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LA SILLA OBSERVATORY

3.6m + CAT Upgrade
WC 51: CES Instrument
Additional Requirement Specifications

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1 INTRODUCTION

1.1 Purpose

The present document contains the requirement specifications (RS) for the refurbishment of the Coudé Echelle Spectrograph (CES) instrument. Due to the advent of the Very Long Camera (VLC) and the Fibre Link to the Cassegrain focus of the 3.6m telescope the performance of several instrument functions requires improvement. The high spectral resolution now reachable demands to overcome work arounds that have been accepted for a long time.

1.2 Reference Documents

The following documents contain additional information and are referenced in the text.

References

[1] 3p6-SPE-ESO-006-001, 26/08/96 — User Requirements for 3.6m Cassegrain adapter and calibration unit

[2] 3p6-SPE-ESO-045-02, 18/09/96 — User Requirements for CES fibre link

[3] 3p6-SPE-ESO-053-02, 18/09/96 — User Requirements for CES image slicer unit

[4] User Requirements for the VLC of the CES, N. Piskunov et al., Feb 18, 1997

[5] 3P6-SPE-ESO-051-002, 27/04/97 — User Requirements for CES Instrument software

1.3 Abbreviations and Acronyms

The following abbreviations and acronyms are used in this document:

3.6m	ESO 3.6m Telescope
CAT	Coude Auxiliary Telescope
CES	Coude Echelle Spectrograph
CFA	Cassegrain Fibre Adapter
ICS	Instrument Control Software
LC	Long Camera
RS	Requirements Specifications
VLC	Very Long Camera

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2 OVERVIEW

2.1 Document overview

The following sections give the requirements for those parts of the spectrograph for which refurbishment is planned. The requirements are subdivided into requirements for individual parts of the instrument (Section 3), general requirements for the instrument (Section 4), and requirements related to the Cassegrain fibre adapter (CFA; Section 5). Whenever neccessary the current status of the instrument is outlined to illustrate the need for improvement. A final section contains suggestions for technical solutions. These suggestions do not need to be adhered to, but were only included to give an overview of solutions that are already being discussed.

Before presenting the specific requirements an overview of the typical (not necessarily complete) scientific usage of the CES is given (Section 2.2). The requirements for the instrument refurbishment detailed in the following sections should make the CES an instrument with which these scientific goals can be achieved.

2.2 Scientific usage of the CES

With the new Very Long Camera (VLC) the CES will remain also in the VLT era ESO's highest resolution spectrograph achieving resolving powers of up to $R = 220,000$ with the highest resolution image slicer and up to $R = 280,000$ with the slit unit. The latter option is feasible only for very bright stars. In comparison, ESO's cross-dispersed Echelle spectrographs work at lower resolving power: UVES at UT2 will provide $R \leq 110,000$, EMMI with Grating #14 at the NTT yields $R = 70,000$ and FEROS at the ESO 1.5m will work at $R = 48,000$.

Typical observing programs for the CES include

1. Studies of stellar line profile variability via line bisectors analysis.
   Line bisector analysis can be used to identify non-radial pulsations and activity related phenomena such as convective inhomogeneities and star spots. As an important application this type of observation can provide ancilliary data on the host stars of planetary candidates found in high-precision radial velocity surveys. Such ancilliary data are required in order to identify instrinsic stellar variability as the cause of the apparent radial velocity variations.
   For most objects this type of study becomes feasible only at very high resolving power ($R > 200,000$) and spectral sampling denser than the 2-pixel sampling limit (≈ 2.7 pixel or better). It is aided by a clean instrumental profile and low levels of stray light, both well known virtues of the CES (see e.g. Dravins D. 1987, A&A 172, 200 and A&A 172, 211).

2. Studies of convection properties in late-type stars via line bisector analysis.
   Only at a resolving power as high as provided by the VLC systematic studies of convective properties as a function of spectral type, age, and metallicity become feasible.

3. Doppler imaging of stellar surfaces.
   The high resolving power makes it possible to extend the Doppler imaging technique also to "moderate rotators", i.e. stars for which rotational broadening is no longer the dominant line broadening mechanism ($v \sin i \approx 15$ km/s). Thus a larger sample of stars is accessible to this technique. For late-type stars this means that stars can be studied whose activity level can be more easily compared with the solar activity.

4. Stellar rotational velocities.
   The precision at which stellar rotational velocities can be determined depends strongly on the available resolving power. Knowledge of precise rotational velocities is important for a wide

range of applications. Specifically, it helps to put constraints on the stellar inclination and at rotation periods, both important ancilliary data for planetary candidates from RV surveys.

5. Stellar differential rotation.
   In active stars differential rotation measurements are important for an understanding of the underlying dynamo mechanism. Such measurements, which normally use Fourier techniques, benefit strongly from high resolving power.

6. Chemical evolution in the galaxy.
   Accurate measurements of isotopic ratios for different elements become possible at high resolving power. An example is Barium line broadening due to hyperfine structure splitting in odd isotopes which can be used to discriminate between different nucleosynthesis processes (r-process or s-process).

7. Spectral and velocity structure of circumstellar shells.
   Also these studies will benefit greatly from an increased resolving power and high spectral stability.

8. Components and structure of the interstellar medium.
   Accessible is mainly the interstellar medium along the line of sight towards stars. E.g. to determine the dimension of the "local bubble".

9. Stellar radial velocities (RV).
   It will be very useful for the above applications if the quality of the obtained spectra also allows the determination of the position of spectral features at a precision of ≈ 0.2 pixel. This value is therefore required both for the spectral stability and for the re-positioning accuracy after a wavelength change and corresponds to a (differential) RV measurement accuracy of ≈ 100 m/s at 5500 Å.
   Accurate RV zero points will facilitate the intercomparison of line profiles from time series of spectra, will enable to follow features and asymmetries in line profiles, and will make it possible (for periodic phenomena) to co-add spectra into phase bins in order to increase the signal-to-noise ratio without deteriorating the resolution of the data.

10. High-precision stellar radial velocities.
    If self-calibration techniques are used (e.g. using an iodine gas absorption cell), the CES with its VLC, fibre-linked to the 3.6m and with the new 4×2 K CCD has the potential for differential RV measurements of solar-type stars at a precision of upto $3 - 4$ m/s. This precision can be used to search for extra-solar planets or for stellar oscillations. High spectral stability will help strongly to achieve this goal.

The requirements for a refurbishment of the CES should be specifically taylored to exploit this scientific niche of observations at very high resolving power.

This requires in particular:

- instrumental stability,
- repeatability of an instrumental setup after a wavelength change.

Instrumental stability is required in order not to degrade the achievable resolving power. Instabilities from source like instrument vibrations, wavelength drifts or limited encoder resolution must be kept smaller than 0.2 pixel during a 12 h night.

Repeatability of an instrumental setup after a wavelength change is required in order not to compromise time-series studies of stellar line profiles and to make high quality radial velocity studies possible. The repeatability must be better than 0.2 pixel.

3 REQUIREMENTS FOR INDIVIDUAL INSTRUMENT UNITS

3.1 Entrance slit

3.1.1 Necessity of an entrance slit

The main reason for continued use of an entrance slit to the CES is that it is required for spectrograph alignment. Most observing programs with the CES-to-3.6m fibre link [2] will be using one of the three image slicers for $R = 220,000,\ 110,000$ and $80,000$ [3] instead. However, the entrance slit can also be useful in scientific applications and should not be abandoned for such purposes. Reasons for this are:

- Resolving powers higher than those achievable with the image slicers can be used on very bright stars. With the current minimal slit width of 50μ a maximal resolving power of $280,000$ is achievable with the new VLC[4] of the CES; note that the 2-pixel sampling requirement generally limits the achievable resolving power to $\leq 300,000$ for narrower slits.
- The instrumental profile of a slit is less complicated than that of an image slicer and will therefore be preferred for some applications.

3.1.2 Current status of entrance slit

The current entrance slit unit was recently functioning in a very unstable way. Its temporary replacement by the old scanner exit slit proved even more unreliable. After a subsequent overhaul the entrance slit presently yields good results with a repositioning accuracy of the slit width of $\leq 2\mu$ rms, but further monitoring is required to assess its reliability.

3.1.3 Requirements for new entrance slit design

The entrance slit should preferably remain motor controlled and not operated manually (cf. Table 2 in Section 6.5).

If the current design proves unstable and cannot meet the following specifications, a newly designed entrance slit will be required.

Accuray: The requirement for the entrance slit is to maintain the currently achievable positioning and repositioning accuracy of $\leq 2.0\mu$ rms which (via the slit width vs. resolving power relation) can be translated into corresponding uncertainties in the resulting resolving power of up to $\pm 1.1\%$ at $R = 220,000$ and $\pm 0.8\%$ at $R = 150,000$. At 5400 Å where the FWHM of the instrumental profile is 2.81 px for $R = 220,000$ and 4.15 px for $R = 150,000$ an uncertainty of the width of narrow spectral lines of up to ± 0.029 pixels at $R = 220,000$ and ± 0.035 pixels at $R = 150,000$ is implied. (The fact that this uncertainty is smaller at higher resolution results from the fact that the sampling limit is approached.)

Reliability and maintainability The failure rate should be monitored. No more than two slit overhauls per year should be accepted. A higher failure rate should trigger a redesign of the slit unit.

3.2 Decker

When using the CES-to-3.6m fibre link a decker will not be required even when the slit is used since the input spot of the object into the spectrograph is limited by the fibre and sky coverage will be made using a second fibre.

Having a decker available is, however, useful when the procedure of aligning the CCD with the grating rules is done using the slit. For this purpose a removable decker of fixed height should be available.

There is a possibility that the CAT direct beam will continue to use the CES. For this purpose a small number of fixed height deckers should suffice. The current decker design with a stepper motor allowing to choose decker heights between 1 and 20 arcsec should be given up. Instead a limited number of fixed deckers should be offered that are to be installed manually. In case a decision is made to continue access to the CES via the CAT three different deckers with fixed heights of 10, 5, and 1 arcsec in the image scale of the 3.6m (equal to 24.2, 12.1 and 2.42 arcsec in the image scale of the CAT) should be foreseen.

3.3 Predisperser exit slits

There is one predisperser exit slit for the blue path and one for the red path. No modification is required for them. However, it is suggested that they should share the same Maccon controller channel (see section 6.5).

3.4 Predisperser drive system

3.4.1 Current status of the predisperser drive system

The predisperser prism (actually there is one prism for the blue path and one for the red path) is currently the most unstable part of the CES. Optimal encoder values for the rotational centering of the predisperser prism vary quickly with time and have been observed to change within a few units during an hour and by more than 10 units from day to day. The production of a reliable table listing the appropiate encoder values as a function of central wavelength is presently impossible.

The reason for this irregular behaviour is a mechanical backlash in the drive system which together with instabilities such as an air current in the predisperser unit (see Sections 4.1.1 and 4.1.2) leads to unpredictable settings. The current drive system for the prism uses a mechanical arm driven by a screw whose linear movement is controlled by a linear encoder. Thus the rotation of the prism is measured in an indirect fashion only.

The current predisperser encoder has a step size equivalent of 1 arcsec per encoder unit and a resolution of 2 encoder units or 2 arcsec. Rotating the predisperser away from optimal centering has the following effects:

- A movement of the predisperser by one resolution step of 2 encoder units causes a shift (centering uncertainty) of about 110 ± 50 pixels in dispersion direction of the location of the maximum light obtained with narrow entrance and predisperser exit slits (e.g. both at 50μ width as in the "predisperser test"). This relation is non-linear and valid for near-centering, larger movements lead to increasingly larger shifts of the light maximum.

- A shift in central wavelength is also caused by rotation of the predisperser. At 6435 Å this shift was determined (using ThAr lines) to be -0.532 pixel per encoder resolution of 2 units. This is equal to a wavelength shift of -0.0055 Å or -255 m/s in radial velocity.

- Decentering the predisperser prism leads only to a minor degradation in overall flux throughput. For a 100μ slit this value was within $\pm 3\%$ (maxima) for a decentering of up to 10 encoder units (or about 2400 pixels of the light maximum in the predisperser test), i.e. it was within the normal instability of the used quartz lamp.

Note that the shift effects have gained importance due to the higher magnification of the F/12.5 VLC (by a factor of 2.66 over the previous F/4.7 LC).

3.4.2 Currently adopted workarounds

The shortcoming of non-repeatable optimal predisperser settings has existed in the CES for many years, and observers have learned to "live with it" by carrying out a trial and error centering procedure after each change of central wavelength. Due to the higher magnification of the VLC this procedure has now become time consuming and can even lead to erroneous selections of adjacent Echelle orders. Improvement is strongly required.

In order to overcome the instability of the predisperser observers have always disabled its motor by software after a wavelength change and subsequent predisperser centering. This practical remedy should no longer be required, and a redesign of the predisperser drive system should make it superfluous.

3.4.3 Neccessary modifications and requirements

The drive system of the predisperser must be redesigned in order to overcome the non-repeatability of the predisperser setting as well as to facilitate the centering.

First, facilitating the centering of the predisperser must be achieved by compensating for the higher magnification of the VLC using a higher encoder resolution. Therefore, an encoder resolution at least $2.66\times$ higher than the current one is needed, i.e. a resolution of 0.75 arcsec is required corresponding to a centering accuracy of the light maximum of ≈ 40 pixels and a shift of the central wavelength of ≈ 0.05 pixel or 0.00021 Å or 96 m/s per encoder resolution.

Second, to overcome the non-repeatability of the predisperser setting a redesign of the drive system is required. Using a circular encoder that directly measures the rotation of the prism without mechanical backlashes is recommended.

Reliable predisperser settings should be achieved and the CES isntrument control software (ICS)[5] should automatically center the predisperser prims at the optimum angle for the chosen wavelength. During normal functioning no predisperser test measurements should be required any more.

3.5 Turntable of the Echelle grating

3.5.1 Encoder resolution

The resolution of the grating turntable encoder is 0.1 arcsec, but during regular operations uncorrected shifts up to 0.2 arcsec have occasionally been observed. At 5395 Å the turntable rotation rate is -77.2 arcsec/Å, at 6435 Å it is -62.83 arcsec/Å. At these wavelengths the encoder resolution of 0.1 arcsec corresponds, respectively, to wavelength uncertainties of 0.0013 Å and 0.0016 Å, or radial velocity uncertainties of 72 m/s and 74 m/s. In units of detector pixels this uncertainty corresponds to a displacement by 0.15 pixel and 0.16 pixel in the dispersion direction. It is ≤ 0.2 pixel over the whole useful wavelength range for the CES.

3.5.2 Grating repositioning accuracy

At 6435 Å the repositioning accuracy of the grating turntable was determined to have an rms of about 0.12 pixel or 0.0012 Å or 54 m/s. It is therefore comparable to the resolution of the grating turntable.

3.5.3 Modifications

Higher encoder resolution is not absolutely mandatory. However, the drive electronics of the grating turntable must be modified such that the Maccon module can be used.

At present all kinds of software failures move the grating and repositioning is required. This should be prevented in the new control.

3.6 Shutter

The shutter currently used with the VLC was taken from the LC as a provisional solution. It was mounted on the x-y-table that holds the CCD dewar together with the 45° folding mirror. This shutter is not light tight and a permanent solution must be sought (already on track). A new shutter design has to go together with the advent of the foreseen new EEV CCD (2K×4K).

Depending on the solution for the requirement of very short exposures outlined in Section 4.2.3 the shutter will have to be devised such that exposure times as short as 10 msec will be possible.

3.7 Camera mirror mount

At present the mount of the new VLC camera mirror (in the frame of the old scanner mirror) is such that it can be easily tilted when touched, e.g. during the positioning of the Hartmann mask. At the moment the Hartmann test is therefore made with a mask on the grating. This solution is far from optimal, too, since positioning of the Hartmann mask usually leads to small rotational movements of the grating which then repositions itself (see Section 3.5.2 for the accuracy of this process).

Therefore a mechanical solution must be found to give the camera mirror a proper fixation.

3.8 Hartmann mask

The Hartmann mask on the camera mirror can at present be moved only by hand leading to the tilt problem outlined above (Section 3.7). For reasons of stability no manual intervention should occur during normal operations. Instead the Hartmann mask should be permanently mounted on the camera mirror and get its its own motor drive to produce the three positions "open", "left half open", "right half open".

3.9 45°-mirror mount

The current mount of the 45°-mirror mount is reminiscent of a tuning fork and vibrationally very unstable. A mechanical solution must be sought to stabilize it. The design for this should aim at a minimum of additional vignetting (of the beam from the grating to the camera mirror).

4 GENERAL REQUIREMENTS FOR THE INSTRUMENT

4.1 Test setup using a calibration fibre

A solution should be foreseen to perform tests of the instrument when the Cassegrain fibre adapter[1] (CFA) is not mounted. Such tests are important for the monitoring of the instrument performance and to locate operational problems.

Since removal of the fibres from the Cassegrain cage is not a recommended procedure, an additional short calibration fibre should be mounted at the fibre exit mount (where space is foreseen for additional fibres) for that purpose. It should then be equipped with a ThAr lamp and a quartz white light lamp used with the proper input beam.

The test calibration unit should be usable via the CES instrument control software (ICS)[5].

4.2 Overall stability of the CES

4.2.1 Spectral drift

Spectral drifts have been measured many times by means of cross-correlating spectra taken with the quartz lamp and the iodine gas absorption cell. Drift values up to 0.2 pixel/h were observed with the VLC. At 5395 Å this corresponds to 0.002 Å/h or 100 m/s/h. Most probably the observed drifts are related to temperature instabilities.

In the course of an observing night this drift can become the dominant source of wavelength instability.

A major source of temperature instability is the wall between the pre-slit room and the main Coudé room. While the latter is air-conditioned the former is not with the effect that a strong air current is always present in the predisperser unit which is likely a major source of instability in the predisperser.

4.2.2 Measures for thermal stabilization

In order to get rid of the temperature gradient between pre-slit room and main Coudé room the wall separating the rooms must be removed.

Removal of this wall has the following advantages:

- Eliminating of the air current within the predisperser unit.
- Better overall thermal stability of the instrument.
- Easier optical alignment of the instrument with all parts visible from the slit area.

As a consequence of removing this wall a double door between the CES control room and the slit room should replace the current single door in order to prevent accidental light leakage and to improve the thermal insulation from the control room.

A large fraction of the main Coudé room remains unused by the instrument itself. A new wall should be inserted accordingly in the main Coudé room reducing the enclosed volume around the instrument and thereby facilitating the air-conditioning. This new wall must be placed such that the openings for the air-conditioning are not blocked. A reduction of the overall air-conditioning current is likely to also improve on the overall level of vibrations present in the instrument. This reduction must be finetuned in order not to violate the requirement for instrument drift given below (Section 4.2.3).

Additional measures to improve the thermal stability should be studied such as a better insulation of the remaining volume or a polyurethane foam enclosure.

4.2.3 Requirement for maximal spectral drift

The overall spectral drift of the instrument in the course of a night should not considerably exceed the wavelength instabilities produced by other effects such as the limited resolution of the grating turntable encoders and the future predisperser prism encoder. An attempt should therefore be made to get spectral drifts down to ≈ 0.2 pixels/h throughout an entire 12 h-night.

4.3 Instrument vibrations

4.3.1 Vibration monitor

Spectrograph vibrations have been an intensively monitored issue for the CES. Prevailing frequencies are 24, 21, 7.2, 47 and 13 Hz (ordered by decreasing strength). The level of vibrations as it affects science exposures has been successfully reduced in the course of the last year as a consequence of various measures. Remaining vibration levels as measured with the VLC via cross-correlation of time series of iodine spectra (each with 1 sec exposure time) are currently $0.09 - 0.11$ pixel rms when the air-conditioning plant on the 3.6m ground floor is running and $0.07 - 0.09$ pixel rms when it is off.

Since some of the measures taken to reduce the vibration level might wear out with time (e.g. dampers) and new vibration sources might appear (e.g. connections between 3.6m building and central pillar on which the Coudé floor rests), it would be desirable to have a vibration monitoring device permanently mounted in the CES. It should consist of an accelerometer attached to a spectrum analyser.

4.3.2 Very short exposures for vibration measurements

In order to measure true amplitudes of vibrations it would be desirable to have an option for very short exposure times with a sufficiently bright light source (e.g. the instrument laser located in the pre-slit area). To properly sample vibrations up to 50 Hz exposure times as short as 10 msec are required.

4.4 Summary of specifications relevant for instrumental stability

Table 1 summarizes the current and future (required) performance of the instrument in terms of spectral stability. The upper part of the table contains the relevant characteristics of the entrance slit, the grating turntable, and the predisperser drive system, whereas the lower part contains the performance limits in terms of spectral drift, vibrations, and degradation of the resolution.

4.5 Straylight

Various sources of straylight have been discovered in the CES. These sources have been successfully removed, but at part with temporary measures whose final solutions are pending such as paper covers within the predisperser unit. Especially the predisperser exit slit motor which produces IR light needs a permanent cover (an action point is already open for this). It would be easy to have a straylight monitor available for the use of day operations. It should consist of a photomultiplier with sensitivity from UV to IR coupled to the CES exposuremeter.

4.6 Drawings of the instrument design

No up-to-date mechanical drawings of the instrument exist. They are required for inclusion into an updated User's Manual.

5 REQUIREMENTS RELATED TO THE CASSEGRAIN FIBRE ADAPTER

5.1 Calibration lamps

Currently the calibration lamps available for the CES-to-3.6m fibre link are the lamps in the Cassegrain calibration flange and a ThAr lamp in the Cassegrain fibre adapter[1].

The lamp of interest in the calibration lamp flange is the quartz flatfield lamp which has proven to be too inefficient. As an intermediate solution a portable quartz lamp with a fibre extension was inserted into the Cassegrain fibre adapter. The adapter carriage must be modified such that it can permanently host a quartz flatfield lamp. In order to not complicate a future option for a polarization analyser the quartz lamp should be accessible through the same carriage position as the ThAr lamp.

The ThAr lamp already in the fibre adapter is useful, but still week requiring exposure times of several minutes. The focussing of its light onto the fibre must be improved.

All calibration lamps must be controllable through the CES instrument control software (ICS)[5].

5.2 Carriage of Cassegrain fibre adapter

Control of the lamps located in the Cassegrain fibre adapter implies control of the adapter carriage through the ICS. There must be three selectable positions: “Free”, “Lamps”, and “Polarisation analyser” (for the time being also a free position).

5.3 Object guiding

The 3.6m autoguider currently does not allow guiding on the fibre view camera. Presently, the object is centered on the fibre, a process that is aided by exposure meter readings (a lengthy, time consuming and inconvenient procedure) and then guiding is performed using the guide probe.

In order to gain maximum guiding accuracy and thereby maximizing the flux throughput through the fibre, guiding on the fibre with the fibre view camera is mandatory.

5.4 Colour filters for guiding

In order to minimize the effects of differential refraction which are important for a high resolution spectroscopic instrument the option to insert colour filters in front of the fibre view camera is required.

The following broadband filters should be made available: Blue, Visual, Red. Software control from the ICS is desirable.

6 SUGGESTIONS FOR TECHNICAL SOLUTIONS

6.1 Entrance slit

If a new design for a entrance slit is required, it is suggested that a linear motor be used replacing the current stepper motor.

6.2 Predisperser drive system

Heidenheim offers circular encoders with resolutions higher than the required one. It needs to be functioning only over a limited range of rotation of several degrees.

6.3 Test calibration unit

A suggested solution would be the following: During the time when the CES is not used by the 3.6m the Cassegrain fibres are removed from the Cassegrain adapter and stored in the Cassegrain cage. The CFA is then taken to the pre-slit room, mounted on a fixed mount and the test calibration fibre is inserted into the CFA. The exit end of the test calibration fibre would remain permanently mounted in the fibre exit mount.

This way the ThAr and Quartz white light lamps of the CFA can be untilized (cf. Sect. 5.1) and chosen regularly via the ICS. No additional solutions are required for software, electronics, etc.

Needed for this solution are:

- A calibration fibre of length $2 - 4$ m with the same properties as the Cassegrain fibres.
- A fixed mount for the fibre adapter plate in the CES pre-slit room.

6.4 Measurements of vibration amplitudes

The goal to achieve exposure times of 10 msec could either be considered in the shutter design (Section 3.6), realized with an additional shutter device or perhaps with a pulsed laser.

6.5 Carriage of Cassegrain fibre adapter

Two lamps (ThAr and quartz) will have to be selectable from the same carriage position. It is suggested that a folding mirror be inserted for this purpose which will be activated with the power of the FF lamp. Thus it will not require its own Maccon channel.

6.6 Maccon functions

Each of the new Maccon controllers has four channels that can be used for instrument functions. Table 2 lists the required functions. It demonstrates that with only one Maccon controller only the absolutely indispensible functions can be controlled. Important functions such as the choice of the colour filters for guiding or control of the entrance slit require a second Maccon controller.

Table 1: Summary of parameters relevant for spectral stability

Performance limits of individual instrument parts				
Instrument part	parameter	current	required	mechan. equiv.
Entrance slit	$\Delta FWHM$	$\leq$ 0.035 px	$\leq$ 0.035 px	$\leq 2\ \mu$ rms
Grating turntable	resolution	$\leq$ 0.2 px	$\leq$ 0.2 px	$\hat{=}\ 0.1''$
	positioning (rms)	0.2 px	0.12 px	$\hat{=}\ 0.06''$
Predisperser drive	resolution	0.53 px	0.20 px	$\hat{=}\ 2.0'' \longrightarrow 0.75''$ 1)

Performance limits of the instrument as a whole				
Effect	parameter	current	required	physical equiv.
Spectral drift	slope	$\leq$ 0.2 px/h 2)	$\approx$ 0.2 px/night	2 mÅ, 100 m/s
Vibrations	shift (rms) 3)	0.1 px 2)	$\leq$ 0.1 px	1 mÅ; 50 m/s
Overall degradation of resolution	$\Delta FWHM$	0.57 px 4)	0.29 px	5.1 $\longrightarrow$ 2.6 mÅ; 280 $\longrightarrow$ 140 m/s

1) If a Heidenheim circular encoder is used the actually achieved resolution will be $\approx 0.20''$ or 0.053 px.
2) Measured value.
3) Spectral shift as measured in series of exposures with 1 s exposure time.
4) Value predicted from performance limits of grating turntable and predisperser drive system. Note that the mechanical uncertainty of the current entrance slit is too small to contribute significantly to the degradation of the resolving power.

Table 2: CES instrument functions

Indispensible functions (one Maccon controller)	Important functions (2nd Maccon controller)
Grating turntable	Colour filters for guiding
Predisperser prism	Entrance slit
Predisperser exit slits (blue & red)	Hartmann mask
Calibration lamp carriage	—