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Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral

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LA SILLA OBSERVATORY

FEROS-II:
User Requirements

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Contents

1 Introduction **1**
1.1 Purpose . . . 1
1.2 Scope . . . 1
1.3 Applicable Documents . . . 1
1.4 Abbreviations and Acronyms . . . 2
1.5 Release Notes . . . 2

2 Rationale **3**
2.1 Scientific Rationale . . . 3
2.1.1 Detector-Controller and Detector Controller System upgrade . . . 3
2.1.2 Science Fibres, Fibrehead And Fibrehead/TCCD Lens upgrade . . . 3
2.1.3 Atmospheric Dispersion Corrector . . . 4
2.1.4 Calibration Unit upgrade . . . 4
2.1.5 Environment Monitoring upgrade . . . 4
2.1.6 Stabilized LED upgrade . . . 5
2.1.7 Improved Functionalities . . . 5
2.2 Operational Rationale . . . 5
2.2.1 Detector Controller and Detector Control System upgrade . . . 5
2.2.2 Stabilized LED upgrade . . . 5

3 Detailed User Requirements **6**
3.1 Delivery . . . 6
3.2 Detector Controller upgrade . . . 7
3.2.1 Observing Modes . . . 8
3.2.2 Readout Modes . . . 8
3.3 Detector Control System upgrade . . . 8
3.4 Science Fibres, Fibrehead and Fibrehead/TCCD Lens upgrade . . . 8
3.5 Atmospheric Dispersion Corrector . . . 9
3.6 Calibration Unit upgrade . . . 9
3.7 Environment Monitoring upgrade . . . 10
3.8 Stabilized LED upgrade . . . 10
3.9 Improved Functionalities . . . 10

4 One (double-sided) Page Summary of User Requirements **11**

A ADC Positional Update Period **13**
A.1 The Model . . . 13
A.1.1 Standard conditions . . . 13
A.1.2 Refraction index in standard conditions . . . 14
A.1.3 Refraction index in other conditions . . . 14
A.1.4 Refraction index in presence of water vapor . . . 14
A.2 Results . . . 15

1 Introduction

FEROS-II is a substantial project to be executed during 2003. It will consist of several sub-projects:

- Detector Controller upgrade
- Detector Control System upgrade to VLT standards
- Science Fibres, Fibrehead And Fibrehead/TCCD Lens upgrade
- Atmospheric Dispersion Corrector
- Calibration Unit upgrade
- Environment Monitoring upgrade
- Improved functionalities: Guiding on TCCD, Blind offset target acquisition, Acquisition and archival of TCCD images, pre-warming of calibration lamps, remote sensing of level of liquid nitrogen remaining in resevoir.
- Stabilized LED Upgrade

In the following sections, the scientific (and in some cases operational) rationale for each of these components is presented, follow by the detailed user requirements for each of them.

1.1 Purpose

This document (LSO-URS-ESO-22400-0002) provides the User Requirements of the client for the FEROS-II project, Science Operations.

1.2 Scope

This document is intended as input to the design phase to be implemented by La Silla Engineering Department.

1.3 Applicable Documents

The following documents, of the exact issue shown, form a part of this document to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this document, the contents of this document shall be considered as a superseding requirement.

- [1] 2p2-SRS-ESO-22400-0001, Pritchard: FEROS-II Software User Requirements
- [2] LSO-URS-ESO-90400-0002, Saviane: Implementation of ADC for FEROS: User requirements
- [3] LSO-TRE-ESO-75441-005, Gilliotte: LED/Optics: FEROS on 2p2 Telescope, New ADC Design Technical Report

1.4 Abbreviations and Acronyms

1.52m	The ESO-1.52 m telescope at the LSO
2.20m	The MPG/ESO-2.20 m telescope at the LSO
ADU	Analog to Digital conversion Unit
AG	Autoguider
BIAS	Brorfelde Image Acquisition System
CCD	Charge-Coupled Device
DCS	Detector Control System
DICB	Data Interface Control Board
DRS	Data Reduction Software
ESO	European Southern Observatory
eu	encoder units
FEROS	Fibrefed, Extended Range Optical Spectrograph
FFHV	FEROS Fibrehead Viewer
FITS	Flexible Image Transport System
FRD	Focal Ratio Degradation
GUI	Graphical User Interface
ICS	Instrument Control System
LED	Light Emitting Diode
LSO	La Silla Observatory
MPG	Max-Planck-Gesellschaft
PSF	Point Spread Function
SWC	Software and Communications team at LSO
S/N	Signal to Noise
TBD	To Be Done/Discussed/Decided
TCS	Telescope Control Software
TIO	Telescope & Instrument Operator
VLT	Very Large Telescope
ZD	Zenith Distance

1.5 Release Notes

This is version-1.0, the finalized release version.

Version 0.4 was a 'final-final-draft' release...

Version 0.3 was a 'fianl-draft' released for comments which presented for the first time the 'One page summary'.

Version 0.2 was an internal, unreleased version.

Version 0.1 was the first draft release, released specifically for the June 5th FEROS-II project meeting.

Please mail comments to `jpritcha@eso.org`.

2 Rationale

All of the upgrades to be described in section 3 can primarily be justified scientifically. In addition, the FIERA upgrade and the LED upgrade can be justified from operational and support perspectives.

2.1 Scientific Rationale

Scientific justifications are not always easy to quantify. It would be clear if we could say '*this change will result in 10 additional published articles per year*'. But this is seldom the case. Moreover some of the proposed improvements will benefit some observers a great deal and others not at all (e.g. improved short wavelength performance).

2.1.1 Detector-Controller and Detector Controller System upgrade

Upgrading the Detector to FIERA controller, and the associated upgrade of the software to VLT standard will have a significant impact on science.

Firstly integrating FEROS into the VLT data-flow system will mean access to FEROS data by the wider community, not just the observer and his/her collaborators as is currently generally the case.

We can expect a significant decrease in readout time which will perhaps result in a decrease in total overhead. Currently the CCD readout time is approximately 2min30sec. With a FIERA controller we can expect the readout time to decrease to about 40sec. In practical terms this saving however will be, at least, partially offset by the non-parallel nature of the default VLT philosophy. With the current system we can preset to the next target whilst the readout of the previous exposure is in progress. Depending on the distance between the current target and the next, we can often be guiding with the next target accurately aligned on the fibre before the current readout completes. Under VLT philosophy, the current OB must be completed before the next one can be started.

Overheads should therefore be minimised by designing the FEROS OS with parallel operation in mind, i.e. the OS accepts commands from two BOBs, so that the preset for the next OB is sent from one BOB while the other BOB is still running the current OB waiting for the CCD to read out. Of course the OS must then be built in a way to accept setup commands to the TCS while completing the readout WAIT command. Safetys will also need to be integrated into the template sequencer code to handle the different observing states and, for example, ensure the next observation does not attempt to start while the current one is being readout. Such a high level of parallelism is implemented for FLAMES so could be used as a model.

Finally, and perhaps most importantly (in terms of science), the required associated upgrade of the whole system to VLT standards will permit FEROS to be operated in Service Mode. Given the popularity of Service Mode in general, and the number of programmes which center on periodic phenomena (for which Service Mode is particularly well suited) we can expect this to be very popular with the FEROS community.

2.1.2 Science Fibres, Fibrehead And Fibrehead/TCCD Lens upgrade

Currently, the maximum peak efficiency measured at the 2.20m is 13%. From the 1.52m we would expect that 18% is acheivable. We believe that the current discrepancy results from two principle sources:

1. Wrong input f-ratio to science fibres due to poorly matched micro-lens.

2. Non-minimal Focal Ratio Degradation due to unnecessary bending and possibly twisting of fibres.

An overall increase in efficiency by absolute 5% represents a relative increase by 5/13 equals 38%. This should be reflected at all times, not just at times of optimal performance (seeing & transparency of atmosphere). Obviously we can not promise that a 38% increase in efficiency and hence throughput, will result in a 38% increase in the number or quality of scientific published results, but clearly this will represent a substantial improvement to performance and all observing programmes will benefit.

The current lens between the the Fibrehead and the TCCD is an 'off the shelf' item and of poor optical quality. This will adversely affect the quality of guiding, and hence throughput, once guiding with the TCCD is implemented.

2.1.3 Atmospheric Dispersion Corrector

An ADC for FEROS will not only restore the performance as at the ESO-1.52m, but will actually provide a significant step toward realising the full potential of FEROS. The ADC will provide greater throughput during observations at ZDs greater than ~ 30 degrees over the full spectral range of the instrument which afterall is on of the defining qualities of FEROS.

With no ADC but assuming the fibre head upgrade (i.e. a 2 arcsec aperture), theory predicts that for 1 arcsec seeing and assuming the image is centered at 400nm, the S/N degradation due to differential refraction at $ZD = 60$ degrees is ca. 95% at ~ 350 nm and 50% at ~ 900 nm, i.e. a star which produces a S/N of 100 at 350 nm at the Zenith will produce a S/N of only 5 at 350 nm and $ZD = 60$ degrees in the same exposure time, all other things being equal. Assuming that the noise is equal to the square-root of the signal, then the signal degradations would be 99.75% and 75% respectively. With the ADC the corresponding S/N degradation due to differential refraction will be less than 5% (i.e. signal degradation of less than 10%) over the entire spectral range, i.e. with the ADC we will have the same performance (w.r.t. differential refraction) down to $ZD = 60$ degrees as we get with no ADC at $ZD \sim 10$ degrees at ~ 350 nm and at $ZD \sim 20$ degrees. Even adding a very conservative additional 10% loss due to the extra optical components (i.e. total signal degradation of 20%) with the ADC we get the same performance down to $ZD = 60$ degrees as we get with no ADC at $ZD \sim 30$ degrees.

2.1.4 Calibration Unit upgrade

Correct calibration of the science data is without question a necessity. Currently calibration of the spectra at the shortest wavelengths (350 – 400 nm) is less than optimal due to the low flux level from the flat-field lamps in this range, hence the need for a bluer lamp (e.g. deuterium lamps as used in UVES).

The overall low flux levels in both flat-field and wavelength calibration lamps means that taking calibrations during the night, an important element in an accurate and confident calibration, is not practical since exposure times are ~ 1 min for flat-fields and ~ 2 min for wavelength calibrations.

Sufficient flux across the entire spectral range of FEROS for both flat-fields and wavelength calibrations should be obtainable in less than 10 sec.

2.1.5 Environment Monitoring upgrade

Since the environment of the instrument is not strictly controlled (as for example for HARPS) accurate temperature, pressure and humidity measurements must be available (and included in header information) so that the effect of these variables can be corrected for. Again this is not an improve-

ment that will necessarily benefit all FEROS observing programmes, but certainly those aiming to do precision radial velocity work will benefit from it.

The current environmental monitoring system is non-VLT compliant (hardware and software) and too limited at just 2 temperatures and one humidity. The new system will require 6 sensors for each of the three quantities.

2.1.6 Stabilized LED upgrade

The existing Betalight system used for CCD tests will be replaced by a remote, computer controlled Stabilized LED system. This upgrade will greatly reduce the need to enter the FEROS Climate Controlled Room, which will result in improved stability of that environment, and therefore improved stability of the instrument and therefore the data produced.

It will also allow to conduct CCD tests during FEROS observing runs, instead of, as currently, only during the time when the instrument is NOT in use (to avoid undue disturbance to the climate in the FEROS Climate Controlled Room).

2.1.7 Improved Functionalities

The described improved functionalities will all provide improvements in either throughput, or productivity:

- Telescope guiding on the Fibrehead Viewing TCCD (including guiding on the fibre and guiding on a field star modes): Improved throughput through improved guiding since differential refraction effects will be minimized (especially in the case of guiding on the fibre).
- Blind offset acquisition: Ability to observe faint targets.
- Acquisition and archival of Fibrehead Viewer images: Certainty for observer (especially in Service Mode) the correct target has been observed.
- Pre-warm calibration lamps during science exposures: improved productivity through minimization of overhead.
- Remote sensing of level of liquid nitrogen remaining in resevoir: less likely to reach critically low levels.

2.2 Operational Rationale

2.2.1 Detector Controller and Detector Control System upgrade

A fully VLT compliant FEROS will then be far more maintainable for La Silla support teams (SWC and LED).

2.2.2 Stabilized LED upgrade

A remote, computer controlled Stabilized LED system will reduce risk of accident. Due no doubt to the tight confines of the available space in which to work, during the first 8 months of operation at the 2.20m the light-and-dust cover panel which provides access to the (currently installed) betalight system has already been dropped on several occasions resulting in damage to the cover (bent corners) which often then makes it impossible to re-install the cover, compromising instrument performance since stray light from the CCD controller can then enter the instrument.

3 Detailed User Requirements

3.1 Delivery

In principle, all sub-projects should be delivered in early October, in time to be commissioned during the two requested commissioning periods which we expect will be scheduled in October and November (exact dates yet to be scheduled). However it is recognised that La Silla Engineering Department has limited resources and FEROS-II is not the only critical project for La Silla Engineering Department for 2003. Therefore we acknowledge the possibility that it might not be possible to deliver some of the sub-projects in time for the start of Commissioning-VI[1] (i.e. early October). In this case later delivery dates will need to be negotiated.

For the sub-projects which must be commissioned *online* (i.e. with actual stars in 'real' observing conditions) the sub-projects must be delivered in time to be commissioned during early Period-72 (i.e. early October and November, but see below for clarification).

Sub-projects which can be commissioned *offline* can be delivered at a later date if resources necessitate, though obviously it is preferable that all sub-projects be delivered in a timely fashion.

In the following sections, the mode of commissioning for each sub-project will be specified.

For information the following request for technical time specifically for this project was made:

> Technical Time request for ESO Period-72 for FEROS:
>
> - 6 TECHNICAL nights - Commissioning-VI: VLT upgrade, ADC and FibreHead Upgrade Technical Commissioning. ***October 2003***
> - 6 TECHNICAL nights - Commissioning-VII: VLT upgrade, ADC and FibreHead Upgrade Science Commissioning. ***November 2003***
>
> **Notes:** FEROS will NOT be available to the community from 7 days (see below) before Commissioning-VI until the completion of Commissioning-VII. Also bear in mind that MPI time at the 2.20m is 1-31/12, Hence Commissioning MUST be complete by December 1st.
>
> A minimum of 7 days of WFI time (preferably in Service Mode) are required prior to Commissioning-VI during which new hardware (ADC + FibreHead) will be installed in the FEROS/WFI adapter and new fibres will be installed between FibreHead and Instrument.
>
> Preferably the Commissionings should begin on Wednesdays and be separated by precisely 4 weeks to best match the tournos of technical staff involved.
>
> Given these constraints there seems to be two obvious choices:
>
> 1. FEROS available beginning of October but unavailable from mid October till end of Novemeber: 22/10-28/10 and 19/11-25/11 [noon-noon] In this case the last night of any FEROS observing period in October must be no later than 14/10. These periods unfortunately coincide with New Moon.
> 2. FEROS unavailable from 1/10 – 11/11 but available from 11/11: 8/10-14/10 and 5/11-11/11 [noon-noon]: In this case NO time in October would be available to FEROS, but from November 11 onward would be. This option minimises the impact on DARK time and is therefore probably preferable.

[1] Commissionings-I & II were carried out when FEROS was originally installed at the ESO-1.52m, Commissionings-III, IV & V were carried out in Oct 2002, Nov 2002 and Mar 2003 respectively for the initial move of FEROS to the MPG/ESO-2.20m.

Table 1: Present CCD characteristics. These statistics are based on CCDTests made between 2003-03-11 and 2003-06-16. For each mode between 24 and 26 sets of tests have been performed during this time. A minus superscript after the uncertainty indicates 'less than'.

Amp/Gain Mode	**BIAS** $[ADU]$	**GAIN** $[e^-/ADU]$	**RON** $[ADU]$	**Shut' Err'** $[sec]$	**Lin' Err'** [%]
BLOW	376.6 ± 2.0	2.839 ± 0.053	2.058 ± 0.018	0.013 ± 0.008	$1.003 \pm 0.001/0.996 \pm 0.002$
BABLOW	376.7 ± 1.9	2.716 ± 0.014	2.066 ± 0.015	0.003 ± 0.013	$1.025 \pm 0.002/0.951 \pm 0.001$
AABLOW	382.7 ± 1.7	2.824 ± 0.014	2.673 ± 0.331	0.002 ± 0.014	$1.009 \pm 0.002/0.985 \pm 0.001^-$
ALOW	382.6 ± 1.6	2.820 ± 0.013	2.684 ± 0.337	0.005 ± 0.012	$1.002 \pm 0.001/0.998 \pm 0.001^-$
BHIGH	412.8 ± 1.7	0.557 ± 0.004	7.897 ± 0.071	0.003 ± 0.015	$1.002 \pm 0.001^-/0.998 \pm 0.001$
BABHIGH	413.1 ± 1.7	0.563 ± 0.003	7.886 ± 0.057	0.010 ± 0.007	$1.003 \pm 0.001/0.996 \pm 0.001$
AABHIGH	420.8 ± 2.1	0.550 ± 0.025	11.07 ± 1.74	0.009 ± 0.007	$1.002 \pm 0.003/0.998 \pm 0.004$
AHIGH	420.9 ± 1.4	0.549 ± 0.022	10.99 ± 1.75	0.008 ± 0.012	$1.001 \pm 0.001/0.998 \pm 0.001$

Of course it remains to be seen what will be scheduled...

In any case, it is now clear that FEROS will probably be unavailable to the community from the day after the last night of FEROS scheduled observations in Period-71 (i.e. September 8th) until the end of Commissioning-VII. This is because according to current planning the current fibrehead+fibre system will be extracted and taken to Garching for laboratory characterisation as early as possible to allow the maximum time for this characterisation plus the installation of the new fibrehead+fibre system. This will also permit work on the Detector Controller System to start on September 8th and thus allow a reasonable amount of time for this procedure.

3.2 Detector Controller upgrade

The Detector will be upgraded to a FIERA system. Of the existing system probably only the CCD and cryostat will be reusable.

The total, average overhead per exposure will be reduced or at least maintained at its current level. CCD readout time is a critical component of this. Currently, the telescope can be preset to the next target during the readout of the last exposure of the current target. Since the VLT philosophy of completing one OB before starting the next means the telescope will not be able to preset to the next target until the last CCD readout of the OB has completed, the CCD readout time must be significantly reduced in comparison to the present readout time of 2min30sec±2sec.

All other properties of the CCD performance (bias level, ReadOut Noise (RON), shutter error and linearity) must likewise be maintained at their current levels or improved upon. Current properties of the CCD in the various readout modes are given in table 1.

The DCS must provide 4 Detector Monitoring (DetMon) sensors (3 temperature, $T_{\mathrm{CCD,Actual}}$, $T_{\mathrm{CCD,Reference}}$, $T_{\mathrm{N_2}}$ and 1 pressure P_{Dewar}). They will have the following properties:

- The temperature sensors will be accurate to ±0.1 degree Celsius over a range of −200–+40 degrees Celcius (i.e. operating temperature to room temperature).
- The pressure sensor will be accurate to 0.1 hPa over a range of 10^{-7}–10^{+3} hPa (i.e. operating pressure – atmospheric).

The standard warning systems (i.e. beepers) will be implemented to alarm when CCD temperature or cryostat pressure are out of normal operating ranges.

The physical format of the CCD is 2048×4096. Fifty overscan pixels (for bias level estimation) on each side of the CCD image will be included in the full-chip format (i.e. 2148×4096).

This sub-project must be commissioned *online* and therefore must be delivered before the start of Commissioning-VI.

3.2.1 Observing Modes

1. BIAS image
2. DARK image
3. Wavelength Calibration image
4. Smooth Field (aka flat-field) image
5. Object-Sky mode Science image
6. Object-Calibration mode Science image

Each of the above observing modes will produce one or serveral *Science*[2] image(s).

3.2.2 Readout Modes

1. 'Best' detector-performance readout mode
2. 'Fast' detector-performance readout mode
3. Single window of any size from 1×1 to the full chip 2148×4096.

3.3 Detector Control System upgrade

The upgrade of the Detector Controller will necessitate implementing a new DCS. The User requirements for the DCS upgrade are presented in the separate document [1].

This sub-project must be commissioned *online* and therefore must be delivered before the start of Commissioning-VI.

3.4 Science Fibres, Fibrehead and Fibrehead/TCCD Lens upgrade

New Science Fibres will be installed. The new fibres will be longer to allow a smoother path for the fibres in order to minimize Focal Ratio Degradation (FRD) due to stress on fibres from bending. At the time of installation great care will be taken to ensure that the fibres are NOT twisted, a potential (but unknown) source of FRD in the current system. The fibres may have become twisted during the move of FEROS from the ESO-1.52m to the MPG/ESO-2.20m.

A new fibrehead featuring a new optical design based on rod micro-lenses (rather than the current ball lenses) will be implemented. The change in micro-lens should result in a change in fibre aperture size from the current 1.6 arcsec to 1.8 arcsec[3]. Apart from these changes the head will be of the same design as the current one.

[2] Here a *Science* image means an image generated by the Science CCD (and thus includes science, calibration and test images) as distinct from a *Technical* image generated by the Technical CCD.

[3] Andreas Kaufer recommends to base the design on the assumption of a 90 μm fibre diameter, thus allowing for $\pm 5\,\mu$m of decentering error when mounting the rod lens on the fibre. In this case the aperature should be 0.090 mm×8/4.6 × 11.7 arcsec/mm= 1.8 arcsec.

The primary user requirement of this upgrade is that it restores optimal optical system performance as measured by observations of spectrophotometric standard stars, and in particular the measured peak efficiency as derived by the `efficiency.prg` MIDAS script of the FEROS DRS. To date, the maximum measured peak efficiency is 13%. This goal will be accepted without question when a measurement of 18% or better has been achieved. It is worth reminding at this stage that this is the maximum to be expected. It will be achieved on nights of excellent photometric quality (V extinction of less than 0.150 mag/airmass and RMS scatter of less than 0.005), high transparency (less than 0.05 mag/airmass) and excellent image quality (i.e. sub-arcsec seeing).

A secondary requirement is that both the current and the new complete fibre + fibrehead systems should be fully characterised in the lab, prior to installation of the new system.

The lens system between Fibrehead and TCCD must be upgraded to image quality optical components. Image quality across the TCCD should be uniformly optimal.

This sub-project must be commissioned *online* and therefore must be delivered before the start of Commissioning-VI.

3.5 Atmospheric Dispersion Corrector

The User Requirements for the Atmospheric Dispersion Corrector are presented in the separate document [2].

This sub-project must be commissioned *online* and therefore must be delivered before the start of Commissioning-VI.

3.6 Calibration Unit upgrade

Currently the FEROS Calibration Unit (FCU) suffers from two significant problems:

1. Low overall flux levels
2. Poor flux levels at short wavelengths (less than ~ 400 nm), especially in the flat-field.

The first problem results directly from the changes required by the move from 1.52m to 2.20m. The change is in delivery of the calibration light to the fibre head. In comparison to the 1.52m there are two lenses and 15 m of fibre optic cable in addition to the situation at the 1.52m.

The second problem is inherent to the current Calibration unit and was present even at the 1.52m, although now it is perhaps very slightly worse, probably again due to the extra optical components described above.

The FEROS calibration unit must be able to deliver both flat-field and emission arc light with sufficient flux over the full FEROS spectral range to 'properly calibrate over the full spectral range' with exposure times in the range 1 – 10 sec. More specifically:

- The flat-field lamp(s) must produce a S/N of 50 or more over the range 350 – 363 nm (i.e. the bluest order) in an exposure time in the range 1 – 10 sec.
- The emission arc lamp(s) must produce emission lines with S/N of 100 or more over the range 350 – 363 nm (i.e. the bluest order) in an exposure time in the range 1 – 10 sec.

It must be possible to ensure that the relative flux levels in the two calibration fibres can be balanced.

This sub-project can be commissioned *offline* and therefore can, if absolutely necessary, be delivered sometime after Commissioning-VI.

3.7 Environment Monitoring upgrade

The current, non-VLT compatible system will be replaced by new, VLT-compatible hardware which will provide 6 sets of temperature, humidity and atmospheric pressure sensors (i.e. 18 sensors in total).

The 18 environmental monitoring (EnvMon) sensors (6xT+H+P) will have the following properties:

- The temperature sensors will be accurate to ± 0.1 degree Celsius over a range of $0 - 40$ degree Celsius.
- The humidity sensors will be accurate to 0.1,% humidity over a range of $0 - 100\%$.
- The pressure sensors will be accurate to 1 hPa over a range of $760 - 780$ hPa.

The temperature and humidity sensors are critical, the atmospheric pressure sensors are desirable if cost-effective.

This sub-project can be commissioned *offline* and therefore can, if absolutely necessary, be delivered sometime after Commissioning-VI.

3.8 Stabilized LED upgrade

The currently installed Betalight system will be replaced by a remotely computer controlled Stabilized LED system (similar to that used by HARPS). New LCU functions will be required.

The LEDs will directly illuminate the FEROS camera (as the current Betalight system does), they will in no way interfere with the normal operation of FEROS and the system will provide sufficient flux to reach full-well potential of the CCD in all operating modes within 120 sec.

Ideally the system will consist of three sets of LEDs of three different colours; red, green and blue.

During Commissioning both the Stabilized LED system and the Betalight system must be available for direct comparison of results.

This sub-project can be commissioned *offline* and therefore can, if absolutely necessary, be delivered sometime after Commissioning-VI.

3.9 Improved Functionalities

The following mostly software enhancements to the present system are required:

- Telescope guiding on the Fibrehead Viewing TCCD (including guiding on the fibre and guiding on a field star modes)
- Blind offset acquisition
- Acquisition and archival of Fibrehead Viewer images
- Pre-warm calibration lamps during science exposures
- Remote sensing of level of liquid nitrogen remaining in resevoir, as implemented for HARPS. The same model of sensor should be used in order to ease implementation.

This sub-project must be commissioned *online* and therefore must be delivered before the start of Commissioning-VI.

4 One (double-sided) Page Summary of User Requirements

1. **Detector Controller upgrade**: *online* Commissioning
   - BIAS system upgraded to FIERA – **Critical**.
   - CCD readout time minimised – expectation ~ 40 sec – **Critical**.
   - Two readout modes: *Best* and *Fast* – **Critical**.
   - CCD RON in *Best* readout mode maintained at current level ($< 2.5 \pm 0.05$ ADU) or improved upon. Likewise for other properties – **Critical**.
   - Control of CCD shutter – **Critical**.
   - Telemetry and warnings: $T_{\rm CCD,Actual}$, $T_{\rm CCD,Reference}$, $T_{\rm N_2}$, $P_{\rm Dewar}$ – **Critical**.
   - Full chip format: 2148×4096 which includes 50 overscan pixels on each side of image – **Critical**.
2. **Detector Control System upgrade**: *online* Commissioning
   - Fully implemented, VLT-compliant DCS, ICS and OS – **Critical**.
   - High degree of parallelism, e.g. preset while reading out – **Desirable**.
3. **Science Fibres and Fibrehead upgrade**: *online* Commissioning
   - Maximise efficiency – acceptance criterion: 18% on sky – **Critical**.
   - 1.8 arcsec apertures – **Critical**.
   - Complete laboratory characterisation of present and new systems – **Desirable**.
4. **Fibrehead/TCCD Lens upgrade**: *online* Commissioning
   - Improve image quality in TCCD – expect circular images within 10% across full field of view of TCCD – **Desirable**.
5. **Atmospheric Dispersion Corrector**: *online* Commissioning
   - Maximum image decentering of 0.2 arcsec in the forseen configuration (1.96 arcsec fiber aperture diameter), for a wavelength range 350–920 nm, over ZD range 0–60 degrees – **Critical**.
   - Maximum light loss in the ADC of 10% across full spectral range (350–920 nm) – **Critical**.
   - Tolerance in parallactic angle positioning is: 1 deg (desirable), 5 deg (max acceptable) – **Critical**.
   - No vignetting of the WFI beam when parked – **Critical**.
   - Tracking of the ADC must be continuous, Maximum tracking speed required is 2.5 deg/min. Presetting speed required is 90 deg/min – **Critical**.
   - Overhead: 2 minutes absolute maximum – **Critical**.
   - Software controlled with three modes: OUT, preset to mean paralactic angle of exposure and continuous tracking of paralactic angle – **Critical**.
   - Compatible with the "object-calibration" mode – **Desirable**.
6. **Calibration Unit upgrade**: *offline* Commissioning
   - Improve flat-field flux in bluest orders – acceptance criterion: S/N of 50 or more over the range 350 – 363 nm (i.e. the bluest order) in an exposure time in the range 1 – 10 sec – **Critical**.

- Improve Wavelength Calibration flux in bluest orders – acceptance criterion: emission lines with S/N of 100 or more over the range 350 – 363 nm (i.e. the bluest order) in an exposure time in the range 1 – 10 sec – **Critical**.

7. **Environment Monitoring upgrade**: *offline* Commissioning
   - Six temperature sensors accurate to ± 0.1 degree Celsius over a range of 0 – 40 degree Celsius – **Critical**.
   - Six humidity sensors accurate to 0.1,% humidity over a range of 0 – 100% – **Critical**.
   - Six pressure sensors will be accurate to 1 hPa over a range of 760 – 780 hPa – **Desirable**.
8. **Stabilized LED upgrade**: *offline* Commissioning
   - Remote, computer controlled – **Critical**.
   - Direct illuminatation of CCD Camera – **Critical**.
   - Sufficient flux to reach full-well potential of the CCD in all operating modes within 120 sec – **Critical**.
   - Three sets of LEDs of three different colours; red, green and blue – **Desirable**.
9. **Improved Functionalities**: *online* Commissioning
   - Telescope guiding on the Fibrehead Viewing TCCD (including guiding on the fibre and guiding on a field star modes) – **Critical**.
   - Blind offset acquisition – **Desirable**.
   - Acquisition and archival of Fibrehead Viewer images – **Desirable**.
   - Pre-warm calibration lamps during science exposures – **Desirable**.
   - Remote sensing of level of liquid nitrogen remaining in resevoir – **Desirable**.

online Commissioning implies sub-project *must* be delivered before start of Commissioning-VI (i.e. early October, exact dates yet to be scheduled).

offline Commissioning implies sub-project can, if absolutely necessary, be delivered sometime after Commissioning-VI.

A ADC Positional Update Period

The question of the necessity of 'continuous' updating of the ADC position has rasied some doubts. It turns out that (according to J.Guzman [SWC]) the standard VLT ADC implementation allows only for either 'OFF' or 'AUTO' modes and in the 'AUTO' mode the ADC position is automatically updated with a frequency of about once per ten seconds. So in fact to implement non-continuous positioning, will infact be more, not less work for SWC. In anycase, the following appendix shows that infact there is clear scientific justification for the implemented 'AUTO' mode.

We pose the question 'if we preset the ADC to the correct position, how long is it before the image separation caused by differential refraction exceeds the required specifications (0.2 arcsec)'. In answering this question we show **'continuous' updating of the ADC position is indeed necessary, and that a good choice for the update period is of the order of** 10 **seconds**.

A.1 The Model

We investigate this using the following model. For any given telescope pointing at time $t = t_0$ the effect of differential refraction is known, and is specified by a image separation between the image at the reference-wavelength (in practice the wavelength at which we are guiding) and the image at any other arbitrary wavelength is given by a magnitude (d) in the direction of the paralactic angle (p). At this time the prisms of the ADC are preset to the appropriate angles and this differential refraction is corrected for, i.e. the ADC introduces a reverse separation of magnitude d in direction p. As time passes, the image separation and paralactic angle evolve, and in general at time $t = t'$ the image separation and paralactic angle are given by d' and p'. Because in general $d \neq d'$ and $p \neq p'$ there will be spearation (r) of the images at the reference-wavelength and other wavelengths. The situation is shown graphically in figure 1.

It is easy to show that the separation is given by:

$$r = \sqrt{d^2 + d'^2 - 2dd' \cos[p']} \tag{1}$$

The differential refraction d in arcsec between images at two wavelengths λ and λ_0 is given by (Smart, 1931):

$$d = \delta R = R(\lambda) - R(\lambda_0) = \frac{206264.80625}{10^6} \times [(n(\lambda) - 1) \times 10^6 - (n(\lambda_0) - 1) \times 10^6] \times \tan(Z) \tag{2}$$

where $n(\lambda)$is the refraction index of air at wavelength λ, and Z is the zenith distance. Since $n(\lambda)$is always close to 1, $(n(\lambda) - 1) \times 10^6$ is used instead, in order to make computations easier. The computation of the refraction index is streamlined by first computing the index for dry air in standard conditions, then correcting for a different pressure and temperature, and finally adding the contribution of humidity.

A.1.1 Standard conditions

Standard pressure, temperature and humidity conditions are defined as $P_s = 1013.25 \times 10^2$ Pa, $T_s = 288.15$ K (i.e. 15 C), and dry air. At high altitudes the pressure is smaller, and one can guess the value of pressure as $P = P_s \times e^{-h/h_0}$, where $h_0$is the scale height of the atmosphere (typically $h_0 = 7$ km). However, for La Silla we have actual measurements, just have a look at the "meteomonitor". Thus a typical value can be $P = 775 \times 10^2$ Pa.

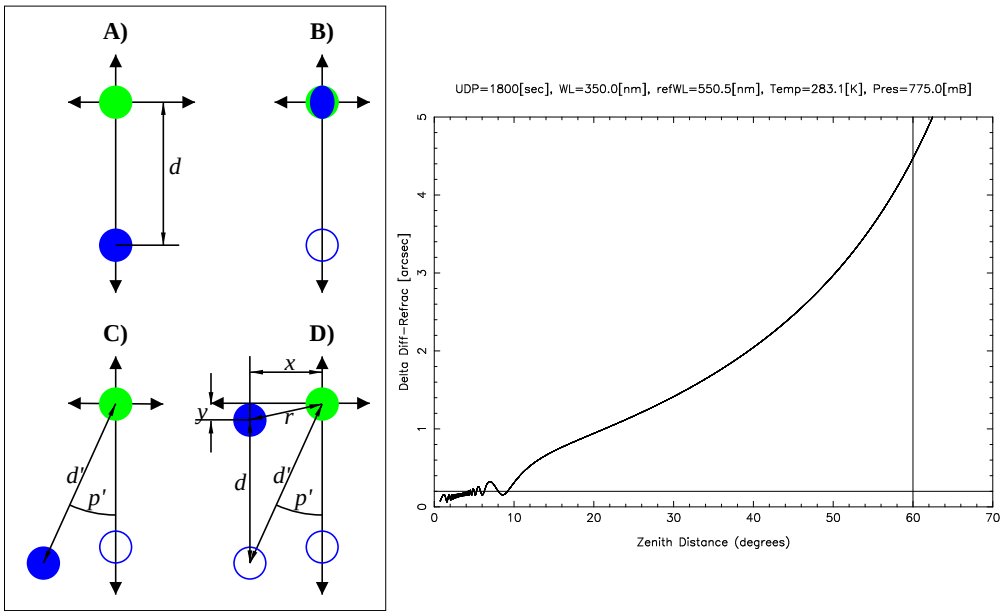


Figure 1: The effect of Differential Refraction. In the left sub-figure, A) and B) show the situation at time $t = t_0$ while C) and D) show the situation at some other time $t = t'$. A) and C) show the without-ADC situation while B) and D) show the with-ADC situation. The green spot represents the reference wavelength and the blue spot some other wavelength. In figure B) the blue spot is non-circular just to show that the green spot is underneath, obviously the ADC should NOT distort the image. The distance r is the image separation at time t' caused by the ADC being set to the correct position only at time t_0. The axes are aligned with the paralactic angle at time t_0. In the right sub-figure, the separation as a function of zenith distance is plotted for update period $t' = 20$ sec at a object declination of -30 degrees for the 2.20m telescope.

A.1.2 Refraction index in standard conditions

We call n_s the refraction index of air, in standard conditions, and compute it as:

$$(n_s - 1) \times 10^6 = 64.328 + \frac{29498.1 \times 10^{-6}}{146 \times 10^{-6} - (1/\lambda)^2} + \frac{255.4 \times 10^{-6}}{41 \times 10^{-6} - (1/\lambda)^2}$$

A.1.3 Refraction index in other conditions

Then for other temperatures and pressures, the refractive index in dry air is given by

$$(n_d - 1) = (n_s - 1) \times \frac{P}{T} \times \frac{T_s}{P_s}$$

A.1.4 Refraction index in presence of water vapor

If there is water vapor in the air, and its pressure is P_w, then the refractive index is smaller, and it is computed as

$$(n - 1) \times 10^6 = (n_d - 1) \times 10^6 - 43.49 \times (1 - 7.956 \times 10^3 \times (1/\lambda)^2) \times \frac{P_w}{P_s}$$

Normally one has readings of relative humidity H, not of water vapor pressure, so the latter is computed as

$$P_w = P_{w,sat} \times \frac{H}{100} \times 10^2$$

where 10^2 is used to convert from millibar to Pa, and $P_{w,sat}$ is the saturation pressure of water vapor,

which in turn is computed (in millibar) as

$P_{\mathrm{w,sat}} = 6.11 \times 10^{(7.5\times t)/(t+237.7)}$

where t is the tempeature in Celsius (so $t = T - 273.15$). A typical vapor pressure is 550 Pa.

A.2 Results

Separations r have been computed for FEROS at the 2.20m for various *ADC Position Update Periods* (3600, 1800, 60 and 20 seconds) as a function of wavelength, Zenith Distance and Declination for a reference wavelength of 550.5 nm (i.e. the central wavelength of Johnson V as will be used for guiding with the FEROS TCCD). The plots are shown figures 2 and 3. Each figure (consisting of four subfigures) shows the results for a given update period. Each subfigure shows the results for a specific wavelength. Each line in each subplot shows how the separation (r) varies as a function of Zenith Distance (Z) for a given declination

Figure 2 shows that after 60 mins, even after just 30 mins, separations quickly exceed the specifications. Clearly the position of the ADC MUST be 'continuously' updated. Since truely continuous updating of the ADC position is not practically possible, the question now is with what frequency must the position be updated.

For an update period of 60 sec (figure 3) the separations at 350 nm are within specification during *at least part of* the Zenith Distance range but only over the declination range approximately -40 to $+00$. With an update period of 20 sec though, even at 350 nm the separations are always (if only just) within specification over the full pointing range of the 2.20-m telescope.

It should be kept in mind that these results apply to a 'perfect ADC', i.e. one that can perfectly correct for the differential refraction over the full spectral range simultanesously (see [3]). In reality, the corrections will in general be imperfect adding an additional error. Therefore with an update period of 10 secs as implemented for HARPS, the ADC will probably perform within specification in most circumstances.

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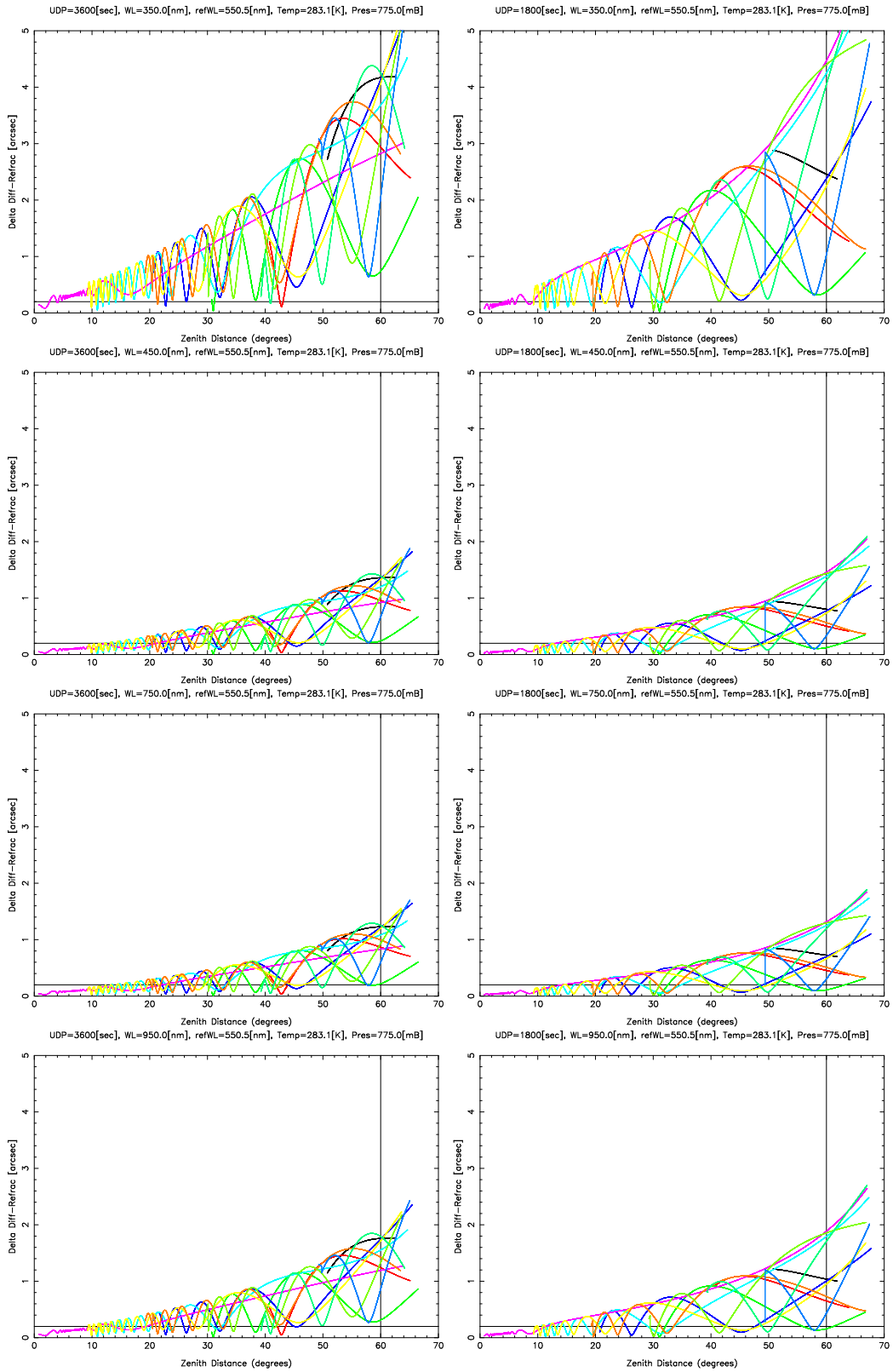


Figure 2: Separations (r) for an ADC Position Update Period of 60 min (left) and 30 min (right) at the two extreme wavelengths of FEROS, 350 nm (top) and, 950 nm (bottom) and two intermediate wavelengths, 450 nm (upper-middle) and 750 nm (lower-middle). Each line shows r as a function of Zenith Distance (Z) for a different declination: -80 (black), -70 (red), -60 (green), -50 (sky-blue), -40 (aqua), -30 (pink), -20 (yellow), -10 (orange), $+00$ (dark-green), $+10$ (light-green) and $+20$ (marine-blue). Lines at $r = 0.2$ and $Z = 60$ indicate the user requirements.

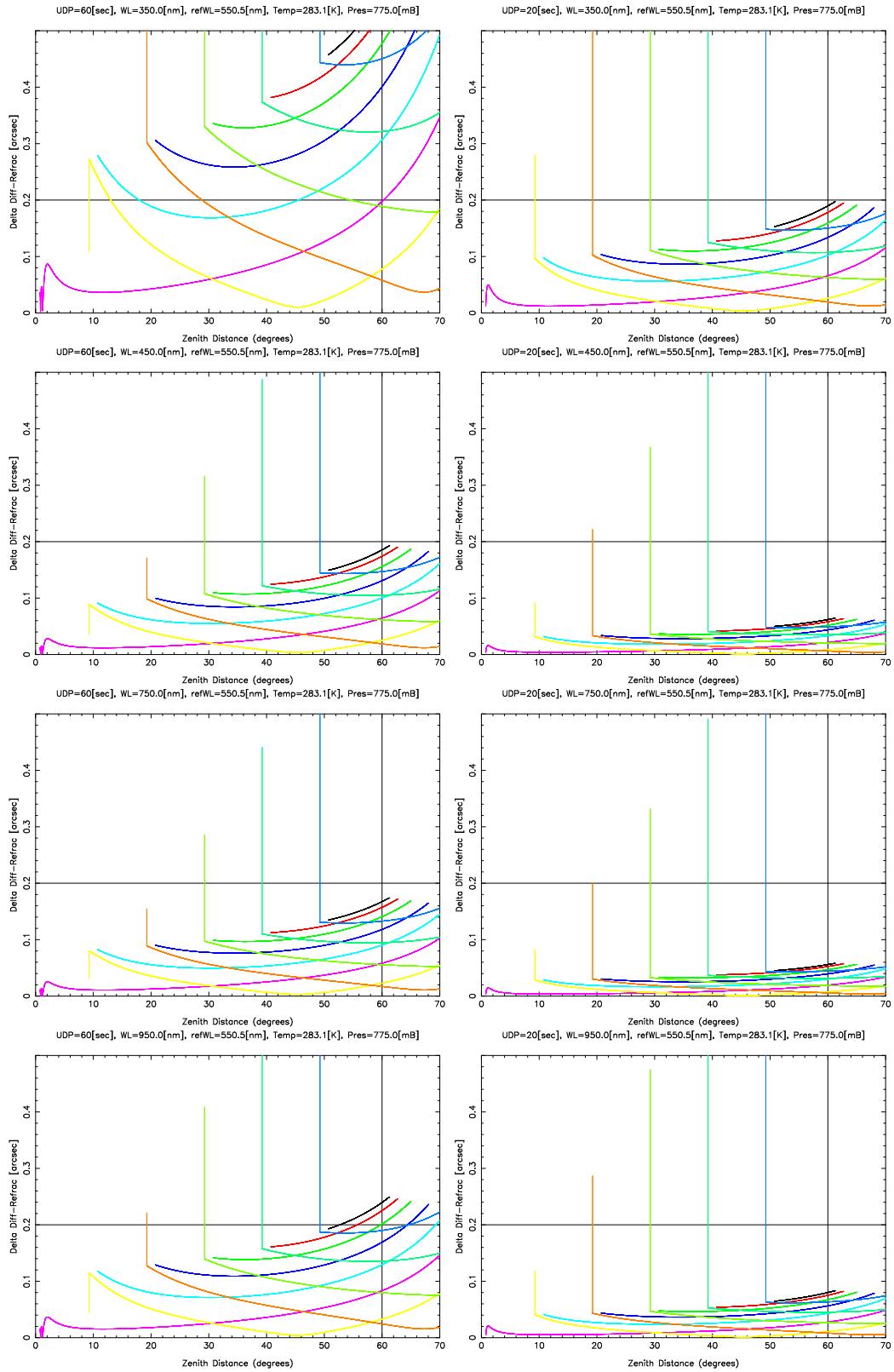


Figure 3: Separations (r) for an ADC Position Update Period of 60 sec (left) and 20 sec (right) at the two extreme wavelengths of FEROS, 350 nm (top) and, 950 nm (bottom) and two intermediate wavelengths, 450 nm (upper-middle) and 750 nm (lower-middle). Each line shows r as a function of Zenith Distance (Z) for a different declination: -80 (black), -70 (red), -60 (green), -50 (sky-blue), -40 (aqua), -30 (pink), -20 (yellow), -10 (orange), $+00$ (dark-green), $+10$ (light-green) and $+20$ (marine-blue). Lines at $r = 0.2$ and $Z = 60$ indicate the user requirements.