Since December 2004 both sources have been available and the Calibration Plan has included both lamps. Neither lamp provides an ideal calibration source. The ThArNe source provides better flux in the bluest orders but has numerous strongly saturated lines in the red orders. This is a particular problem for the OBJCAL mode due to contamination of the object spectrum. The ThAr+Ne source on the otherhand mostly avoids contamination of the object spectrum, but has poor flux in the bluest orders. In an attempt to cover all possibilities the calibration plan therefore acquires arc-line spectra with both lamps and at a range of exposure times.

Selection between the sources is made simply by the Rotating Selection Mirror (RSM) (see figure 2.4).

The RSM reflects the selected source (or in the case of the ThArNe source keeps out of the light path) into the collimator. The FCU Shutter then selects which fibre(s) the beam illuminates. After the shutter, two lenses focus parts of the beam onto each CALIBRATION fibre input. Between the lenses and the fibre inputs is a Neutral Density Filter Wheel (NDFW) which allows control of the flux level in OBJCAL mode so that it is possible to match the flux level in the calibration spectrum in long SCIENCE exposures to the flux obtained in the much shorter calibration exposures. The dynamic range of the NDFW is approximately 0.0–2.5, thereby allowing flux matching OBJCAL exposures of exposure time from 1.0 – 316 times the exposure time of the calibrations. Since useful ThAr can be obtained with exposure times from 10 – 100 sec, this means OBJCAL exposures from 10 – 31,600 sec are possible, though of course other constrainst limit maximum reasonable exposure times of the order of 1 hr.

2.6   FEROS/WFI Adapter

The FEROS/WFI Adapter includes the M3 mirror, fibrehead, Sliding Calibration Selection Mirror (SCSM), the FEROS FibreHead Viewer (FFHV) including a standard ESO, large format Technical CCD and an Atmospheric Dispersion Corrector (ADC). With M3 in the telescope beam is reflected onto the downward facing fibrehead which is a polished, solid aluminium block. The SCIENCE fibres are mounted into the back of the fibrehead and are illuminated via the fibrehead apertures, holes 2.0 arcsec in diameter on the sky separated by 2.9 arcmins, oriented EW of each other in the

default orientation of the telescope rotator. The FWA also includes the Sliding Calibration Selector Mirror (SCSM) which is used to control which of the SCIENCE fibres is illuminated by light from the CALIBRATION fibres whose exit is also mounted in the Adapter and the Atmospheric Dispersion Corrector.

2.7   Spectral Coverage, Resolution and Overall Efficiency
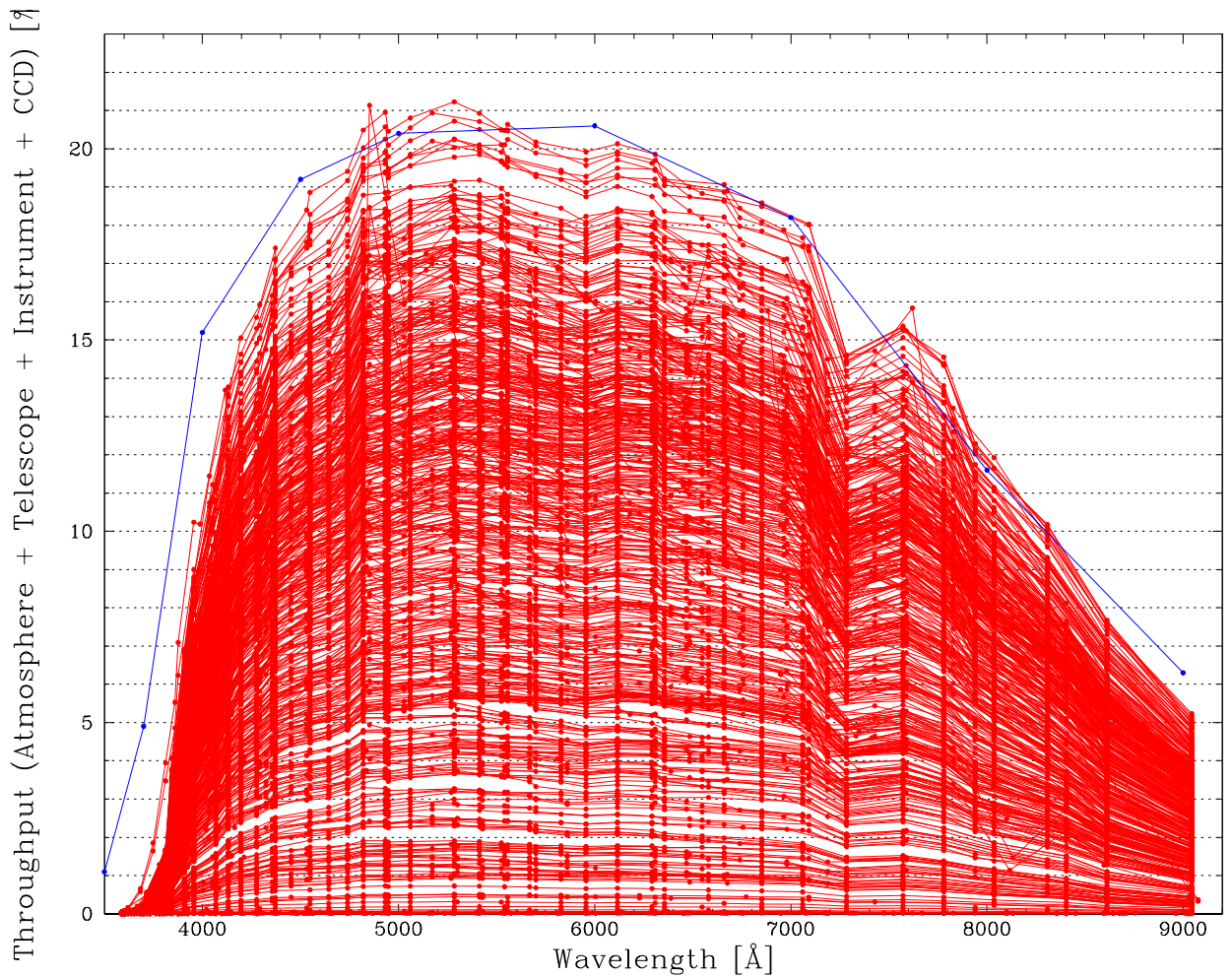
Figure 2.5: The measured efficiency.
Empirical measurements of the efficiency of FEROS+2.20m are made according to the FEROS Calibration Plan every night when FEROS OBs are are executed (both Visitor & Service Mode) and are plotted in the graphic below. Each order is joined by a line. The blue line represents the theoretical expectation tabulated above.

The user can only affect the spectral resolution by the choice to some extent by binning the CCD. The factors outside his/her control which affect the resolving power are the diameters of the SCIENCE fibres, the number of slices created by the image slicers (2), image quality of the optics including the focus and the alignment, CCD effects (chip tilt, diffusion of photoelectrons, charge transfer) as well as the echelle dispersion. The instrument does not include a remotely controlled focus adjustment, since

the camera automatically compensates for temperature variations within the instrument enclosure. A two-slice image slicer results in a resolving power of 48,000 with a degradation less than 10% over the whole wavelength range.

The individual transmission and reflection efficiency curves of the various optical components and of the CCD and the combined overall efficiencies are tabulated at
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/InstrumentCharacteristics/InstrumentEfficiency.html`
The predicted global instrument efficiency is higher than 20% from 400 to almost 800 nm. With these efficiencies and an efficiency of 60% for the 2.20m telescope, in 'good'[4] observing conditions, a spectrum with a S/N of 100 in V can be obtained in 10 minutes for a 10th magnitude star, while approximately one hour is required to reach a S/N of 10 for a star of 16.5 mag.

Furthermore, making appropriate assumptions on the reflectivity of the three telescope mirrors (also tabulated at the above webpage), the overall telescope + instrument + detector efficiency has been computed and compared with measurements of standard stars.

Observations of spectrophotometric standard stars are acquired on most nights and are archived at
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/InstrumentCharacteristics/InstrumentEfficiency.html`
Typically, due to imperfect atmospheric transparency, less than ideal seeing (i.e. worse than 1.0 arcsec) and imperfect focusing of the telescope, peak efficiencies of 10-17% are achieved from night to night, though 20% peak efficiencies are certainly not unknown. Observations agree well with theoretical expectations with a maximum peak efficiency actually slightly exceeding expectation being measured on occasion.

The design specification for the transmission of the the ADC is at least 90% across the complete spectral range of FEROS. As shown in , the transmission is above 90 % for most of the wavelength range. Therefore, the use of the ADC is highly recommended at airmass higher than 1.2. It is also important to remind that the ADC provides a spectral flux shape **independant of zenith distance**. Hence for any work where the spectral flux shape is important, the ADC is a must.

2.8   Instrument Features and Problems to be aware of

2.8.1   Interference fringes in Internal Flatfields

The internal flatfields show interference fringes for wavelengths above approximately 6550Å (i.e. Order number 30≡m=34). See:
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/InstrumentCharacteristics/FFOrderByOrder.html`

These fringes are stable with telescope pointing so presumably result from reflections internal to the spectrograph, camera or most probably the CCD itself.

Solution: The internal flatfields correct well for these fringes.

2.8.2   Contamination of Object spectrum by ThArNe source in OBJCAL mode

A number of very bright emission lines in the red part of the spectrum of the ThArNe source (the source labelled WLC in p2pp templates) saturate so badly that they have substantial bleeding and actually bleed into the pixels of the other fibre. This is a particular problem for the OBJCAL mode because the bleeding thus contaminates the stellar spectrum.

The only occassion in which the ThArNe source (WLC in p2pp) should be used is if the spectral region of interest is wavelengths less than ∼4000 Å and wavelenghts greater than ∼6000 Å are completely

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[4]Clear sky and seeing 1-1.2 arcsec.

irrelevant.

Note there is still no clear way to control the flux level to be achieved, except by adjusting the exposure time directly. This means if we need to change the lamp sources during the period, exposure levels are liable to change and OBs may need to be adjusted.

Currently for the Calibration Plan we make ThAr+Ne and ThArNe exposures of 3, 15 & 30sec. Sample calibration images which users could use to check flux levels etc, are now available for download from:

`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/ImageDB/index.html`

or by following the "Data Archive and Sample Images" link at the bottom right of the FEROS home page.

Solution: Use the ThAr+Ne source (ThAr+Ne in p2pp) for OBJCAL mode observations.

2.8.3   Flux calibration

Due to the comparable size of the Fibre apertures (2 arcsec) and the typical image quality (FWHM 1 arcsec), one can never be certain of the fraction of light going down the fibre and hence an ABSOLUTE flux calibration is practically impossible. Currently, there NO way we can be sure of this. Note that the DIMM can NOT be relied upon for this information as the seeing measured by the DIMM is not necessarily (and in practice almost never) the same as the seeing measured at the 2.20m). Therefore **the best one can hope for is to get the SHAPE of the spectral flux distribution, but not the absolute level**.

Solution: To get the absolute level right one would need (for example) to do simultaneous/contemporaneous photometry (for example with WFI) of the spectrophotometric standard star and the SCIENCE target in photometric conditions in order to tie down the absolute flux at (at least) one wavelength, or one could do wide slit, low resolution spectroscopy (with for example EMMI of EFOSC)...

2.8.4   Bi-modal CCD RON

CCDTests from which the Conversion Factor, ReadOut Noise, Linearity of the CCD can be calculated are run almost daily in at least one readout mode. All parameters behave well and according to expectation except the ReadOut Noise (RON) which shows a bimodal distribution of values, see for example:

`http://www.ls.eso.org/lasilla/sciops/2p2/CCDs/60/FIERA/LAMP5/225kHz,1,low,1x1/`

During the middle part of 2004, the measured RON varied between the two upper and lower values more or less on a daily basis. Since we take tests only daily we can not be certain if it was not varying even faster than this, e.g. on a time scale of hours, therefore it is somewhat problematic to be certain of the exact value of the RON for any given image during this period. In the latter part of 2004 the RON settled down to the lower value through until about July 2005, although with a return to bimodal behaviour during late Jan and early Feb of 2005 and with a slight change in the mean value of the lower value after the upgrade of the CCD FIERA system in late June. In about July the RON jumped up to the upper value, where, as of this writing, it seems to be stable, at least for the time being, which at least is better than varying on a hourly-daily but unknown timescale.

2.8.5   Low flux level in bluest orders in Flatfields

At the ESO-1.52m telscope, just before moving FEROS to the 2.20m telescope, the S/N level in the bluest order was ~15 in comparison to a peak S/N of ~1200 in the best illuminated orders in an

exposure time of $\sim$45 sec. Immediately after arriving at the 2.20m the S/N level in the bluest order was $\sim$0 in comparison to a peak S/N of $\sim$300 in the best illuminated orders in an exposure time of $\sim$600 sec, clearly a problem. After much effort it was discovered that neutral density filters used inside the Calibration unit were not very neutral and infact strongly attenuated the blue flux of the internal flatfield lamps.These were thus replaced with a combination of filters whose aim was to attenuate the brightest wavelengths from the flatfield lamps (i.e. mostly the red part) while leaving unaffected (as much as possible) the fainter wavelengths of the flatfield lamps (i.e. mostly the blue part). This effort has resulted in raising the S/N in the bluest order to approximately **50** in comparison to a peak S/N of $\sim$800 in the best illuminated orders in an exposure time of $\sim$2.4 sec. Clearly the situation is currently better than it has ever been before but it would still be better to have a constant maximal signal to noise in all orders.

2.8.6   Few and faint lines in bluest orders in wavelength calibration spectra

With the default setting of the LINE_THRES of 1000.0 in the default guess sessions used at the telescope and available from the web, few if any lines are found in the bluest few orders of the wavelength calibration spectra. For the medium and long ThArNe exposures of the calibration plan useful lines are evident but LINE_THRES must be reduced to $\sim$100 in order to detect a few of these. For the ThAr+Ne, no useful lines are evident until the third order (above 3700Å).

Solution: Carefully adjust LINE_THRES parameter for the ThArNe calibrations.

2.8.7   CCD Cosmetic Defects

The FEROS CCD is of good cosmetic quality. The major defects are the several complete or partial bad columns, (see table 2.2).

Table 2.2: CCD bad columns. In the standard application of the FEROS DRS pipeline the entire columns are replaced by the means of the nearest row neighboors of each pixel.

Column(s)		
RAW FITS	**prered Im**	**Row start/finish**
270	321	1675/4096
273	324	1675/1779
385	436	1616/1695
386	437	1617/4096
387–389	438–440	1617/1640
393–394	444–445	1622/1740
697	748	0868/4096
894	945	1514/2100
908–909	959–960	1501/1690
934	985	1475/1680
951	1002	1459/4096
967	1018	1454/1500
1009–1015	1060–1066	1415/4096
1113–1115	1164–1166	1404/4096
1349	1400	0608/4096
1350	1401	0000/4096

Chapter 3

Preparing the Observations

3.1 Introduction

Before the actual execution of observations, several steps have to be taken. The preparation of an observing program is split in two parts: Phase I and Phase II. In Phase I the emphasis in the application for ESO observing time is put on the scientific justification and on the technical feasibility of the proposed observations. In Phase II the successful applicants prepare the detailed instrument set-up and observing plan through the completion of so-called **Observation Blocks**. Together with the Phase I and Phase II documentation (`http://www.eso.org/observing/proposals/`), the information contained in this chapter (and in Chapter 4) provides a guideline for the Phase I and Phase II preparation process for FEROS observations. In Chapter 5 information is given for astronomers who come to La Silla to observe with FEROS.

The preparation process for FEROS programmes can be summarized as follows:

Phase I

- Definition of scientific justification

- Choice of instrument mode

- Estimate of exposure time to reach the needed S/N ratio

- Estimate of telescope and instrument overheads

- Determination of scheduling constraints (e.g. visibility, time-critical observations)

- Overview observation plan (e.g., target list, calibration needs)

Phase II (*for successful applicants*)

- Identification of detailed instrument set-ups

- Identification of target acquisition requirements (e.g., finding charts, offset star)

- Preparation of needed Observation and Calibration Blocks.

Part of the observing time at the MPG/ESO 2.20-m telescope is carried out in **service mode** by the Observatory Staff (i.e., in absence of the applicant). All information necessary to successfully execute the proposed observing program has to be provided (in the form of Observation Blocks, finding charts, and other relevant information) in advance of the observations to ESO, following the instructions sent to the applicants. The Observatory staff will combine the execution of different

programs in the same night optimizing the time sequence and the seeing and moon requirements. Observations carried out with the applicant present at the telescope are referred to as **visitor-mode** observations. In this mode the astronomer prepares (or finalizes) the OBs at the Observatory in advance of his/her nights. He/she decides about the sequence of observations during the night, but their execution is, however, still performed by the telescope and instrument operator (TIO).

To facilitate the preparation of Phase I (and Phase II) proposals, besides the information provided in this User Manual, ESO has developed a sophisticated Exposure Time Calculator (**ETC**, see Section 3.4). The ETC permits to estimate the signal-to-noise ratio for a given configuration and exposure time (taking into account specific atmospheric conditions) and determines the spectral format resulting from the selected instrument set-up.

The Observing Blocks are prepared using another ESO-provided software tool called **P2PP**, see [2] and `http://www.eso.org/observing/p2pp/`.

Before preparing the observations, it is advisable to review the FEROS webpages
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS`
which give information on current problems and possible new instrument artifacts detected during the current observing period and not yet described in the FEROS User Manual.

A FEROS data-reduction pipeline is also running at the Observatory. It enables automatic extraction and wavelength calibration of all spectra of stellar objects taken with FEROS in 1x1 binning readout modes. It permits an on-line check of the quality of the observations (resolution, S/N in the extracted spectra). The science data are calibrated with calibration exposures obtained on a daily basis as part of the FEROS Calibration Plan.
Note, that the FEROS on-line pipeline is intended as a quick-look and quality-control tool and was designed for robustness of the reduction and not for best-possible reductions. **The reduced data should be checked or compared with offline reprocessed data before beeing used for for publication**

3.2   FEROS instrument modes and basic choices

After the detailed description of the FEROS spectrograph, its subsystems and functions (Chapter 2), we provide an overview of the two FEROS observing modes. Light from the two fibres simultaneously recorded on the detector permits two observing modes:

- Object-Sky (OBJSKY)

- Object-Calibration (OBJCAL)

Apart from the instrument mode, a decision has to be made regarding the acquisition of the target. Under normal conditions, the target is centered directly on one of the fibrehead apertures (normally the one defined as the OBJECT fibre due to its superior throughput ,see figure 2.3). It is none the less possible to acquire the target onto the SKY/CALIBRATION fibre aperture though it is hard to imagine any circumstance where this would be scientifically justifiable.

Observing in the two different modes is fully remotely controlled[1]. Both modes are offered in both Visitor and Service modes. In both modes, the internal flatfield (**Hal+Hal**) and both wavelength calibration (**ThArNe** and **ThAr+Ne**) light sources are available for the two fibres for calibration spectra via remote control of the FCU.

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[1]At the 1.52m, it was necessary to manually change the fibre configuration at the telescope to switch between modes. At the 2.20m, switching is now achieved via positioning of mirrors via remote control.

3.2.1   The Object+Sky Configuration

In the OBJSKY mode the two fibres record the star light and nearby sky background simultaneously. The Sliding Calibration Selection Mirror in the FEROS/WFI Adpater (see section 2.6) is in the PARK position. The ADC[2] can be used to correct the light from the target for the effect of Atmospheric Dispersion.

For calibration purposes, the internal flatfield or the wavelength calibration source are normally recorded through both fibres, but each fibre can, if desired, be illuminated individually.

3.2.2   The Object+Calibration Configuration

In the OBJCAL mode the object fibre is used as in the OBJSKY mode described above. Light from one of the sources of the FCU is delivered to the sky fibre via the appropriate positioning of the Sliding Calibration Selection Mirror in the FEROS/WFI Adpater (see section 2.6).

Then, the light of the calibration source (normally ThAr+Ne, but ThArNe or Hal+Hal is also possible) can be recorded throughout the whole object exposure to monitor the stability of the spectrograph. The position of the neutral density filter wheel is set automatically according to the exposure time and the user specified Equivalent lamp exposure time.

With the OC observing mode and the software techniques described below, a long-term radial velocity accuracy of < 25m/s is reached for sharp-lined solar-like stars.

The ADC is NOT available in OBJCAL mode due to a physical conflict between the ADC and SCSM mechanisms.

3.3   Introducing Observation Blocks

An **Observation Block (OB)** is a logical unit specifying the telescope, instrument, and detector parameters and actions needed to obtain a "single" observation. It is the smallest "schedulable" entity, which means that the execution of an OB is normally not interrupted once it has been started. In Service Mode OBs are executed once and once only; when identical observation sequences are required (e.g. repeated observations using the same instrument setting, but different targets), a series of OBs must be constructed. In Visitor Mode it is possible to repeatedly execute the same OB. The detailed definition of FEROS Observation Blocks and Templates is given in Ref. [1].

For example: one would like to obtain a spectrum of a point source. First, the instrument mode has to be chosen, OBJSKY or OBJCAL. The instrument mode is set within the FEROS acquisition, observation, and calibration templates. In addition the information on the target position has to be provided in the acquisition template. For the observation itself either the `FEROS_ech_obs_objsky` or the `FEROS_ech_obs_objcal` template must be used according to which mode is required. The parameters to be set for both modes are the read-out mode of the detector (see section 2.4) and the exposure time and the binning. For the OBJCAL mode the additional parameters of which lamp to use and the lamp warmup time must be specified. If one likes to carry out a dedicated wavelength calibration after the science exposure, the attached wavelength calibration template (`FEROS_ech_cal_wave`) has to be added. Together, the three selected templates form an Observation Block that is used to perform the required observation.

The preparation and editing of Observation Blocks is done with the Phase II proposal preparation software (**P2PP**, [2]) which successful applicants for observing time can obtain from ESO (`http://www.eso.org/observing/p2pp/`) for installation at the astronomer's home institute. This

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[2]Implemented during March 2005, and updated in March 2006

software is also available on the offline computing facilities as well as at the observer's station at the Observatory, for preparation of the OBs in advance of the observations.

3.4 The FEROS Exposure Time calculator

The FEROS **Exposure Time Calculator** (ETC) is accessible from the FEROS web pages. The ETC models the instrument and detector. It is the basic tool for an observer in the planning of an FEROS observation. It can be used to compute S/N to be expected for the specified target and atmospheric conditions as a function of exposure time.

3.4.1 Definition of the target

For the input flux distribution to the ETC four options can be selected: (1) A blackbody energy distribution at a given temperature; (2) a power-law distribution; (3) a template spectrum: stellar spectra from spectral type O5 to M2, nebular spectra, galaxy spectra, or a quasar spectrum; (4) a single line at a wavelength, width, and flux level to be specified. In all cases but point (4) the object magnitude (in a given broad-band filter) have to be entered. For extended sources magnitudes are given per square arcsec. In addition to the target, the sky conditions (phase of the moon and FWHM of seeing disc) must be chosen.

The final entry is the exposure time.

The output for the spectral format consists of a table listing the spectral format, i.e. the wavelength at the order maximum, the order separation in the direction perpendicular to the dispersion, the start and end wavelength of each order, and the start and end of the Free Spectral Range (i.e., the non-overlapping part of the consecutive orders). An second table with expected counts and graphs of Efficiency, Object and Sky counts, Imax and S/N can optionally be displayed.

For clear skies and excellent seeing (i.e. DIMM seeing better than ~ 1 arcsec) the ETC is accurate to within 10–30%.

For Service Mode programmes, if a constraint of PHOT or CLEAR conditions is specified, it is advisable to multiply the exposure times determined by the ETC by TWO in order to maximise the probablity of achieveing the required S/N in typical conditions. If you are aiming your FEROS Service Mode programme as a 'filler' programme and are therefore willing to accept THIN to THICK conditions then you should multiply the exposure times determined by the ETC by FOUR in order to maximise the probablity of achieveing the required S/N in such conditions, however bearing in mind that your OBs always have the chance of being executed in better conditions than your constraints, it is thus best to break the total exposure into 2-4 individual exposures so as to avoid the possibility of saturation.

3.5 Target Acquisition and Guiding

The pointing of the MPG/ESO 2.20-m telescope is accurate to ≈ 5 arcsec (rms); this does, however, not guarantee that the target will be centered on the fibre after telescope pointing. In case of crowded fields the identification of the object is carried out by the astronomer, or, in case of service observations, with help of a **finding chart** provided by the user. Final coordinates and when required the finding chart in the format specified in the Proposal Instructions must be submitted during Phase II of the proposal preparation. **The target coordinates must be accurate to** $\leq 1''$ to avoid an unnecessary waste of telescope time during the target acquisition phase. In most cases, the Digital Sky Survey (DSS) can be used to prepare finding charts and is accessible from the ESO world-wide-webpages

(`http://archive.eso.org/dss/dss`) or using Skycat. For crowded fields or faint extended objects other well-suited image sources have to be used. The DSS and other tools can be accessed through the Proposal Preparation and Submission page (`http://www.eso.org/observing/proposals/`), which allow the calculation of site sky ephemerides, the determination of object observability, airmasses, etc. For the observation of **moving targets**, the acquisition templates allow to enter additional velocities in right ascension and declination in units of arseconds per second.

The target is identified on the image of the FEROS Fibrehead Viewer (FFHV) by the visiting astronomer or in case of service observations by the ESO staff astronomer. The target is identified by clicking on it with the mouse and automatically positioned on the fibre.

The tracking of the telescope is corrected for errors of low frequency (< 1 Hz) by an autoguiding facility. Normally guiding is performed on the target itself on the fibre (*guiding-on-fibre*), using the FFHV. But in crowded fields (one or more field stars of 'comparable' brightness (i.e. within 3 mag) within 10 arcsec of the target) a field star in the field of view of the FFHV can be used (*guiding-on-fieldstar*). In this case it is not possible to check the centering of the object on the fibre during the observation, except by momentarily turning off the autoguiding, however the guiding is reliable for at least 1 hr so this is not normally necessary. In extreme cases, when there happens to be one contaminating field star near the target, thus preventing guiding-on-fibre, but no other field stars suitable for guiding within the field of view of the FFHV, the WFI tracker chip can be used for guiding. With a field of view of 10×21 arcmin, a suitable guide star is ALWAYS available.

For guiding-on-fibre a *Dynamic Centering* algorithm which analyses the guiding images themselves, insures that the reference position of the fibre is always accurately known, and accounts for adapter flexure which could cause the apparent position of the fibre to shift on the FFHV. In practice however it is found that the FEROS/WFI Adapter is very rigid and flexure from one extreme pointing of the telescope to another (e.g. from the maximum western pointing to the maximum eastern pointing) is negligable.

The FFHV image is automatically saved at the end of each acquisition. It is included in the observers data package (both Service and Visitor mode). The FFHV images are NOT archived in the ESO archive, due to non-DICB compliance of the FFHV image headers.

3.6   Computing time overheads for your program

By using the FEROS **Exposure Time Calculator** the user obtains estimates of the observing time needed to reach the desired S/N ratio depending on the object magnitude and observing configuration and conditons. In order to arrive to the total observing time in hours or nights required for the program it is necessary to add the time for the various actions related to the scientific observation. When applying for service-mode observations, the **computation of the overheads is required** and has to be included in the application.

The current (date of this issue of the UM) estimate of the overheads is provided below.

- **Telescope pointing, target acquisition and centering on fibre:**
  Assuming that the telescope is moving to a new object at 180 degrees from the current pointing, allowing for accurate acquisition onto the fibre and time for the autoguiding to get the object accurately centered on the fibre and finally 'GRABing' the FFHV image, the whole sequence can be completed in 5min. If a *blind offset acquisition* is required acquisition can require up to 7min. If the new target requires just a small motion of the telescope and then re-acquisition of the guiding star, 3min. Please note though for Service Mode programmes since it is never known in advance the order of OB execution, it is not possible to know if it will be a 'small' preset, and therefore in p2pp the execution time for the acquisition template is always 5min

(or 7min for blind offset acquisition).

- **Adapter and calibration unit set/up and CCD read-out time**
  Changing from OBJSKY to OBJCAL mode or vice versa, or changing from SCIENCE to CAL-IBRATION exposures take at most 1 minute. Changing from one CALIBRATION type to another (e.g. from FF to wavelength calibration) takes 10 sec. When turning on the calibration lamps a warmup time must considered. A study made 2005-10-03 showed that approximately 4mins of warmup time was required for the flatfield lamps to reach a stable flux level, see:
  `http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/TechnicalReports/FFLampWarmUpTime/index.html`
  For the calibration plan daytime calibrations the FF lamps are warmed up for 5mins and the wavelength calibration lamps are warmed up for 1min before being used. If FFs are to be acquired during the night then it depends on their intended purpose. If they are to be used for obtaining an instantaneous tracing of the orders then no warmup is required. If on the other hand they are intended to check the instantaneous FF response then a warmup will be required in order to have the lamp reach stable operating conditions. For calibrations made during the night a warmup for the wavelength calibration lamps can probably be safely skipped.

  The read out time for the CCD (1 port) is:

  - fast, high gain, unbinned read-out mode [225kHz,1,low,1x1]: 41 seconds
  - slow, low gain, unbinned read-out mode [60kHz,1,high,1x1]: 148 seconds

  The shortest possible cycle time with the FEROS instrument can be achieved by the use of the

  - ultrafast, medium gain, unbinned read-out mode [625kHz,1,med,1x1]: 21 seconds.

  However this readout mode has NOT yet been fully commissioned. It should therefore be considered **experimental** and is offered in Visitor Mode only, where it will be the responsibility of the visitor to verify the scientific integrity of the resulting data.

- **Calibrations**
  BIAS frames and FF, ThArNe and ThAr+Ne calibration lamp exposures are taken during the day, see section 4.1. If wavelength accuracy is critical, either the OBJCAL mode should be used or a ThAr+Ne or ThArNe calibration should be taken immediately after the science exposure. This will take into account any significant change in the air pressure, humidity and/or in the air temperature (see Chapter 4.2). The same applies to the FF at wavelengths where the effect of fringing is important ($\lambda \geq 650$ nm).

As an example, we consider a target where the ETC computes an exposure time of 180 minutes to reach the desired S/N ratio and it is required to obtain the highest accuracy in the wavelength calibration and in the FF correction. We split the exposure time into three integrations of 1 hour to permit median filtering of the cosmic rays. Additionally both FF and wavelength calibrations exposures are attached for high radial velocity accuracy and accurate flatfielding. We thus have:
(telescope pointing 360 sec + FCU+Adapter setup 60 sec) +
(1 exposure 3600 sec + read-out-time 41 sec + FCU+Adapter setup 60 sec + ThArNe exposure 10 sec + read-out-time 41 sec + FCU+Adapter setup 10 sec + LampWarmup 60 sec + FF exposure 60 sec + read-out-time 41 sec) x three times.

This leads to a total time of 12189 sec or 203.15 m, of which 183.5 m is integration and just under 20 m is overhead ($\sim$10%). The overhead becomes relatively more important if many short exposures with many attached calibrations are required.

3.7 Check list

1. Decide whether to OBJSKY or OBJCAL mode.

2. Decide for visitor (justification needed) or service mode.

3. Use ETC to check exposure time

4. Any special constraints needed (time-critical observations, etc.) ?

5. Define calibration needs over and above the standard calibrations as defined in the calibration plan.

6. Compute time to be requested including overheads.

Chapter 4

The calibration of FEROS data

4.1 The FEROS Calibration Plan

The observatory's calibration strategy for the FEROS instrument is summarised at
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/CalPlan`
Table 4.1 provides a summary of the calibration plan as at the time of this writing (Nov, 2005) for scientific FEROS data. A minimum set of calibrations (see below) are acquired each afternoon in both the 225kHz,1,low,1x1 and 225kHz,1,low,2x2 readout modes as part of the Daily Health Check. More extensive sets of calibrations (see below) are semi-automatically acquired each morning daily according to the science data obtained in the previous night. The same calibrations are applicable for both OBJSKY and OBJCAL mode. If additional calibrations are needed, the corresponding Observation Blocks have to be provided by the Visitor observer or the Service mode PI using the data and instructions provided in the following sections.

In a nutshell, the FEROS Calibration Plan provides for the acquisition of daytime calibrations in the afternoon before and the morning after each night's observations.

Each afternoon a Daily Health Check OB which allows the verification of the basic health of the instrument as well as initialisation of the FEROS MIDAS DRS in both 1x1 and 2x2 binning modes is executed. The Daily Health Check OB currently consists of:

- In 225kHz,1,low,1x1 readout mode

    - 2 BIAS frames
    - 2 Hal+Hal Flatfield frames with a peak intensity of approximately ∼30,000 ADU (exposure times are adjusted periodically as lamp intensities evolve and old lamps are replaced with new ones.)
    - 1 ThAr+Ne Wavelength Calibration frames of 15 sec duration.

- In 225kHz,1,low,2x2 readout mode

    - 2 BIAS frames
    - 2 Hal+Hal Flatfield frames with a peak intensity of approximately ∼30,000 ADU (exposure times are adjusted periodically as lamp intensities evolve and old lamps are replaced with new ones.)
    - 1 ThAr+Ne Wavelength Calibration frames of 3.75 sec duration.

The afternoon calibrations are carried out via the execution of the *Daily Health Check* OB typically loaded into Bob from the OT tool. This OB takes approximately 20mins to complete.

Table 4.1: FEROS Science Data Calibration Plan. Note that same calibrations are applicable for both OBJSKY and OBJCAL mode.

Calibration	number	frequency [1/days]	purpose
Internal Flatfields	10	1 / 1	creation of master flats
attached Flatfields	n	o.r.	high-precision flatfielding
Dome Flatfields	n	o.r	Fringe correction in red orders
Internal Wavelength	12	1 / 1	dispersion solution, resolving power
attached Wavelength	n	o.r.	high-precision wavelength calibration
Bias	5	1 / 1	creation of master biases
Dark	1	1 / 10	creation of master darks
Flux Standard	n	o.r.	response correction, flux calibration
Telluric Standard	n	o.r.	removal of telluric spectrum
Radial Velocity Std.	n	o.r.	absolute radial velocity calibration
o.r. = on request only, corresponding OBs to be provided by user			
n = number to be defined by user			

Each morning a standard set of calibration data are acquired. A standard calibration data set is currently defined as:

- 5 BIAS frames

- 10 Hal+Hal Flatfield frames with a peak intensity of approximately ∼30,000 ADU (exposure times are adjusted periodically as lamp intensities evolve and old lamps are replaced with new ones.)

- 2 ThAr+Ne Wavelength Calibration frames of 3 sec duration.

- 2 ThAr+Ne Wavelength Calibration frames of 15 sec duration.

- 2 ThAr+Ne Wavelength Calibration frames of 30 sec duration.

- 2 ThArNe Wavelength Calibration frames of 3 sec duration.

- 2 ThArNe Wavelength Calibration frames of 15 sec duration.

- 2 ThArNe Wavelength Calibration frames of 30 sec duration.

The morning calibrations are carried out automatically using the ESO CALOB tool. The CALOB tool insures that morning calibrations are acquired for each readout mode *actually used* during the night.

Additionally to the standard sets of calibrations, the following calibration data are acquired:

- 1 one hour DARK (once every ten days)

- 2 1min Solar spectra (ADC=OUT, approx 1hr before sunset, weather permitting)

- 2 1min Solar spectra (ADC=IN, approx 1hr before sunset, weather permitting)

- 2 2min Spectrophotometrcic Standard star spectra (ADC=OUT, weather permitting, at least one star per night)

Table 4.2: Exposure times for Calibration Lamps (unbinned, high gain, fast readout mode [225kHz,1,low,1x1]). CCD pixel saturation occurs at $\sim 65000\,\mathrm{ADU}$ but the response is linear only to $\sim 50000\,\mathrm{ADU}$. Exposure times have to be scaled down by a factor of $\sim 1/4$ for the 2x2 binning, and by the ratio of the Conversion factors for the high gain, slow [60kHz,1,high,1x1] and medium gain, Very Fast [625kHz,1,med,1x1] readout modes.

LAMP	MAXIMUM INTENSITY ADU	EXPOSURE TIME sec	REMARKS
Hal+Hal	30000	2.4	
ThArNe		3,15,30	
ThAr+Ne		3,15,30	

- 2 2min Spectrophotometrcic Standard star spectra (ADC=IN, weather permitting, at least one star per night)

The Calibration Plan is executed by the observatory staff. Visiting astronomers who require addition calibrations beyond the scope of the calibration plan are responsible for these themselves however Standard Calibration (StanCal) OBs are available at the telescope and from the web.

4.2   The FEROS calibration unit

As described in section 2.5 the FEROS Calibration Unit (FCU) provides 'internal' flatfield and wavelength calibration sources. The FCU is installed in the FEROS Room, not mounted on the telescope[1]. Light from the FCU is delivered to the fibrehead via the CALIBRATION fibres. Table 4.2 lists the lamps and exposure times to be used for the default readout mode, and how to derive suitable exposure times for the other readout modes.

4.3   Calibration in wavelength

The ThArNe and ThAr+Ne lamps provides accurate wavelength calibrations over the complete spectral range when the FEROS-matched line table (available from in the MIDAS calib data and from the FEROS DRS web page
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/DRS`
is used. However neither lamp, and no single exposure time provides an ideal calibration for all orders. Therefore standard sets of calibrations include exposures with both lamps and with three different exposure times. The rms of the wavelength fit achieved during the daily DRS initialisation using the combined (i.e. all three exposure times) ThArNe exposures is typically better than 0.006 Å.

Wavelength calibration (WLC) exposures using either ThArNe or ThAr+Ne lamps can be made simultaneously with the science exposures in the OBJCAL mode to account for the effects of changing temperature and/or pressure, or of a (small) earthquake. Alternatively WLC exposures can be taken immediately before and/or after the science exposures. Typically however, even for high precision radial velocity work, it is only necessary to take a few WLC exposures dispersed through the night. This is valid for Visitor Mode programmes but is NOT done for Service Mode programmes. For SM programmes requiring high precision radial velocities, either the OBJCAL mode should be used, or WLC exposures should be attached to each science observation. To this purpose the user can insert

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[1]As it was when FEROS was at the ESO-1.52m telescope.

in the OB after the Observation Templates a so-called **attached calibration template** where a lamp is selected and all instrument parameters except the exposure time are left unchanged. The telescope will lose the guide star during the lamp operation because the SCSM will obscure the beam from the telescope to the fibrehead, however in typical WLC exposure times, errors in tracking will be small and reacquisition of the target onto the fibre to take another science exposure will be fast. The instrument currently repositions the moving functions with great accuracy.

Changes in temperature, pressure and/or humidity change the refractive index of air and hence change the path of the beam through the spectrograph and hence finally the position of the spectra on the CCD. For the normal range of temperature, humidity and atmospheric pressure of the observatory, temperature has the biggest effect on the refractive index of air. Furthermore temperature changes also affect the instrument itself causing it to shrink or expand, therefore the temperature of the spectrograph is controlled by placing it inside the FEROS Climate Controlled Room where an airconditioning unit controls the air temperature. The design specification for this system is to be stable within ± 0.5 degrees Celcius. In practice during a given night temperature stability is generally better than ± 0.2 degrees Celcius, though from day to day the variations can be somewhat larger. A continuously updated database of recorded environmental sensor data can be found at:
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/EnvMonArchive`

In a night the air pressure at La Silla can change by several hPa while the humidty can, and often does, change by more than 50%. However the FEROS Climate Controlled Room is a room built of insulated steel panels and is located inside another room in the center of the 2.20m telescope building, i.e. it is to a certain extent isolated from the outside world, and thus external environmental changes reach the instrument only slowly.

Image file headers contain values of the humidity inside the instrument encloure and temperatures at two locations within the instrument, three within the FEROS Climate Controlled Room and one outside the FEROS Climate Controlled Room at the beginning and end of each exposure. Ambient environmental data, including air temperature, humidty and pressure are also recorded in the headers.

4.4   Flat-fielding

There is one internal flat-fielding lamp (Hal+Hal) provided by the FCU plus the possibility to make dome flatfields. The internal lamp provides a well-exposed[2], smooth continuum spectra from approximately 380 nm to 650 nm[3] within reasonably short exposure times (see Table 4.2). Below 380 nm[4] peak S/N in individual flatfield exposures at the center of the blaze function of each order falls rapidly to ∼50 in the bluest order.

The flatfield spectra provide a good correction of the blaze function of the echelle. They are also useful to correct for the pixel-to-pixel variation in CCD sensitivity as a function of the impinging wavelength of the light and to correct for the structures introduced by imperfections of the fibre geometry (fibre function[5]). The same cautions regarding stability depending on air pressure and temperature mentioned for the wavelength calibration in section 4.3 also apply to flatfields. Internal flatfield exposures can also be attached to science OBs, as could dome flatfields, however the overhead for dome flatfields is prohibitive.

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[2]Peak S/N in individual flatfield exposures at the center of the blaze function of each order of ∼500 or more.
[3]Orders 35 to 58.
[4]Orders 59 to 63.
[5]Equivalent to the slit function of conventional spectrographs

4.5 Solar spectra

As per the FEROS Calibration Plan, every afternoon, weather permitting, i.e. if not too cloudy, approximately 1 hr before sunset, four one minute solar spectra are acquired, two spectra with ADC=OUT and two with ADC=IN.[6]

4.6 Flux standard star observations

Spectrophotometric standard stars can be used to obtain response curves of the instrument to allow a relative flux calibration of the spectra. Such calibrations are obtained at the beginning of each night during Service Mode. Normally telescope focusing using a spectrophotometric standard star field followed by four two minute science exposures (two spectra with ADC=OUT and two with ADC=IN) of a spectrophotometric standard can be made approximately 30mins after sunset and will thus normally finish well before the official start of the night, thus minimally impacting even on Visitor Mode programmes. In addition, the instantaneous atmosphere+telescope+instrument efficiency is measured and reported by the FEROS pipeline within minutes of the exposures thus giving the observer practically instantaneous feedback on the quality of the night which can be useful for planning the rest of the night's observing.

Absolute flux calibrations are **NOT** possible with FEROS due to the diameter of the SCIENCE fibre apertures which projects to 2.0 arcsec on the sky. Since the seeing at La Silla is typically 1.0 ± 0.5 arcsec with stability over time scales of a few minutes probably no better than ~0.2 arcsec, one can never be certain of the fraction of light going down the fibre and hence an ABSOLUTE flux calibration is practically impossible. To get the absolute level right one would need (for example) to do simultaneous/contemporaneous photometry in order to tie down the absolute flux at (at least) one wavelength, or one could do wide slit, low resolution spectroscopy (with for example EMMI of EFOSC)...

4.7 Quality Control

All calibrations acquired with the Daily Health Check OBs, the StanCal OBs or the CALOB OBs are pipeline processed and used to initialise the DRS. Parameters of the master images and the DRS initialisation (e.g. BIAS level, FF lamp flux levels, RMS of wavelength solution) are extracted and plotted to monitor for trends and as indicators of possible problems, e.g. aging of lamps etc.

These plots are available online at: `http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/QC`

4.8 Special calibrations

4.8.1 Use of reference stars to correct for fringing or atmospheric lines

Stars with featureless spectra (typically white dwarfs or fast rotating hot stars) can be used to provide a good template to correct for fringing as an alternative to the use of internal flatfield lamps. These spectra can also be used to identify and estimate the depth of atmospheric H_2O and O_2 absorption lines. Stars of magnitudes between 5 and 9 are best suited for this type of observations because they require short exposures but do not saturate the detector at the shortest shutter opening times.

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[6]These spectra can be helpful for order tracing in the bluest orders in older data where the Hal+Hal lamp flux was insufficient.

The OBs for these stars should be prepared in Phase II by the observers who require them for their program. A bright subsample of the hot flux standards stars is well suited for these observations.

Chapter 5

Observing

This Chapter summarizes the instrument-related information for the visiting astronomers coming to La Silla to observe with FEROS.

5.1 Before the observing nights: preparation of OBs

Visiting astronomers are normally asked to come to La Silla one night in advance of their observing run. They should arrive already well documented on the instrument properties and on the preparation of the OBs for their observing run (or ready to finalize them if they have been prepared in advance at the home institute). These activities take place on a Linux-PC Workstation in the User's Computer Room in the Library building just below the hotel, which can also be used for electronic mail correspondence with the outside world, telnet/ssh connection to the home institute, access to the World Wide Web, text-file editing, etc. Normally a 'p2pp introduction', i.e. advice on the OB preparation, will be given by the support astronomer of the Observatory.

5.2 During the night

Observations with the FEROS instrument are carried out at the User Station of MPG/ESO 2.20-m telescope console, located in the RITZ[1] Control Building located between the NTT and ESO 3.60-m telescopes. From there all three La Silla telescopes offered to the ESO community[2] and instruments are remotely controlled. The telescope and instrument operator (TIO) carries out the observations and is responsible for the checking that the telescope and instruments perform correctly; the main area of responsibility of the visiting astronomers is the selection of the OBs to be executed, based on the sky conditions and on the results of the previous observations. The main actions are outlined below.

5.2.1 Target acquisition

The OB to be executed is loaded to the BOB panel and started. The Telescope Control Software (TCS) reads the target coordinates from the OB and the telescope is pointed. Once the telescope has completed the pointing, the FEROS Fibrehead Viewer (FFHV) Camera, which images the fibrehead produces an image of the target field (6×4 arcmin) as reflected by the fibrehead, can be used for the final step of target acquisition. The FFHV images are properly oriented in the sky and

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[1]Remote Integrated Telescope Zentrum.
[2]The MPG/ESO 2.20-m telescope, the ESO NTT telescope and the ESO 3.60-m telescope.

the coordinates, which can be read with the cursor, are converted to sky coordinates. The target coordinates entered in the OBs have to be accurate to better than $< 1''$ to avoid unnecessary waste of telescope time in the identification process. The image of the FFHV field is automatically saved at the end of the acquisition. The telescope pointing rms accuracy is of the order of 5 arcsec so that the target will always appear close to the center of the FFHV images displayed on the WS panel, or if the telescope Coordinate Correction has been previously made with a target on the fibre then very close to, if not well centered on, the fibre. The visiting astronomer has to validate the target identification on the image. This is particularly important if the field has other close-by objects of similar magnitude.

Note that **if the target is invisible** to the limit of the FFHV camera (e.g. an emission line nebula), it is possible to define in the OB a blind offset from a nearby visible star. The coordinates of the science target have to be entered in the target description. In the acquisition template of the OB, the offsets to the guidestar have to be entered in arcseconds (target coordinates + offsets = acquisition star coordinates).

Whatever the acquisition procedure, once the instrument operator signals that the target is centered on the fibre, the exposure is started.

The tracking of the telescope is corrected for errors by the autoguiding, usually using guiding-on-fibre in the FFHV.

5.2.2 Monitoring the integration

There is unfortunately no facility to monitor the development of the observation, (no flux meter for example). The observer must instead rely on the experience of the TIO (at first) and later their own experience based on watching the image quality in the FFHV.

5.2.3 Evaluation of the results, off-line data analysis

At the end of each integration, the CCD frame is read-out by the FIERA controller and transferred to the Instrument Workstation and subsequently to the archive. At the same time the frames are displayed automatically on a Real-Time Display (RTD) panel. They can be analysed using the standard RTD tools. Previous exposures can be re-loaded when necessary.

Data obtained with observing templates[3] are also reduced on-line by the FEROS instrument pipeline[4] using a pre-populated calibration database. The raw files and the products of the pipeline are FITS files (cf. section 6.2). They can be assessed and inspected by the astronomer on the assigned off-line WS, which is also available for running the major image analysis systems like MIDAS, IDL and IRAF. This preliminary reduction (extraction, wavelength calibration, flat-fielding) provides advanced information on the quality of the obtained data but has to be regarded as a quick-look reduction facility.

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[3]As against maintenance templates.

[4]Implemented within a standard MIDAS context. Context 'feros', of course...

Chapter 6

The reduction of FEROS data

6.1 Real Time Display and quick look

As as they are read out by the FIERA Controller and transferred to the instrument WS, the CCD frames are automatically displayed on a Real Time Display (RTD) panel on a screen of the instrument WS. The visiting astronomer can use the standard tools of the RTD on the astronomer's offline WS to visually display and inspect the spectra, to produce intensity traces, and to compute the statistics of pixels values in a subwindow. Previous exposures can be reloaded.

6.2 Pipeline reduction of FEROS data

FEROS was delivered to ESO with a reduction pipeline which[1] supports all readout modes and binnings. The science data are calibrated with calibration exposures obtained in the afternoon before the start of the night.

The FEROS Calibration Plan (cf. section 4.1) ensures that ESO maintains and provides on a daily basis bias images, internal spectroscopic flatfield spectra, calibration lamp spectra, solar spectra and spectrophotometric standard star spectra. The CCD characteristics like read-out noise and gain are currently measured on a daily basis. Dark current are carried out once every ten days and are available on request from the ESO archive (for SM programmes, if not by chance included in the data package) and in the data package for Visitor Mode programmes.

Both 'optimum' and 'standard' extraction modes are possible, however there are currently problems of an unknown origin with the optimum extraction method resulting in a semi-sinusoidal modulation of some spectra, which appears and disappears from exposure to exposure. This problem seems to be relevant to high S/N spectra only and has not been seen in low S/N spectra.

More information about the FEROS pipeline and Service Mode data packages is given in appendix A and available under
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/DRS.`

6.3 Off-line data reduction

Any echelle data reduction package (under MIDAS, IRAF, or based on IDL) can be 'easily' adapted to extract and calibrate FEROS data. MIDAS has a dedicated context 'feros'. This is the same pipeline run at the telescope though the latest version of the user procedures should be obtained

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[1] since November 2005

from the La Silla FEROS DRS web page

`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/DRS`

Various parameters and techniques can be applied to improve the quality of the reduction over that typically achieved at the telescope.

Most recently, on the 1$^{\text{st}}$ of November 2003, the content of the FEROS FITS image header records were complete revised[2] and due to the change over from the Copenhagen University BIAS CCD controller system to the ESO standard FIERA CCD controller system. The standard version of the FEROS DRS user procedures, as provided by any standard MIDAS installation, do not know how to cope with these changes. The version of these procedures provided at the La Silla FEROS DRS web pages (see above) is specifically intended to be able to cope with data from all epochs of FEROS's history, from the original BIAS system installed at the ESO 1.52-m telescope, to the slightly modified BIAS system as originally installed at the MPG/ESO 2.20m telescope to the current FIERA based system.

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[2]In order to achieve VLT standard DICB compliance.

Chapter 7

Other useful information

7.1 List of standard stars

Any flux standard star can be used for flux calibration and blaze correction. The standards to be preferred should have measurements at a step of 2 nm or less to have at least a few points for each echelle order. For the pipeline reduction it is necessary to use stars for which the flux Table is available in MIDAS. In particular, flux standards from the MIDAS `/calib/data/spec/ctio` directory will be automatically recognised,[1] the efficiency will be calculated and reported. The FEROS webpage
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/CalPlan`
contains a pointer to the lists of flux standards.

7.2 Lists of arc lines

Tables of the ThAr and Ne lines used in the pipeline reduction are available in the FITS table `ThAr50000.mt` contained in all 'guess' session archives, a selection of which are available from La Silla FEROS DRS web page
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/DRS`
.

7.3 Pointers to FEROS sample observations

The FEROS webpage
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/ImageDB/index.html`
contains links to sample calibrations as well as information for obtaining scientific observations and calibrations available from the ESO Science Archive Database.

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[1]Provided the name of the standard is entered in the target name field of the acquisition template exactly as it is correspnding filename in the MIDAS `/calib/data/spec/ctio` directory.

Appendix A

Using the DRS pipeline at the telescope

The FEROS on-line data reduction software (DRS) gives the possibilty for a complete standard reduction of the science spectra which arrive during the night from the CCD system.

A.1 Installing at 'home'

The on-line DRS is based on the MIDAS context feros which has been distributed with MIDAS since version 98NOV. A short intoduction to the MIDAS context feros is found here.

The DRS as run at the telescope is available in the form of a gzipped tar archive (FEROS-DRS.tgz) and should be obtained from the La Silla FEROS DRS web page
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/DRS`
To install the package follow the instructions in the README file
`http://www.ls.eso.org/lasilla/sciops/2p2/E2p2M/FEROS/DRS/FEROS-DRS/README`
(also included in the FEROS-DRS.tgz file). Various parameters and techniques can be applied to improve the quality of the reduction over that typically achieved at the telescope.

The version of the online DRS in the directory

/midas/<MIDASVERSION>/contrib/feros/locproc/ is now out of date and should only be used for data older than October 2002. On the 1st of November 2003, the content of the FEROS FITS image header records were complete revised[1] and due to the change over from the Copenhagen University BIAS CCD controller system to the ESO standard FIERA CCD controller system. The standard version of the FEROS DRS user procedures, as provided by any standard MIDAS installation, do not know how to cope with these changes. The version of these procedures provided at the La Silla FEROS DRS web pages (see above) is specifically intended to be able to cope with data from all epochs of FEROS's history, from the original BIAS system installed at the ESO 1.52-m telescope, to the slightly modified BIAS system as originally installed at the MPG/ESO 2.20m telescope to the current FIERA based system.

A.2 As run at the telescope

FEROS images are delivered to the offline workstation (`w2p2off`) via the VLT Data Flow System. The data arrive into the directory `/data/raw/<yyyy-mm-dd>`. According to standard practice at the

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[1]In order to achieve VLT standard DICB compliance.

MPG/ESO-2.20m telescope, the they are written with their INS file names, i.e. `FEROS_ech_obs_objsky_<NNNN>.fits` `FEROS_ech_cal_flat_<NNNN>.fits`, etc. There is also a softlink made in the directory `/data/backlog/<yyyy-mm-dd` with the VLT *DP ID* filename, i.e. FEROS.yyyy-mm-ddThh:mm:ss.sss.fits pointing at the original file in `/data/raw/<yyyy-mm-dd>`.

Two bash shell script daemon-like process handle queuing these images for reduction (`ferosQueueIms`) and submitting queued images to the MIDAS DRS session (`ferosReduceQueuedIms`). Part of this process is the creation of a softlink with file name format `fero<NNNN>.mt` pointing at the softlink in `/data/backlog/<yyyy-mm-dd>`. It is this `fero<NNNN>.mt` file that is processed by the DRS using the command:

`@@ loadccd fero <NNNN>`

where filenum is the running 4-digit filenumber of the CCD frame.

The loadccd program itself

- loads the frame `fero<NNNN>.mt` into the display

- adds the incoming file to the catalogue Feros.cat

- starts the automatic reduction via `@@ autoreduce fero <NNNN>`

- runs DRS initialisation automatically as appropriate if StanCal or CALOB OBs are being executed

According to the four possible exposure types (SCIENCE, FLATFIELD, CALIBRATION, and DARK) given in the descriptor EXPTYPE, the autoreduce program starts the following actions:

- DARK

    adds the incoming BIAS files to the catalogue Bias.cat. If the file was generated by FIERA and if the OB name had StanCal in characters 5 to 11 and it is the first exposure of the template then the command `@@ init ThAr<MMMM> reset` is run automatically.

    adds the incoming DARK files to the catalogue Dark.cat

- FLATFIELD

    adds the incoming file to the catalogue FF.cat. If the file was generated by FIERA and if the OB name had StanCal in characters 5 to 11 and it is the last exposure of the template then the command `@@ average_cat FF.cat` is run automatically.

- CALIBRATION

    adds the incoming ThArNe files to the catalogue ThAr.cat. If the file was generated by FIERA and if the OB name had StanCal in characters 5 to 11 and it is the last exposure of the template and it is the last templat of the OB then the command `@@ average_cat ThAr.cat` followed by `@@ init ThAr<MMMM> flat 0.85` are run automatically.

    adds the incoming ThAr+Ne files to the catalogue ThArNe.cat

- SCIENCE

    adds the incoming file to the catalogue Objects.cat

    start the pre-reduction of the the file (`@@ prered <NNNN> raw_image`) where raw_image is the name of the inputfile for the following on-line reduction.

    computes the barycentric velocity according to the telescope position and writes the result to the descriptor BARY_CORR

computes and subtracts the interorder background of the echelle spectrum (`BACK/FEROS`)

straightens the echelle orders (`STRAIGHTEN/FEROS`)

extracts the echelle orders (`EXTRACT/FEROS`)

removes the blaze function and the pixel-pixel variations (`UNBLAZE/FEROS`)

rebins the echelle orders to wavelengths (`REBIN/FEROS`) according to beforehand determined dispersion coefficients. In this step also the barycentric correction is applied.

merges the echelle orders (`MERGE/FEROS`) into two 1D spectra named f<NNNN>1 and f<NNNN>2 where the spectrum with the ending 1 referes to the spectrum recorded on the object fibre and the spectrum with the ending 2 to the spectrum recorded on the sky/calibration fibre.

Image catalogues listing `fero<NNNN>.mt` files in the MIDAS working directory can be reprocessed with the command:

`@@ loadccd_cat [image.cat]`

If the option argument `[image.cat]` is omitted, `loadccd_cat` creates a new catalogue with filename `locdccd.cat` containing all `fero<NNNN>.mt` files in the MIDAS working directory and then processes all of these.

This standard reduction is controlled by the FEROS context keywords which can be listed together with their current contents by the command `SHOW/FEROS` and are set with the command `SET/FEROS key=[value]`. See below for useful keywords to be used during the observing session.

A.3   Startup of MIDAS

Normally the entire observer's enviromnent, including the MIDAS session where the FEROS DRS pipeline will be run during the night, is started up by the TIO during the daily instruments and telescope startup procedure.

If a something goes wrong during the night and the MIDAS session, or anything else is lost, ask the TIO or support astronomer to restart it.

A.4   Initialization of the DRS at the beginning of the night

To use the automatic data reduction as described above, the DRS has to be initialized at the beginning of the night. For this purpose several flatfield and wavelength calibration exposures have to be taken in the Object-Sky mode of FEROS before the beginning of the night. This is normally taken care of each afternoon by the TIO and/or support astronomer according the the FEROS Calibration Plan and is achieved via the execution of one of the Standard Calibration OBs.

If a visiting astronomer wishes to repeat the initialization personally the basic sequence to follow is:

- Reset the image catalogues FF.cat, ThAr.cat, Dark.cat, Object.cat by the command `@@ init ? reset`

- Acquire at least 2 biases 2 flatfield and 2 wavelength calibration images (create an OB in p2pp).

- Initialize the DRS for the night with the command `@@ init [guess] 0.85` where guess is the name of a previously saved guess session. Typically this is the session saved in the night

before. The session names are formed automatically from the filenumber of the first calibration exposure in the catalogue ThAr.cat and the prefix ThAr, e.g., ThAr0741.

Now the following initialization steps are performed:

- Initialization of the session keywords and tables (`INIT/FEROS`)

- Averaging of the frames of the respective catalogues FF.cat, ThAr.cat.

- Setting of the CCD gain keyword according to descriptor `CCD_GAIN` and the values specified in init.prg

- Locating of the echelle orders in the averaged flatfield (`LOCATE/FEROS`); the fitted positions are shown in the display window.

- Standard reduction of the flatfield (`BACK/FEROS`, `STRAIGHTEN/FEROS`, `EXTRACT/FEROS`). The extraction is done twice: the first time, the cross-order profiles are determined for an optimum extraction with cosmic removal for the science exposures; the second time the flatfield orders are extracted. The name of the reduced flatfield is found in the keyword `FLAT_IMG`.

- Standard reduction of the wavelength calibration (`BACK/FEROS`, `STRAIGHTEN/FEROS`, `EXTRACT/FEROS`). The name of the reduced calibration is found in the keyword WLC_IMG

- Search for emission lines in the reduced calibration frame (`FIND/FEROS`).

- Wavelength calibration by iterative fitting of the dispersion coefficients (`CALIBRATE/FEROS`). The residuals of the individual lines are plotted over the order number. The spread should not exceed a peak-to-peak of 0.02 Angstroms.

- The session parameters are saved as session `WLC_IMG`.

With this step completed, the FEROS on-line DRS is initialized.

Every new incoming spectrum will be saved and reduced now as described above.

A.5   On-line Reduction Options During the Night

The context keywords allow to control the parameters of the reduction process. The keywords can be listed together with their current contents by the command `SHOW/FEROS` and are set with the command `SET/FEROS key=[value]`. Alternatively the keywords can be set using the FEROS GUI which is started by the command `CREATE/GUI feros`.

If the keywords are set to new values, they will only affect the automatic on-line DRS for next incoming files. If one of the files already transfered to the IWS (fero<NNNN>.mt should be reduced again according to the new settings of the keywords, this is easily achieved by re-starting the `@@` `autoreduce` command manually as follows:

`@@ autoreduce fero` <NNNN>

Useful keywords for the observing session might be:

1. EXT_MODE controls the method used for the extraction of the spectra.

   The three options are:

SET/FEROS EXT_MODE=S the standard extraction is performed where the flux across the slit is ust summed.

SET/FEROS EXT_MODE=M the standard extraction is performed as above but with clipping of cosmics

SET/FEROS EXT_MODE=O the optimum extraction is performed with clipping of cosmics

In addition EXT_MODE=B (for both) is understood by autoreduce to execute standard and optimum extractions.

2. MERGE_MTD controls the merging of the orders.

The options are:

SET/FEROS MERGE_MTD=SINC the default merging into a 1D spectrum with weighted adding of overlapping regions. The lengths of the orders are determined from table BLAZE.tbl

SET/FEROS MERGE_MTD=AVE should not be used

SET/FEROS MERGE_MTD=NOAPP the orders are not merge but written into individual 1D spectra; the order number is appended to the filename as 4-digit number.

3. REBIN_MTD controls the rebinning of the spectra.

The options are:

SET/FEROS REBIN_SCL=I the rebinning is done into a `linear` wavelength scale. The stepsize has to be set in the keyword REBIN_STEP.

SET/FEROS REBIN_SCL=O the rebinning is done into a `logartithmic` wavelength scale. The stepsize has to be set in the keyword REBIN_STEP.

A.6   Utility programs

A.6.1   List of files

An extended list of files with the most important header informations can be obtained with the command

`@@ listferos [tablename] [filenum_start,filenum_end]`

where tablename is the name for the output table; filenum_start,filenum_end are the 4-digit filenumbers of the interval of files to be listed. The program will ask at the end to prepare a printout on the laser printer. It will take care of the proper formatting of the printer output.

It is recommended to use this program at the end of the night to check the integrity and completeness of the data files obtained during the night before archiving them on the COPY DAT.

A.6.2   Plot of temperatures

A plot (and a table) with the spectrograph and room temperatures corresponding to the obtained CCD frames can be obtained with the command

`@@ temperature [tablename] [filenum_start,filenum_end]`

where tablename is the name for the output table; filenum_start,filenum_end are the 4-digit filenumbers of the interval of files to be used. In the table also the measured relative humidity is stored and can plotted with the command

`plo/table [tablename] :JD24 :RHUM`

A.6.3   Signal-to-Noise Ratio

After a spectrum fero<NNNN>.mt of a science object has been passed the on-line DRS, the achieved Signal-to-Noise Ratio (SNR) can be tentatively measured in a line-free region of the spectrum with the following command

`@@ snr <NNNN> [start,end] [fibrenum]`

where the parameters start,end determines the wavelength interval to be used for the SNR estimate; fibrenum refers to the fibre to be used, i.e., 1 for the object fibre (default), 2 for the sky fibre.

Note that the performance of this procedure is heavily affected by sharp spectral features as spectral lines or cosmic ray hits. Further, the SNR of the used flatfield may limit the SNR measured.

A.6.4   Spectrograph focus test

After a wavelength calibration spectrum fero<NNNN>.mt has been taken and the DRS is initialized as described above, the command

`@@ focus <NNNN>`

reduces the calibration spectrum, measures the FWHM of the emission lines and plots the FWHMs over the position in dispserion direction. A FWHM of 2.2 pixels corresponds to a resolving power of R=48,000.

A.6.5   System efficiency test

After a spectrum fero<NNNN>.mt of a standard star has been taken and the spectrum has be passed the automatic standard reduction, the command

`@@ efficiency <NNNN> [standard star flux table]`

computes the efficiency of the instrument including the telescope, fibres and the detector as function of the wavelength.

The flux tables of the standard star must be available in the subdirectories of `/midas/calib/data/spec/` and have to be given with the subdirectory, e.g. as `ctio/hr9087`.

A.6.6   Radial Velocities by Cross-Correlation

Radial velocities with high precision can be obtained in the OC mode of FEROS. The on-line DRS

provides a very simple cross-correlation tool to obtain online radial velocities with respect to one reference exposure of the object.

It should be emphasized that the routines described here are meant as on-line tools to obtain an estimate for the measured radial-velocity shifts. However, to obtain high precision radial velocities over long periods, dedicated reduction software and special operational precautions have to be taken. This is beyond the scope of the FEROS on-line DRS.

The algorithm works as follows: The program crosscorrelates the calibration spectrum (thar) from

the initialization of the night order by order with the corresponding calibration spectrum from the reference night (tharref) to obtain the zero point of the night.

For the object spectrum obtained during the night (object), the program crosscorrelates the simultaneous calibration spectrum on the calibration fibre with the calibration spectrum on the calibration fibre from the initialization to obtain the drift correction between the zero point of the night and the actual object exposure. The object spectrum (object) is crosscorrelated with the object spectrum from the reference night (objectref). The measured radial velocity shift is corrected for the zero point, the drift during the night, and the barycentric correction. The final radial velocity is obtained by gaussian fitting of the histogram of the derived radial velocities of all orders.

To use the corresponding `@@ xcorall` program, the following steps are necessary:

- initialize the DRS as described above in the Object-Sky mode. The calibration exposure has to be flatfielded with the command

  `UNBLAZ/FERO ThAr[thar]ext FF[flat]ext f[thar]ext`

  where thar, flat correspond to the 4-digit numbers of the intialization frames of the night.

- .observe the object in Object-Calibration mode and let the on-line DRS reduce the spectrum as usual. Make sure that the EXT_MODE=S is used.

- Use afterwards the crosscorrelation program:

  `@@ xcorall [table] [object] [objectref] [thar] [tharref] [hbin] [action]`

  where table is a name for the table with the results (the results from subsequent calls of the program will be appended to the table); object, objectref, thar, tharref refer to the 4-digit numbers of the files described above. With hbin the size of the histogram bins to be used for the final determination of the radial velocity; defaulted to 0.150 km/s.

  If the program is called the very first time, action should be set to create; to add the results from new reductions action has to be set to enter

- The results can be plotted over the modified julian date (MJD) with the command

  `plot/table [table] :jd24 :dbc`

  5.Example for the first (reference) night:

```
        Midas 11> UNBLAZ/FERO ThAr1200ext FF1202ext f1200ext
        Midas 12> @@ xcorall 51Peg 1212 1212 1200 1200 ? ? create
        Midas 13> @@ xcorall 51Peg 1212 1212 1200 1200 ? ? enter
```

  For an observation from a later night:

```
        Midas 698> UNBLAZ/FERO ThAr1410ext FF1212ext f1410ext
        Midas 699> @@ xcorall 51Peg 1417 1212 1410 1200 ? ? enter
        Midas 700> plo/tab 51Peg :jd24 :dbc
```

  If a large number of Object-Calibration exposures has been obtained for one object, the command

```
@@ radvel [objectcat] [objectref] [tharcat] [refthar] [hbin]
```

gives the possiblity to reduce all files at once. For this, a MIDAS catolgue objectcat with all
f[object]ext1.bdf files and a MIDAS catolgue tharcat with the corresponding f[thar]ext1.bdf
files has to be provided. The catalogue names have to entered without the extension .cat; the
result table will carry the name objectcat. Example:

```
 Midas 897> read/icat 51Peg

 Image Catalog:  51Peg.cat
 --------------
 No    Name                 Ident                           Naxis  Npix
 #0001 f1212ext1.bdf                                         2 4102,39
 .
 .
 .
 #0015 f1417ext1.bdf                                         2 4102,39


 Midas 897> read/icat 51Pegthar

 Image Catalog:  51Pegthar.cat
 --------------
 No    Name                 Ident                           Naxis  Npix
 #0001 f1200ext1.bdf                                         2 4102,39
 .
 .
 .
 #0015 f1410ext1.bdf                                         2 4102,39

 Midas 899> @@ radvel 51Peg 1212 51Pegthar 1200
 Midas 900> plot/tab 51Peg :jd24 :dbc
```

Appendix B

On-line DRS filename conventions

```
@@ init
```

- **Filename :** fero<NNNN>.mt

   Content:rawimage in FITS format as transferred to the instrument

   Format: pixel-pixel

- **Filename :**FF.cat

   Content: Catalogue with FLATFIELD exposures

   Format:MIDAS catalogue

- **Filename :**ThAr.cat

   Content: Catalogue with CALIBRATION exposures

   Format: MIDAS catalogue

- **Filename :** Dark.cat

   Content: Catalogue with DARK exposures

   Format: MIDAS catalogue

- **Filename :**Objects.cat

   Content: Catalogue with SCIENCE exposures

   Format: MIDAS catalogue

- **Filename :**FF<NNNN>.bdf

   Keyword: RAW_IMG

   Content: average flatfield frame from catalogue FF.cat; filenum is taken from the first file
   in the catalogue

   Format: position[mm]-position[mm]

- **Filename :**FF<NNNN>ext1.bdf

   Keyword: RAW_IMG,FLAT_IMG

   Content: Extracted flatfield orders of object fibre

   Format: position[mm]-order

- FilenameFF<NNNN>ext2.bdf

    Keyword: RAW_IMG, FLAT_IMG

    Content: Extracted flatfield orders of sky fibre

    Format: position[mm]-order

- **Filename :**ThAr<NNNN>.bdf

    Keyword: WLC_IMG

    Content: average calibration frame from catalogue ThAr.cat filenum is taken from the first file in the catalogue

    Format: position[mm]-position[mm]

- **Filename :**ThAr<NNNN>ext1.bdf

    Keyword: WLC_IMG

    Content: Extracted calibration orders of object fibre

    Format: position[mm]-order

- **Filename :**ThAr<NNNN>ext2.bdf

    Keyword: WLC_IMG

    Content: Extracted calibration orders of sky fibre

    Format: position[mm]-order

- **Filename :**ThAr<NNNN>lines1.bdf

    Keyword: LINE_POS_TBL

    Content: Table with found calibration lines of object fibre; order-by-order dispersion coefficients are stored in the descriptor DCOEF/D/1/195 with 5 polynomial coefficients per order (used for rebinning). Saved to ThAr<NNNN>_LINE1.tbl by SAVE/FEROS ThAr<NNNN>

    Format: MIDAS table

- **Filename :**ThAr<NNNN>lines2.bdf

    Keyword: LINE_POS_TBL

    Content: Table with found calibration lines of sky fibre; order-by-order dispersion coefficients are stored in the descriptor DCOEF/D/1/195 with 5 polynomial coefficients per order (used for rebinning). Saved to ThAr<NNNN>_LINE2.tbl by SAVE/FEROS ThAr<NNNN>

    Format: MIDAS table

- **Filename :** ThAr<NNNN>_INIT.bdf

    Content: Table with session keywords in descriptors; session keywords and defaults in table rows. Session keywords are restored by command INIT/FEROS

    MIDAS Table

- **Filename :** template.bdf

    Content: Image with cross-correlation template for order definition; Copied to ThAr<NNNN>_TEMPLAT by command INIT/FEROS ThAr<NNNN>

    Format: pixels, template must be centered to central pixel

- **Filename :**echpos.tbl

    Keyword: GUESS_TBL

    Content Table with guess for order definition; Copied to ThAr<NNNN>_GORDER.tbl by command INIT/FEROS ThAr<NNNN>

    Format: MIDAS Table

- **Filename :**centers.tbl

    Keyword: CENTER_TBL

    Content Table with order definition; Copied to ThAr<NNNN> by command INIT/FEROS

    Format: MIDAS table

- **Filename :**cop_coeffs1.tbl

    Keyword: COEF_COP

    Content Table with cross-order profile definition of object fibre; Copied to ThAr<NNNN>_COP1.tbl by command INIT/FEROS ThAr<NNNN>

    Format: MIDAS Table

- **Filename :**cop_coeffs2.tbl

    COEF_COP

    Content Table with cross-order profile definition of sky fibre; Copied to ThAr<NNNN>_COP2.tbl by command INIT/FEROS ThAr<NNNN>

    Format: MIDAS Table

- **Filename :** wlc_coeffs1.tbl

    Keyword: COEF_WLC

    Content Table with wavelength-calibration coefficients of object fibre from global fit; Copied to ThAr<NNNN>_WLC1.tbl by command INIT/FEROS ThAr<NNNN>

    Format: MIDAS Table

- **Filename :** wlc_coeffs2.tbl

    Keyword: COEF_WLC

    Content Table with wavelength calibration coefficients of sky fibre from global fit; Copied to ThAr<NNNN>_WLC2.tbl by command INIT/FEROS ThAr<NNNN>

    Format: MIDAS Table

- **Filename :** ThAr50000.tbl

    Keyword: COEF_WLC

    Content: Table with wavelengths of calibration lines optimized for resolving power R=50000. Used for wavelength calibration; Available in MIDAS directory /midas/97NOV/contrib/feros/data/calib/

    Format: MIDAS Table

- **Filename :**BLAZE.tbl

    Keyword: COEF_WLC

    Content: Table with blaze wavelengths of orders. Used for order merging; Available in MIDAS directory /midas/97NOV/contrib/feros/data/calib/calib0002.mt

    Format: MIDAS Table

@@ autoreduce

- **Filename : fero<NNNN>.mt**

  Content :rawimage in FITS format as transferred to the instrument workstation

  Format: pixel-pixel

- **Filename : raw_image.bdf**

  Content : MIDAS frame after prereduction of the rawimage

  Format: position[mm]-position[mm]

- **Filename : back.bdf**

  Content : Background subtraced frame

  Format: position[mm]-position[mm]

- **Filename : back_str_C1.bdf**

  Content : Straightened frame of object fibre

  Format: position[mm]-pixel

- **Filename : back_str_C2.bdf**

  Content : Straightened frame of sky fibre

  Format: position[mm]-pixel

- **Filename : bf<NNNN>ext1.bdf**

  Content : Extracted orders of object fibre

  Format: position[mm]-order

- **Filename : bf<NNNN>ext2.bdf**

  Content : Extracted orders of sky fibre

  Format: position[mm]-order

- **Filename : f<NNNN>ext1.bdf**

  Content : Extracted and flatfielded orders of object fibre

  Format: position[mm]-order

- **Filename : f<NNNN>ext2.bdf**

  Content : Extracted and flatfielded orders of sky fibre

  Format: position[mm]-order

- **Filename : rebinned1.bdf**

  Content : Wavelength rebinnded orders of object fibre

  Format: wavelength[Å]-order

- **Filename : rebinned2.bdf**

  Content : Wavelength rebinnded orders of sky fibre

  Format: wavelength[Å]-order

- **Filename : f<NNNN>1.bdf**

    Content : Merged and wavelength calibrated spectrum of object fibre

    Format: wavelength[Å]

- **Filename : f<NNNN>2.bdf**

    Content : Merged and wavelength calibrated spectrum of sky fibre

    Format: wavelength[Å]

Appendix C

Naming convention for DRS products

```
DRS products are given the following naming convention:

If FEROSUseAFDRSFITS="Y" then DRS products converted to FITS files according
to the following convention:

mDPID = modified DPID = FEROS.YYYY-MM-DDTHH:MM:ss.sss
i.e. without the .fits extension

The one dimensional extracted frames are:

r.<DPID>.1081.fits <==> f<NNNN>1.bdf
r.<DPID>.1082.fits <==> f<NNNN>2.bdf

The list of other products :

r.<DPID>.1051.fits <==> f<NNNN>ext1.bdf
r.<DPID>.1052.fits <==> f<NNNN>ext2.bdf
r.<DPID>.1061.fits <==> rebinned1.bdf
r.<DPID>.1062.fits <==> rebinned2.bdf
```

Appendix D

Data Archiving

FEROS SCIENCE data are archived in the ESO data archive automatically according to the ESO VLT Data Flow System. Specifically, for FEROS the NGAST system originally installed for the WFI instrument at the MPG/ESO 2.20m telescope is used. In anycase, since the data are in the ESO archive they can be accessed via the standard tools, see `http://archive.eso.org/`. FEROS data have been ingested into the ESO Science Archive since the FEROS big-bang, i.e. the upgrade to VLT compatibility, which was made in November 2003. In addition data since August 31st, 2001 has been archived on CD and is maintained by La Silla Science Operations. Access to this archive is limited and depends on the availability of La Silla SciOps staff. Enquiries should be addressed to the La Silla SciOps Shift Leader *lasilla@eso.org*.

Data Packages for Visitor mode runs, including raw data, DRS Pipeline products, FFHV images and relevant log files are provided via CD and/or DVD according to taste. These CDs are created by La Silla SciOps staff. For Visitor Mode programmes the CDs and/or DVDs are usually ready for the observer to take home with him/her before departing from the observatory normally in the afternoon after the end of the last night of observations. The Visitor must complete the web-based backup request form which is accessible from the SciOps home page.

Since Period 76 Data Packages For Service Mode programmes are prepared by ESO's Data Management Department. Data packages are sent via mail to the programme PIs upon completion of the entire set of OBs, or the end of the relevant ESO period, whichever comes first.

Typically one night of FEROS observations plus calibrations will fill one CD (raw data being gzipped) and often entire runs will fit on a single DVD.

Appendix E

The FEROS FITS header

```
---------------------------------------------------------------------
SIMPLE  =                    T          / Standard FITS format (NOST-100.0)
BITPIX  =                   16          / # of bits storing pix values
NAXIS   =                    2          / # of axes in frame
NAXIS1  =                 2148          / # pixels/axis
NAXIS2  =                 4096          / # pixels/axis
PCOUNT  =                    0          / Number of parameters per group
GCOUNT  =                    1          / Number of groups
BZERO   =              32768.0          / pixel=FITS*BSCALE+BZERO
BSCALE  =                  1.0          / pixel=FITS*BSCALE+BZERO
ORIGIN  = 'ESO-LSO '                    / European Southern Observatory
DATE    = '2004-07-08T21:25:30.381'     / UT date when this file was written
TELESCOP= 'MPI-2.2 '                    / ESO Telescope Name
INSTRUME= 'FEROS   '                    / Instrument used.
OBJECT  = 'SolarSpectrum'     / Original target.
RA      =           194.999415          / 12:59:59.8 RA (J2000) at start in (deg
DEC     =            -29.99999          / -29:59:59.9 DEC (J2000) at start in (d
EQUINOX =                2000.          / Standard FK5 (years)
RADECSYS= 'FK5     '                    / Coordinate reference frame
EXPTIME =             119.9999          / Total integration time
MJD-OBS =        53194.89131245         / MJD start (2004-07-08T21:23:29.396)
DATE-OBS= '2004-07-08T21:23:29.395'     / Date of observation
UTC     =            77003.397          / 21:23:23.397 UTC at start (sec)
LST     =            42545.347          / 11:49:05.347 LST at start (sec)
PI-COI  = 'UNKNOWN '           / PI-COI name.
OBSERVER= 'UNKNOWN '           / Name of observer.
CTYPE1  = 'PIXEL   '                    / Pixel coordinate system
CTYPE2  = 'PIXEL   '                    / Pixel coordinate system
CRVAL1  =                  1.0          / value of ref pixel
CRVAL2  =                  1.0          / value of ref pixel
CRPIX1  =                 51.0          / Ref. pixel of center of rotation
CRPIX2  =                  1.0          / Ref. pixel of center of rotation
CDELT1  =                  1.0          / Binning factor
CDELT2  =                  1.0          / Binning factor
EXTEND  =                    F          / Extension may be present
HIERARCH ESO ADA GUID STATUS = 'OFF     '   / Status of autoguider
HIERARCH ESO ADA POSANG      =       0.90000 / Position angle at start
```

```
HIERARCH ESO DET BITS        =              16 / Bits per pixel readout
HIERARCH ESO DET CHIP1 DATE  = '03/10/03'    / Date of installation [YYYY-MM-DD]
HIERARCH ESO DET CHIP1 ID    = 'CCD-60  '    / Detector chip identification
HIERARCH ESO DET CHIP1 INDEX =               1 / Chip index
HIERARCH ESO DET CHIP1 NAME  = 'EEV CCD-44' / Detector chip name
HIERARCH ESO DET CHIP1 NX    =            2048 / # of pixels along X
HIERARCH ESO DET CHIP1 NY    =            4096 / # of pixels along Y
HIERARCH ESO DET CHIP1 PSZX  =            15.0 / Size of pixel in X
HIERARCH ESO DET CHIP1 PSZY  =            15.0 / Size of pixel in Y
HIERARCH ESO DET CHIP1 X     =               1 / X location in array
HIERARCH ESO DET CHIP1 XGAP  =        0.000000 / Gap between chips along x
HIERARCH ESO DET CHIP1 Y     =               1 / Y location in array
HIERARCH ESO DET CHIP1 YGAP  =        0.000000 / Gap between chips along y
HIERARCH ESO DET CHIPS       =               1 / # of chips in detector array
HIERARCH ESO DET DATE        = '03/10/03'    / Installation date
HIERARCH ESO DET DEC         =      0.00000000 / Apparent 00:00:00.0 DEC at start
HIERARCH ESO DET DID         = 'ESO-VLT-DIC.CCDDCS,ESO-VLT-DIC.FCDDCS' / Diction
HIERARCH ESO DET EXP NO      =            1311 / Unique exposure ID number
HIERARCH ESO DET EXP RDTTIME =          41.559 / image readout time
HIERARCH ESO DET EXP TYPE    = 'Normal  '    / Exposure type
HIERARCH ESO DET EXP XFERTIM =          41.682 / image transfer time
HIERARCH ESO DET FRAM ID     =               1 / Image sequencial number
HIERARCH ESO DET FRAM TYPE   = 'Normal  '    / Type of frame
HIERARCH ESO DET ID          = '        '    / Detector system Id
HIERARCH ESO DET NAME        = 'feros - FEROS' / Name of detector system
HIERARCH ESO DET OUT1 CHIP   =               1 / Chip to which the output belongs
HIERARCH ESO DET OUT1 CONAD  =            0.00 / Conversion from ADUs to electrons
HIERARCH ESO DET OUT1 GAIN   =            0.00 / Conversion from electrons to ADU
HIERARCH ESO DET OUT1 ID     = 'R       '    / Output ID as from manufacturer
HIERARCH ESO DET OUT1 INDEX  =               2 / Output index
HIERARCH ESO DET OUT1 NAME   = 'R       '    / Description of output
HIERARCH ESO DET OUT1 NX     =            2048 / valid pixels along X
HIERARCH ESO DET OUT1 NY     =            4096 / valid pixels along Y
HIERARCH ESO DET OUT1 OVSCX  =              50 / Overscan region in X
HIERARCH ESO DET OUT1 OVSCY  =               0 / Overscan region in Y
HIERARCH ESO DET OUT1 PRSCX  =              50 / Prescan region in X
HIERARCH ESO DET OUT1 PRSCY  =               0 / Prescan region in Y
HIERARCH ESO DET OUT1 RON    =            0.00 / Readout noise per output (e-)
HIERARCH ESO DET OUT1 X      =            2048 / X location of output
HIERARCH ESO DET OUT1 Y      =               1 / Y location of output
HIERARCH ESO DET OUTPUTS     =               1 / # of outputs
HIERARCH ESO DET OUTREF      =               0 / reference output
HIERARCH ESO DET RA          =      0.00000000 / Apparent 00:00:00.0 RA at start
HIERARCH ESO DET READ CLOCK  = 'R 225Kps Low Gai' / Readout clock pattern used
HIERARCH ESO DET READ MODE   = 'normal  '    / Readout method
HIERARCH ESO DET READ NFRAM  =               1 / Number of readouts buffered in sin
HIERARCH ESO DET READ SPEED  = 'Fast    '    / Readout speed
HIERARCH ESO DET SHUT ID     = 'Feros shutter' / Shutter unique identifier
HIERARCH ESO DET SHUT TMCLOS =           0.001 / Time taken to close shutter
HIERARCH ESO DET SHUT TMOPEN =           0.001 / Time taken to open shutter
HIERARCH ESO DET SHUT TYPE   = 'IRIS    '    / type of shutter
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HIERARCH ESO DET SOFW MODE    = 'Normal  '   / CCD sw operational mode
HIERARCH ESO DET TELE INT     =          1.0 / Interval between two successive te
HIERARCH ESO DET TELE NO      =            2 / # of sources active
HIERARCH ESO DET TLM1 END     =       138.40 / Telemetry value at read completion
HIERARCH ESO DET TLM1 ID      = 'CCD     '   / ID of telemetry sensor
HIERARCH ESO DET TLM1 NAME    = 'CCD Cold Plate' / Description of telemetry param
HIERARCH ESO DET TLM1 START   =       138.40 / Telemetry value at read start
HIERARCH ESO DET TLM2 END     =       140.20 / Telemetry value at read completion
HIERARCH ESO DET TLM2 ID      = 'CCD2    '   / ID of telemetry sensor
HIERARCH ESO DET TLM2 NAME    = 'CCD Cold Plate2' / Description of telemetry para
HIERARCH ESO DET TLM2 START   =       140.20 / Telemetry value at read start
HIERARCH ESO DET WIN1 BINX    =            1 / Binning factor along X
HIERARCH ESO DET WIN1 BINY    =            1 / Binning factor along Y
HIERARCH ESO DET WIN1 DIT1    =   119.999936 / actual subintegration time
HIERARCH ESO DET WIN1 DKTM    =     120.0091 / Dark current time
HIERARCH ESO DET WIN1 NDIT    =            1 / # of subintegrations
HIERARCH ESO DET WIN1 NX      =         2148 / # of pixels along X
HIERARCH ESO DET WIN1 NY      =         4096 / # of pixels along Y
HIERARCH ESO DET WIN1 ST      =            T / If T, window enabled
HIERARCH ESO DET WIN1 STRX    =            1 / Lower left pixel in X
HIERARCH ESO DET WIN1 STRY    =            1 / Lower left pixel in Y
HIERARCH ESO DET WIN1 UIT1    =   120.000000 / user defined subintegration time
HIERARCH ESO DET WINDOWS      =            1 / # of windows readout
HIERARCH ESO DPR CATG         = 'SCIENCE '   / Observation category
HIERARCH ESO DPR TECH         = 'ECHELLE '   / Observation technique
HIERARCH ESO DPR TYPE         = 'OBJ,SKY '   / Observation type
HIERARCH ESO INS ADC1 DEC     =      0.00000 / Telescope desclination [deg].
HIERARCH ESO INS ADC1 END     =       0.0000 / Position angle at end [deg].
HIERARCH ESO INS ADC1 MODE    = 'OFF     '   / ADC mode.
HIERARCH ESO INS ADC1 RA      =     0.000000 / Telescope right ascension [deg].
HIERARCH ESO INS ADC1 SWSIM   =            T / If T, function is software simulat
HIERARCH ESO INS ADC2 DEC     =      0.00000 / Telescope desclination [deg].
HIERARCH ESO INS ADC2 END     =       0.0000 / Position angle at end [deg].
HIERARCH ESO INS ADC2 MODE    = 'OFF     '   / ADC mode.
HIERARCH ESO INS ADC2 RA      =     0.000000 / Telescope right ascension [deg].
HIERARCH ESO INS ADC2 SWSIM   =            T / If T, function is software simulat
HIERARCH ESO INS ADCA NAME    = 'OUT     '   / ADC arm position name.
HIERARCH ESO INS CALMIRR1 ID = 'PARK    '   / Sliding cal. sel. mirror unique ID
HIERARCH ESO INS CALMIRR1 NAME= 'PARK    '   / Sliding cal. sel. mirror name.
HIERARCH ESO INS CALMIRR1 NO =            1 / Sliding cal. sel. mirror number.
HIERARCH ESO INS CALMIRR1 TYPE= 'FREE    '   / Sliding cal. sel. mirror element.
HIERARCH ESO INS CALMIRR2 ID = 'LAMP1   '   / Rotating sel. mirror unique ID.
HIERARCH ESO INS CALMIRR2 NAME= 'LAMP1   '   / Rotating sel. mirror name.
HIERARCH ESO INS CALMIRR2 NO =            2 / Rotating sel. mirror number.
HIERARCH ESO INS CALMIRR2 TYPE= 'LAMP    '   / Rotating sel. mirror element.
HIERARCH ESO INS DATE         = '2000-06-16' / Instrument release date (yyyy-mm-d
HIERARCH ESO INS DID          = 'ESO-VLT-DIC.FEROS_ICS-1.5' / Data dictionary for
HIERARCH ESO INS FILT1 ENC    =         1932 / Absolute position [Enc].
HIERARCH ESO INS FILT1 POS    =        0.000 / NDFW Position [density].
HIERARCH ESO INS ID           = 'FEROS/1.56' / Instrument ID.
HIERARCH ESO INS LAMP3 SWSIM = T / If T, function is software simulat
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HIERARCH ESO INS MIRR3 NAME  = 'FEROS   '   / FEROS-WFI sel.mirror name.
HIERARCH ESO INS MODE        = 'FEROS   '   / Instrument mode used.
HIERARCH ESO INS PATH        = 'DEFAULT '   / Optical path used.
HIERARCH ESO INS SENS7 ID    = 'HUMI    '   / sensor ID.
HIERARCH ESO INS SENS7 MAX   =     13.450000 / Maximum value.
HIERARCH ESO INS SENS7 MEAN  =     13.446667 / Average value.
HIERARCH ESO INS SENS7 MIN   =     13.440000 / Minimum value.
HIERARCH ESO INS SENS7 NAME  = 'Humidity'   / sensor common name.
HIERARCH ESO INS SENS7 RMS   =      0.004714 / RMS of samples over exposure.
HIERARCH ESO INS SENS7 VAL   =     13.450000 / Sensor numeric value.
HIERARCH ESO INS SENS8 ID    = 'LNLV    '   / sensor ID.
HIERARCH ESO INS SENS8 NAME  = 'LN2 level' / sensor common name.
HIERARCH ESO INS SENS8 VAL   =     63.440000 / Sensor numeric value.
HIERARCH ESO INS SHUT1 ID    = 'DARK    '   / FCU shutter unique ID.
HIERARCH ESO INS SHUT1 NAME  = 'DARK    '   / FCU shutter name.
HIERARCH ESO INS SHUT1 NO    =             1 / FCU shutter number.
HIERARCH ESO INS SHUT1 SWSIM =             T / If T, function is software simulat
HIERARCH ESO INS SHUT1 TYPE  = 'FREE    '   / FCU shutter element.
HIERARCH ESO INS SWSIM       = 'NORMAL  '   / Software simulation.
HIERARCH ESO INS TEMP1 ID    = 'TEMP1   '   / Temperature sensor ID.
HIERARCH ESO INS TEMP1 MAX   =     14.430000 / Maximum value [C].
HIERARCH ESO INS TEMP1 MEAN  =     14.430000 / Average value [C].
HIERARCH ESO INS TEMP1 MIN   =     14.430000 / Minimum value [C].
HIERARCH ESO INS TEMP1 NAME  = 'Temperature 1' / Temperature sensor name.
HIERARCH ESO INS TEMP1 RMS   =      0.000000 / RMS of samples over exposure.
HIERARCH ESO INS TEMP1 VAL   =         14.42 / Temperature sensor numeric value [
HIERARCH ESO INS TEMP2 ID    = 'TEMP2   '   / Temperature sensor ID.
HIERARCH ESO INS TEMP2 MAX   =     14.480000 / Maximum value [C].
HIERARCH ESO INS TEMP2 MEAN  =     14.480000 / Average value [C].
HIERARCH ESO INS TEMP2 MIN   =     14.480000 / Minimum value [C].
HIERARCH ESO INS TEMP2 NAME  = 'Temperature 2' / Temperature sensor name.
HIERARCH ESO INS TEMP2 RMS   =      0.000000 / RMS of samples over exposure.
HIERARCH ESO INS TEMP2 VAL   =         14.48 / Temperature sensor numeric value [
HIERARCH ESO INS TEMP3 ID    = 'TEMP3   '   / Temperature sensor ID.
HIERARCH ESO INS TEMP3 MAX   =     14.790000 / Maximum value [C].
HIERARCH ESO INS TEMP3 MEAN  =     14.783333 / Average value [C].
HIERARCH ESO INS TEMP3 MIN   =     14.770000 / Minimum value [C].
HIERARCH ESO INS TEMP3 NAME  = 'Temperature 3' / Temperature sensor name.
HIERARCH ESO INS TEMP3 RMS   =      0.009428 / RMS of samples over exposure.
HIERARCH ESO INS TEMP3 VAL   =         14.79 / Temperature sensor numeric value [
HIERARCH ESO INS TEMP4 ID    = 'TEMP4   '   / Temperature sensor ID.
HIERARCH ESO INS TEMP4 MAX   =     14.430000 / Maximum value [C].
HIERARCH ESO INS TEMP4 MEAN  =     14.430000 / Average value [C].
HIERARCH ESO INS TEMP4 MIN   =     14.430000 / Minimum value [C].
HIERARCH ESO INS TEMP4 NAME  = 'Temperature 4' / Temperature sensor name.
HIERARCH ESO INS TEMP4 RMS   =      0.000000 / RMS of samples over exposure.
HIERARCH ESO INS TEMP4 VAL   =         14.43 / Temperature sensor numeric value [
HIERARCH ESO INS TEMP5 ID    = 'TEMP5   '   / Temperature sensor ID.
HIERARCH ESO INS TEMP5 MAX   =     14.570000 / Maximum value [C].
HIERARCH ESO INS TEMP5 MEAN  =     14.563333 / Average value [C].
HIERARCH ESO INS TEMP5 MIN   =     14.560000 / Minimum value [C].
```

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HIERARCH ESO INS TEMP5 NAME  = 'Temperature 5' / Temperature sensor name.
HIERARCH ESO INS TEMP5 RMS   =      0.004714 / RMS of samples over exposure.
HIERARCH ESO INS TEMP5 VAL   =         14.57 / Temperature sensor numeric value [
HIERARCH ESO INS TEMP6 ID    = 'TEMP6   '    / Temperature sensor ID.
HIERARCH ESO INS TEMP6 MAX   =     16.750000 / Maximum value [C].
HIERARCH ESO INS TEMP6 MEAN  =     16.723333 / Average value [C].
HIERARCH ESO INS TEMP6 MIN   =     16.710000 / Minimum value [C].
HIERARCH ESO INS TEMP6 NAME  = 'Temperature 6' / Temperature sensor name.
HIERARCH ESO INS TEMP6 RMS   =      0.018856 / RMS of samples over exposure.
HIERARCH ESO INS TEMP6 VAL   =         16.75 / Temperature sensor numeric value [
HIERARCH ESO OBS DID         = 'ESO-VLT-DIC.OBS' / OBS Dictionary
HIERARCH ESO OBS EXECTIME    =           684 / Expected execution time
HIERARCH ESO OBS GRP         = '0       '    / linked blocks
HIERARCH ESO OBS ID          =        163677 / Observation block ID
HIERARCH ESO OBS NAME        = '200-SolarSpectrum-norm' / OB name
HIERARCH ESO OBS OBSERVER    = 'UNKNOWN '    / Observer Name
HIERARCH ESO OBS PI-COI ID   =         51020 / ESO internal PI-COI ID
HIERARCH ESO OBS PI-COI NAME = 'UNKNOWN '    / PI-COI name
HIERARCH ESO OBS PROG ID     = '60.A-9120(B)' / ESO program identification
HIERARCH ESO OBS START       = '2004-07-08T21:23:01' / OB start time
HIERARCH ESO OBS TARG NAME   = 'SolarSpectrum' / OB target name
HIERARCH ESO OBS TPLNO       =             2 / Template number within OB
HIERARCH ESO OCS DET1 IMGNAME= 'FEROS_ech_obs_objsky' / Data File Name.
HIERARCH ESO TEL AG FIBSELEC = 'OBJFIB '     / Fiber currently used (SKY or OBJ)
HIERARCH ESO TEL AIRM END    =         1.035 / Airmass at end
HIERARCH ESO TEL AIRM START  =         1.037 / Airmass at start
HIERARCH ESO TEL AMBI FWHM END=        -1.00 / Observatory Seeing queried from AS
HIERARCH ESO TEL AMBI FWHM START=      -1.00 / Observatory Seeing queried from AS
HIERARCH ESO TEL AMBI PRES END=       773.20 / Observatory ambient air pressure q
HIERARCH ESO TEL AMBI PRES START=     773.20 / Observatory ambient air pressure q
HIERARCH ESO TEL AMBI RHUM   =           23. / Observatory ambient relative humi
HIERARCH ESO TEL AMBI TEMP   =         12.85 / Observatory ambient temperature qu
HIERARCH ESO TEL AMBI WINDDIR=          278. / Observatory ambient wind directio
HIERARCH ESO TEL AMBI WINDSP =          3.30 / Observatory ambient wind speed que
HIERARCH ESO TEL CHOP ST     =             F / True when chopping is active
HIERARCH ESO TEL DATE        = '2000-10-15T15:21:35.745' / TCS installation date
HIERARCH ESO TEL DID         = 'ESO-2P2-DIC.TCS-1.8' / Data dictionary for TEL
HIERARCH ESO TEL DOME STATUS = 'FULLY-OPEN' / Dome status
HIERARCH ESO TEL FOCU ID     = 'CA      '    / Telescope focus station ID
HIERARCH ESO TEL FOCU LEN    =         8.009 / Focal length (m)
HIERARCH ESO TEL FOCU SCALE  =        11.650 / Focal scale (arcsec/mm)
HIERARCH ESO TEL FOCU VALUE  =     22664.000 / M2 setting (mm)
HIERARCH ESO TEL GEOELEV     =         2335. / Elevation above sea level (m)
HIERARCH ESO TEL GEOLAT      =      -29.2543 / Tel geo latitute (+=North) (deg)
HIERARCH ESO TEL GEOLON      =      -70.7346 / Tel geo longitute (+=East) (deg)
HIERARCH ESO TEL ID          = 'v 3.38 '     / TCS version number
HIERARCH ESO TEL MOON DEC    =       3.07020 / 03:04:12.7 DEC (J2000) (deg)
HIERARCH ESO TEL MOON RA     =     11.757354 / 00:47:01.7 RA (J2000) (deg)
HIERARCH ESO TEL OPER        = 'F.Labrana' / Telescope Operator
HIERARCH ESO TEL TRAK RATEA  =     15.000000 / Tracking rate in RA (arcsec/sec)
HIERARCH ESO TEL TRAK RATED  =      0.000000 / Tracking rate in DEC (arcsec/sec)
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HIERARCH ESO TEL TRAK STATUS = 'NORMAL  '   / Tracking status
HIERARCH ESO TPL DID         = 'ESO-VLT-DIC.TPL' / Data dictionary for TPL
HIERARCH ESO TPL EXPNO       =               1 / Exposure number within template
HIERARCH ESO TPL ID          = 'FEROS_ech_obs_objsky' / Template signature ID
HIERARCH ESO TPL NAME        = 'FEROS obs. object-sky' / Template name
HIERARCH ESO TPL NEXP        =               2 / Number of exposures within templat
HIERARCH ESO TPL PRESEQ      = 'FEROS_ech_obs_objsky.seq' / Sequencer script
HIERARCH ESO TPL START       = '2004-07-08T21:23:01' / TPL start time
HIERARCH ESO TPL VERSION     = '1.0     '   / Version of the template
ORIGFILE= 'FEROS_ech_obs_objsky_0001.fits' / Original File Name
ARCFILE = 'FEROS.2004-07-08T21:23:29.396.fits' / Archive File Name
CHECKSUM= '9aoDJUoA9ZoAGZoA'   / ASCII 1's complement checksum


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The corresponding FEROS MIDAS descriptors

When converting FITS files to MIDAS bdf, some of the standard FITS keywords are converted into standard MIDAS descriptors. The following table lists the most important conversions:

```
  FITS     MIDAS
 OBJECT  IDENT
 RA      O_POS(1)
 DE      O_POS(2)
 DATE-OBSO_TIME(1)
 TM-STARTO_TIME(5)
 EXPTIME O_TIME(7)
```

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Appendix F

Acknowledgements

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