Nordic Optical Telescope

Standby Camera and Spectrograph User Requirements

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1 Introduction

This document describes the user requirements for a Standby Spectrograph and Camera (SCS) to be mounted permanently at a folded Cassegrain focus of the Nordic Optical Telescope (NOT).

The general requirement is to provide an instrument with the same general capabilities as currently provided by the Andalucia Faint Object Spectrograph and Camera (ALFOSC) which is normally mounted at the Cassegrain focus of the NOT. The new instrument should be fitted in the area current occupied by the adapter between the main telescope structure and the Cassegrain focus such that it is always available while an other instrument can be mounted at the Cassegrain focus. The general idea is to have a largely fixed instrument set-up with as little changes as possible. In principle the plan is to have the near-infrared camera and spectrograph NOTCam permanently mounted at the Cassegrain focus. This defines the lower limit to the space envelope available for the SCS, with the option of using both the SCS and NOTCam simultaneous.

An major issue in the design of the instrument will be (what I will call here) the adapter unit which redirects the light coming from the telescope. This unit should allow the light to be redirected to (one or more arms in) the SCS, and in principle simultaneously to NOTCam, but should also include an option to redirect the light to the standby spectrograph FIES which is also operated at a folded Cassegrain focus, and possibly to an additional focal station for an other standby instrument (e.g., a Lucky Imager). Furthermore, this unit should allow for polarimetry with the SCS, FIES, and possibly NOTCam, while it likely will be required to re-image light from various calibration lamps to the SCS and possible NOTCam.

Beyond the basic requirements we also define some capabilities which are not essential, but we consider desirable.

2 General requirements

The most general requirement is that the instrument and associated items should fit in the available space (see below) and largely should perform like ALFOSC. For general information about ALFOSC and its capabilities, see:

`http://www.not.iac.es/instruments/alfosc/`

Should we be considering re-using some of the items from ALFOSC, specifically filter [as far as they are ours...], as a requirement for the design?

Specific requirements for the SCS are:

- Focus distance from top of adapter: 434 mm *check; tolerance?*

  Alternate way: Should match NOTCam focal plane within XXX mm *check; tolerance?*
- Effective wavelength range 320–1050 *???* nm
- Encircled energy 80% within 0.4 arc-sec *???*
- Stray light level less than 2% *???*
- Instrument throughput (without telescope and detector but including pick-off mirror and/or dichroic)
  - 90% in imaging and polarimetry *???*
  - 60% in spectroscopy at peak transmission of grating/grism *???*

2.1 Telescope

Relevant telescope parameters are

- Effective aperture ratio of system: f/11
- Focal plane scale: 7.33 arcsec/mm
- Maximum field of view (diameter): 30 arcmin

2.2 Space envelope

The fundamental idea is to have the SCS mounted in the adapter at a folded Cassegrain focus such that it can always be available while an other instrument, in principle NOTCam, is mounted at the main Cassegrain focus. As the NOT is an AltAz telescope, the whole adapter can rotate to correct for field rotation. Currently there are various items mounted in the adapter which includes a pick-off mirror for the fiber-head that feeds light to a echelle spectrograph (FIES) which is mounted in a separate building, a pick-off mirror for a direct imaging standby camera (StanCam; this camera is also used to acquire targets for FIES and image the fiber head during observations), and there is a guide camera mounted on an X-Y table. However, as specified in more detail below, all these items

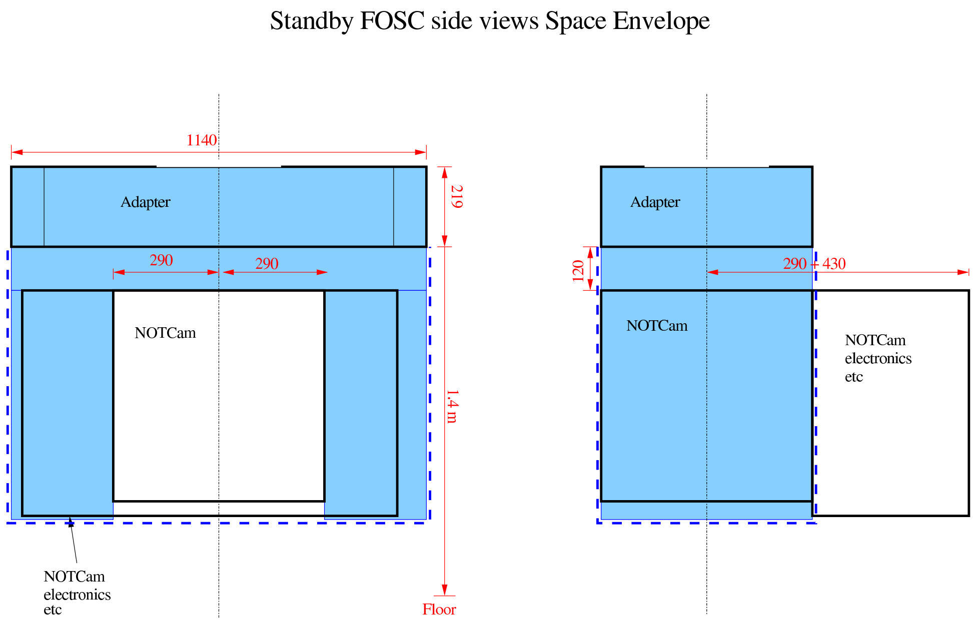

Figure 1: Side view of the available space for a Standby Camera and Spectrograph at the Cassegrain focus. The area marked in blue shows the space projecting from the adapter downward. The area marked in white is not available as that is covered by NOTCam when it is mounted. The position and extend of the NOTCam electronics is also indicated. There is also a more extended area available beyond the blue area, while the adapter housing can also be modified or removed.

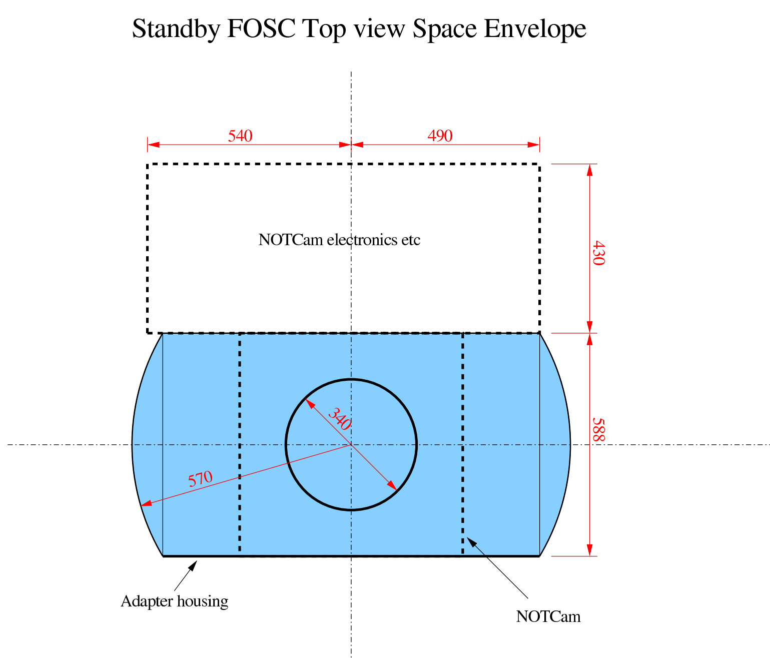

Figure 2: Top view of the available space for a Standby Camera and Spectrograph at the Cassegrain focus. The area marked in blue shows the extend of the space available in the adapter. The position and extend of the NOTCam electronics is also indicated. The adapter housing can also be modified or removed and a more extensive area around it is in principle available.

are expected to be replaced and incorporated in the design of the SCS so in principle the whole area of the adapter can be used.

In fact, as there is no physical limitation due to rotation of the adapter or movement of the telescope the space projecting from the adapter downward can be used. This actually includes the area extending beyond the dashed blue line in Figs. 1 & 2. Specifically, from the bottom of the adapter there is 1.4 m to the observing floor, and from the center of the adapter (and the telescope) there is more than 1.5 m to the fork on which the telescope is mounted. The remaining limitation is the area covered by NOTCam which in principle would be mounted permanently at the main Cassegrain focus. The adapter housing itself limits the available space but there is no fundamental reason why the housing can not be modified or removed.

2.2.1 Weight

A specific issue is the added weight of the new instrument. In the current set-up the maximum total weight of an instrument mounted at Cassegrain is ~250 kg. NOTCam, which is envisioned as being mounted permanently at the Cassegrain focus, weighs ~200 kg, leaving only ~50 kg additional weight for the SCS. However, it should be noted that the various items currently attached to (calibration lamps), or included in the adapter (autoguider system) will in principle be replaced and included in the design of the SCS, which effectively increases the available weight for the instrument. Furthermore, the general idea is that the framework for the instrument is provided by the (modified or new) adapter housing itself, i.e., in principle relatively little extra weight will be needed to provide a proper backbone for the instrument. Also, for a permanent configuration of instruments at the telescope it will be possible to make some gains in allowed weight by optimizing the distribution and weight of other items attached to the main telescope structure. However, a maximum weight for the whole new installation in addition to that of the bare adapter itself should be in the order of less than ~100 kg *???*.

2.3 General design

Like ALFOSC, the SCS should be capable of doing imaging and low-resolution spectroscopy for which requirements are defined in more detail below. For the general design itself there is no specific requirement and any possible design such as having separate imaging and spectroscopic light pathways, using a direct mode or a focal reducer, and/or blue and red arms with their respective CCDs are all possible options.

2.4 Imaging

2.4.1 Detector requirements

From the optical quality of the telescope and the best measured seeing in the optical of $\gtrsim$0.4 arcsec the requirement follows that the optimal pixel size in imagine mode should be ~0.2 arcsec per pixel or less. *For the normal direct f/11 beam from the telescope this would mean ~30μm per pixel in the* *focal plane. A CCD with 15μm pixel would oversample this by a factor ∼2. Conversely, a factor ∼2 focal reducer would be required to get ∼0.2 arcsec per pixel for a CCD with 15μm pixels.*

As for field-of-view, the current field of ALFOSC is 6.4×6.4 arc-minute with 2k×2k 13.5 μm pixels at 0.19 arcsec), while the NOTCam field (for the Wide-Field camera) is 4∼4 arcmin with 1k×1k pixels at 0.234 arcsec. The minimum requirement is for the field-of-view to match that of the NOTCam Wide-Field camera. *The latter only applies if we want to consider simultaneous imaging observations with NOTCam (see below). If not, I do not see any strong requirement on the FOV beyond it not being very different (smaller) than the current FOV of ALFOSC and a minimum requirement for the FOV of ∼4× ∼4 arcmin seems not unreasonable.*

Some more background info: An approximate match (3.8×3.8 arcmin) of the NOTCam FOV is obtained for a CCD with 1k×1k pixels at 30μm (0.22 arcsec per pixel) or a CCD with 2k×2k pixels at 15μm (0.11 arcsec per pixel). A CCD with 4k×4k pixels at 15μm would provide a FOV of 7.5×7.5 arcmin.

Should we actually provide specific requirements for the efficiency of the detector(s) as a function of filter/wavelength, or leave that as a separate issue to be considered when selecting the CCD(s)?

2.4.2 Filters

In the current set-up for ALFOSC there are 7 slots (plus 1 open position) available in ALFOSC to mount filter in its parallel beam. There are a further 12 slot (distributed over two separate filter wheels each with an additional open position) available in a special filter unit placed in the convergent beam (f/11) from the telescope. A set of UBVRi broad-band filters are practically permanently mounted in the filter wheel in parallel beam of ALFOSC. Other broad-band filters and, to minimize wavelength shifts, all narrow-band filters are mounted in the convergent beam.

Without putting any specific limitation on the design, as a general rule we require that any filter within the limitations given below can be mounted such that the wavelength shift across the field-of-few is less than 10% *???* of its bandwidth.

Given the requirements below it seems most logical to have separate filter wheels or slides to mount either the broad-band or narrow-band filters, but this is not a requirement.

- Broad-band filters

  Here we define broad-band filters as those that have an effective band-width of 50 nm or more. From an analysis of ALFOSC observations the main use is of the UBVRi filter set, followed by the SDSS ugriz filter set plus a special wide, sky-contrast filter.

  The general idea for the SCS is to have a single fixed set-up for broad-band observations (either UBVRiz or ugriz+wide filter), were the specific requirement is to have the capability to permanently install 6 broad-band filters for imaging. There is no need for these filter to be easily changeable, but it should be possible to access the filters to clean them (e.g., to remove dust).

  In the case of an instrument design with a blue and a red arm and a permanent separation of the blue and the red light there would be a natural division of the filters in each arm, but then serious considerations should be given to the specific wavelength at which the channels are separated and the effect this might have on the effective filter efficiency curve for filters which cover this wavelength. If one of the arms can be selected to receive the full optical wavelength range that arms should have the capability to permanently install 6 broad-band filters.

- Narrow-band filters

  Should we make the distinct of intermediate-band filters, e.g, between 50 and 10nm? These are basically the Strømgren set plus wide Hα and Hβ filters.

  Here we define narrow-band filters those that have an effective band-width less than 50 nm down to 3 nm. From an analysis of ALFOSC observations there is a fairly wide range of filter being used relatively often. These include the (most used) Hα wide (18 nm) filter and the Strømgren uvby filter set, plus the [OIII], [NII], Hα, and Hβ narrow (3–5 nm) filters and an Hα continuum filter. Beyond that, there is a relatively large set of narrow-band filters such as [SII] and [OII], and various (mostly Hα) red shifted filters.

  As it is not really practical to have all of these filters mounted at the same time the implication is that these kind of filters should be easily mountable. The specific requirement is to have the capability to install a full set of filters such as the Strømgren uvby plus H*beta*-wide and Hβ-narrow, i.e., up to 6 narrow-band filters for imaging.

  In the case of an instrument design with a blue and a red arm similar considerations arise as for the broad-band filters. As the band-width of these filters are narrow the specific wavelength at which the light would be separated for each arm is less likely to effect any filter, but it is more likely that many, if not all filters used for a particular observation are all in one arm. For this reason the requirement would be for both arms to have the capability to install up to 6 narrow-band filters for imaging.

However, in Nordic (and also CAT) service nights the current full capability of mounting filters with ALFOSC (7 in a parallel beam, 12 in a convergent beam) is often used (or at least requested). One could consider the current capability as requirement, but it is not clear if that would be sufficient either, while it is also not clear if the full sets that are requested during service nights are also truly used within one night, i.e., how essential is this?

Note also that given the above requirements there is no problem to have all filters in a single wheel/slide (for each arm), though such a wheel/slide should have at last 12 slots for filters (per arm)...

2.4.3 Filter movement

As it is normal to take exposures with various filters of the same target the time to change filter position for a given filter wheel or slide should be less than the read-out time of the detector (for a 2k×2k CCD being 10 sec with $\sim 6e^-$ noise, and 25 sec with $\sim 3.5e^-$ noise).

This does assume that we would go for a 2k×2k CCD at least for the imaging. In any case, a 10 sec limit on any movement for a wheel or especially a slide might be a rather strong limit. How important is this? Would, e.g., a maximum of 10 sec between adjacent positions and an overall maximum of 30 for movements between any two filters (possible on different wheels/slides) be sufficient?

2.4.4 Simultaneous imaging with NOTCam

Given the most basic requirement for the SCS to provide the capabilities similar to ALFOSC there is no a priori requirement to provide the option to do simultaneous imaging observations with NOTCam. However, we will need some kind of pick-off mirror to divert the light from the telescope to the SCS and it seems relatively simple to replace that with a dichroic which would allow for observations with the SCS and NOTCam at the same time.

The requirement to be able to do simultaneous imaging observations with the SCS and NOTCam implies the use of a dichroic to direct light to both the SCS and NOTCam. The main practical issue is that of being able to focus both the SCS and NOTCam at the same time. Both instruments will have an internal focussing mechanism which have a range of movement of XXX for NOTCam, and YYY for ALFOSC (taking it as first approximation for the SCS) so there will be a tolerance of ZZZ in the relative positioning of the focal planes.

An important issue is to consider how easy and useful it is to combine imaging observations with the SCS and NOTCam. Specifically, the requirements for the observations (exposure times and dither patterns) can be rather different (to some extend even contradicting; e.g., a single long exposure with the SCS versus many short dithered exposures with NOTCam). This puts rather severe limitations on the best way that simultaneous observations in the optical and NIR can be combined where very likely the gains are far less than the theoretical maximum factor of 2.

2.5 Spectroscopy

2.5.1 Detector requirements

From the optical quality of the telescope and the best measured seeing in the optical of $\gtrsim$0.4 arcsec the requirement follows that in the spatial direction the optimal pixel size should be $\sim$0.2 arcsec per pixel or less. For the normal direct f/11 beam from the telescope this would mean $\sim$30μm per pixel in the focal plane.

As for the slit length, in ALFOSC the long-slits cover the full width of the field-of-view of 6.4 arcmin, while in NOTCam the long-slit covers the full width of the field-of-view (for the Wide-Field camera) of 4 arcmin. The minimum requirement would be for the field-of-view to match that of the NOTCam Wide-Field camera.

The latter would only apply if we want to have the option to do simultaneous spectroscopic observations with NOTCam (see below). If not, I do not see any strong requirement on the slit length beyond it not being very different (smaller) than the current width of the FOV for ALFOSC and a minimum requirement for the slit length of $\sim$4 arcmin seems not unreasonable.

In the dispersion direction the wavelength coverage is (at least for the higher resolution grisms/grating) limited by the detector size.

As an option, a rectangular CCD with 2k$\times$4k pixels at 15μm would provide a slit length of 3.8 arcmin slit length in direct mode, or a $\sim$7 arcmin slit length with a factor 2 focal reducer.

2.5.2 Resolution and wavelength range

Background: From an analysis of ALFOSC observations the main mode of spectroscopic observations is with grism #4 which covers the range 320–910 nm at a resolution (for a 1 arcsec slit) of 355. However, the wavelength range is significantly effected in the red by fringing (which is severe beyond ∼750 nm) and 2nd order contamination. There are also several grisms (#6,7,8,14 and 16) which are fairly often used and have resolutions in the range 500–1000. Most of these grisms are in the blue, but it does include one grism (#8) that goes up to 835nm (again, significantly effected by fringing beyond ∼750 nm). The grism set for ALFOSC also include a specially made Volume-Phase-Holographic grism center at Hα which is also used regularly. This grism covers the range 635–685 nm at a resolution of 5000. Echelle and MOS spectroscopy are practically not used.

It seems reasonable to assume that the relative limited use of the red part of the spectrum is largely cause by the severe fringing and we conclude:

To cover the main modes of spectroscopic used in observations with ALFOSC we need to be able to cover the whole wavelength range 320–1050 nm *???* at resolutions of ∼500 and ∼1000.

Assuming the project width of a 1 arcsec slit corresponds to 5 pixel (see Sect. 2.5.1) nearly the whole wavelength range can be covered with a single grism/grating at a resolution of ∼500 on a 2k×2k CCD but 2nd-order contamination would be an issue and the minimum would be 2 grisms/grating (e.g, covering 320–640 and 525–1050nm, respectively). For a resolution of ∼1000 a minimum of 3 grisms/gratings are needed to cover the whole range (e.g., covering 320–525, 478–759 and 695–1050nm, respectively) with a ∼500 pixel overlap between them.

The general idea for the SCS is to have a fixed set-up for spectroscopy (with resolutions of ∼500 and ∼1000 over the whole range, were the specific requirement is to have the capability to permanently install the required grisms/gratings. *In principle following the above this would be 5 grisms.* There is no need for the grisms/gratings to be easily changeable, but it should be possible to access the grisms/gratings to clean them (e.g., to remove dust). In principle, only fixed wavelength ranges are require, i.e., if gratings are used they just need to be installed at a fixed angle. For the red grisms/gratings order-blocking filters are required. For grisms these can be incorporated in the prism glass. For reflection gratings, the filters would need to be put in the beam elsewhere. For 'blue' ∼500 grisms/gratings it should be optional to use a block-filter or not.

In the case of an instrument design with a blue and a red arm and a permanent separation of the blue and the red light there would likely be a natural division of the resolution ∼500 grisms/grating to one for each arm, while for the resolution ∼1000 grisms/grating one probably would need 2 for each arm (i.e., probably one more than in a single arm instrument), but this depends on the specific wavelength at which the channels are separated. The specific requirement is to have the capability to permanently install the required grisms/gratings in each arm. The requirements for the blocking filters remain the same.

If one of the arms can be selected to receive the full optical wavelength range that arms should be the blue arm so that a ∼500 grisms/grating can be used to cover (nearly) the whole optical range when no blocking-filter is used.

I think we should definitely not include an echelle mode in the design, while there also does not seem *any general need for grisms/gratings with a resolution of ≤2000. I do not include here the possibility of having one or more specialized CCD such as the current VPH grism #17, but one might consider to require an extra 1 or 2 slots where grisms/gratings can be easily mounted. One could also consider to only require space for 4 grisms/gratings, e.g., having only one (more centrally place) grisms/grating with a resolution of ∼500 (e.g., covering the range 400–800nm), or having only 2 grisms/grating with a resolution of ∼500 (e.g., covering the ranges 360–565 and 500–766nm, respectively).*

2.5.3 Camera Focus

With a slit in the beam it should be possible to focus the spectrograph such that the slit is in focus on the CCD. The focus drive should be able to account for offsets due to optical components that may be put in the beam in spectroscopic mode, for example blocking filters, gratings/grisms or possibly any optics for (spectro-)polarimetry.

In order to be able to properly focus the spectrograph it is desirable to be able to insert Up/Down/Left/Right Hartmann masks in the beam, preferably far away from the 2 focal planes.

2.5.4 Slits

The requirement is to have various slit widths available at all times ranging from the best possible resolution in the dispersion direction of 2 pixels (in principle for a slit magnification factor of ∼1 and a spatial pixel size of ∼0.2 arcsec this would be ∼0.4 arcsec), a slit matching the median seeing at ∼0.8 arcsec, a slit for poor seeing at ∼1.5 arcsec, and a wide slit ∼¿5 arcsec for standard star measurements and such. This can be either in the form of a single slit unit with a variable slit width, or a slit wheel with a set of slits with fixed slit widths. The slits should allow the use of the full spatial width of the detector.

In case of an instrument design that combines imaging and spectroscopy in a single arm it should be possible to remove the slits or slit unit from the light path. In the case of an instrument design with a blue and a red arm it is highly desirable (*should this be a requirement (see below)?*) to have a single slit unit for both arms. In this case, the light is only split after the light has passed through the slit.

Independent of the specific design for the spectroscopic part of the SCS it should be possible to align the slit(s) with the spatial direction on the detector (being either the column or row direction) to within 0.5 pixels *???* over the full extend of the detector.

An important question here is if for an instrument design with a blue and red arm we want to be able to take spectra in both arms at the same time or not. If yes, then clearly the best option would be to have a single slit (unit) for both arms, which then per definition implies that the light is only split after the light has been folded and gone through the slit in the focal plane, which means an extra reflection (i.e., light loss). One can also use separate slits for each arm which can be put in the respective focal planes after a beam splitter, but to a certain extend you run in to similar problems as for relative alignment of the slits when considering simultaneous spectroscopy with the SCS and NOTCam (see Sect. 2.5.6). Allowing for simultaneous spectroscopy in a blue and a red arm of the SCS, and NOTCam at the same time seems extremely complicated.

A separate issue which is related to the requirements as for the 'Resolution and wavelength range' discussed in Sect. 2.5.2 is the question if we need a requirement for slits that are offset in the dispersion direction. My feeling is that the requirements in Sect. 2.5.2 should cover most wishes, but there might be very specific applications which are not included (e.g., different lines that can not be covered in a single set-up).

In case the slit(s) consist of a design with movable slit-jaws should we require a specific maximum variation in distance between the jaws in the spatial direction and/or the jaws to be parallel within a certain limit?

Considering the typical use of ALFOSC and the added complication, I think we should not consider MOS mode.

2.5.5 Target acquisition

The only requirement is that there should be an easy way to center a target within 0.1 of a pixels *???* in the dispersion direction at a given position in the spatial direction along slit(s). This can either be using the imaging capabilities of the SCS to image and position a target, or using a slit viewing camera in the case of a slit unit with movable slit-jaws.

2.5.6 Simultaneous spectroscopy with NOTCam

The main question is if we want to include the requirement to do spectroscopic observations with SCS and NOTCam simultaneously at all.

The specific requirement is that it should be possible to have light from the same object to be in-focus on the slit (which could be separate slits for a blue and red arm [spectroscopic] arm; see Sect. 2.5.4) and centered in the slit for both instruments, while the slits (up to 3) should also be aligned on the sky to allow for dithering along the slit (for ABBA type observations) which are mandatory in the NIR.

In principle, the relative alignment can be done be adding an alignment mechanism to the slit unit(s) itself such that, together with the camera's focus mechanism, the slit(s) in the SCS can be aligned relative to the slit in NOTCam (where there is also the [possible] requirement of aligning the slit(s) in the SCS with the detector(s); see Sect. 2.5.4). An other possibility is to allow for (a dichroic in) the adapter unit (see Sect. 2.8) to be adjustable. However, the most serious issue would be the amount of relative flexure of the slits as a function of telescope and rotator position which would make all things variable with time/position.

Similar to imaging, an issue to consider is how easy and useful it is to match observations with the SCS and NOTCam. Specifically, only a single grism can be used in NOTCam (and depending on the design in the SCS as well) at the time, limiting the total coverage that can be achieved, while the requirements for the observations (exposure times and dither patterns) can be rather different (to some extend even contradicting; e.g., a single long exposure with the SCS versus many short dithered exposures with NOTCam).

2.6 Polarimetry

The requirements are as follows:

- It should be possible to do polarimetry over the whole wavelength range 320–1050nm *???*
- Both linear and circular imaging polarimetry should be possible with all mounted imaging filters (see Sect. 2.4.2) *Should we maybe limit the requirement to only the broad-band filters?*
- Is it desirable that imaging polarimetry is not limited by the polarimetry optics such that it is possible to cover the full field of view available for normal imaging (see Sect. 2.4.1) using proper masks and stepping the telescope. *Should there be a minimum usable FOV, e.g., 3 arcmin$\times$3 arcmin?*
- Both linear and circular polarimetry should be possible with all mounted grism/gratings (see Sect. 2.5.2). *Should we require the inclusion of order-sorting filters?*
- Is it desirable that spectroscopic polarimetry is not limited by the polarimetry optics such that it is possible to cover the full length of the slit(s) available for normal spectroscopy (see Sect. 2.5.1) using proper masks and stepping the telescope *Should there be a minimum usable slit length, e.g., 3 arcmin?*
- The polarimetric accuracy should be as good as 0.1% (TBC) in the degree of linear polarization. *Should this apply to both imaging and spectroscopy? Is there a similar requirement for circular polarimetry?*
- The degree of instrumental polarization should be below 0.8% *???*.
- If switching between linear and circular polarimetry requires the exchange between a lambda/2 and lambda/4 plate it is desirable that this can be done mechanically

Specifically relevant is the need to consider the polarizing properties of any dichroics and/or pick-off mirrors.

If we also want to be able to do polarimetry with NOTCam an important issue is if we want to be able to do this simultaneous with the SCS or not (but note the general comments about simultaneous imaging and spectroscopy in Sections 2.4.4 & 2.5.6). In the former case, a single dichroic should be able to cover the wavelength range 320–2500 nm. If the latter, it would be acceptable to have separate polarimetry optics for the SCS and NOTCam. In case it is a requirement to be able to do simultaneous observations (or in general in the case of a single set of optics) the polarimetry optics will need to be placed before the unit that diverts the light to the SCS (mirror) or split the light between the SCS and NOTCam (dichroic).

In the case of an instrument design with a blue and a red arm where we want to be able to do (spectro-)polarimetry in both arms at the same time the polarimetry optics should be placed before the light is split by a dichroic. If for (spectro-)polarimetry one of the arms can be selected to receive the full optical wavelength range (receiving light only deflected by a mirror) that arm should be the blue arm so the $\sim$500 grisms/grating can be used to cover (nearly) the whole optical range when no blocking-filter is used (see also Sect. 2.5.2).

A general concern with any requirement of simultaneous polarimetry in different instruments and/or arms is the polarization dependent location of the cut wavelengths of dichroics that need to be used.

One might think of a requirement where to each instrument and/or arm there should always be a light path that does not pass through/via a dichroic. I.e., either a straight-through path to NOTCam, or one or more mirrors to the [arms of the] SCS.

2.7 Coronagraphy

As this option is basically never used with ALFOSC I do not think we should consider this here either.

2.8 Adapter unit

Here, the adapter unit refers to the unit that regulates the light path to the SCS and the Cassegrain focus.

To direct the light to the SCS the adapter unit needs to include a mirror or dichroic that deflects the light to the SCS over an area on the sky corresponding to the full field of view covered by the SCS in imaging mode. The reflection efficiency should be better than 90% *m???* over the wavelength range 320–1050 nm *???*. (*but see the below discussion if in the case of simultaneous observations with NOTCam the z-band should be observed with the SCS or with NOTCam.*

Should there be different, less stringent requirement for the reflectively for a dichroic as compared to a mirror? This might be especially if we would allow or require the adapter unit to have both a mirror and a dichroic that can be inserted in the beam mechanically. If the FOV covered by the NOTCam detector is smaller than that covered by the SCS in imaging mode the area covered by a dichroic might also be allowed to be smaller than the FOV covered by the SCS.

2.8.1 Simultaneous observations with NOTCam

To be able to observe simultaneously with the SCS and NOTCam the adapter unit needs to include a dichroic that should deflect the light over the wavelength range 320–1050 nm *???* to the SCS at the efficiency as specified above, and transmit the light over the wavelength range 1150–2400 nm *???* to the Cassegrain focus at an efficiency of better than 90% *???* over the whole wavelength range.

The main question is if we really want to have the requirement to be able to do simultaneous observations with the SCS and NOTCam (see discussion in Sections 2.4.4 & 2.5.6).

Beyond that, specific considerations should be made of the desired properties of the dichroic. In particular, what should the be cut-off wavelength separating the light. E.g., should the z-band (and Y-band!) be observable with the SCS or with NOTCam. Assuming the main use of combined imaging observations is defining the spectral energy distribution of a target, e.g., observations with the ugrizJHK filters, or UBVRIzYJHK filters, there is a certain advantage in including the z-band in NOTCam. However, this would exclude z-band observations with the SCS in which case we might consider to have both the options of a pick-off mirror and a dichroic available.

2.8.2 Observations with FIES

Beyond the SCS there is also the fiber-fed echelle spectrograph FIES where the fiber head that leads the light to the spectrograph should be mounted at a folded Cassegrain focus in the telescope adapter. For this, the adapter unit should include a mirror that deflects the light to the fiber-head over the area covered by the 4 fiber-heads in the fiber-unit. The reflection efficiency should be better than 90% *???* over the wavelength range 370–730 nm *??? This is the current wavelength range but this will be different with a new CCD.*

The adapter should also have the option to mount a specialized ADC and a polarization unit for FIES that both can be mechanically put in the light path before it is deflected to the fiber-unit. In principle, these units would only be used when observing with FIES and the space covered by these units can be used for other units (e.g., for polarization optics for observations with the SCS and/or NOTCam) when FIES is not in use.

It should be possible to use the imaging capabilities of the SCS to position a target such that its light will fall on the fiber-head (with a projected area on the sky of XX *???* arcsec) for each of the 4 fibers.

Should we include the fiber-head viewing using the SCS as done now with StanCam as well? I was thinking that we could us a simple amateur-type CCD for this, in which case the 'only' requirement would be that space should be allowed for this to be installed.

I do not include the calibration unit for FIES as I assume this to be included with the fiber-unit.

I also assume that the fiber unit can be positioned such that its focal plane coincides with that of the autoguider system within the tolerance of that system (see Sect. 5).

I assume we do not require to have an ADC for use with the SCS and/or NOTCam...

2.9 Calibration unit

For calibration of spectroscopic observations with the SCS a calibration unit is required. This unit should include at least 5 slots for calibrations lamps. In principle the unit will include 2 halogen lamps for flat fielding which are used simultaneously; a bright one for the blue and a dimmer one for the red, each with appropriate filtering. The remaining slots are intended to be used for wavelength calibrations and will in principle consist of a ThAr, a Helium and a Neon lamp.

The light from the different lamps in the calibration unit should provide uniform illumination over the full length of the slit unit(s) (see Sect. 2.5.4 *or even better the whole area of the focal plane covered by the detector(s) of the instrument...???*) in a similar way *I guess this would need to be qualified in some way* to how it is illuminated by light coming from the telescope. Typical exposures times for the different spectroscopic set-ups with the different calibrations lamps should not exceed 10 sec *???* for properly exposed (*maybe needs better/more quantitative definition*) data over the whole slit-length.

A possibility would be to include in the design of the adapter unit (see Sect.2.8 the option to take out the mirror and/or dichroic that diverts the light from the telescope to the SCS and replace that with a lens that provides a proper illumination of the slit unit from a calibration unit positioned on the opposite side from the SCS.

In the case of an instrument design with a blue and a red arm there is no difference in requirements for the calibrations unit beyond the possibility that there would be slits for both the blue and the red arm, in which case the requirement is that both slits need to be illuminated properly. For such a design there should also be no need to use both halogen lamps for flat fielding at the time, but still 2 different lamps would be needed to provide proper flat field illumination either in the red or the blue.

3 NOTCam

It should be possible to observe with NOTCam without any additional optics in the light path. Specifically, it should be possible to move any mirror or dichroic in the adapter unit that deflects the light to the SCS our of the light path to the Cassegrain focus (see also Sect. 6).

3.1 Calibration unit

For calibration of spectroscopic observations with NOTCam a calibration unit is required. This unit should include at least 3 slots for calibrations lamps. In principle the unit will include a halogen lamp for flat fielding, with the remaining 2 slots intended to be used for wavelength calibrations which will in principle consist of a Argon and a Xenon lamp.

The light from the different lamps in the calibration unit should provide a uniform illumination over the full length of the slits in NOTCam *I guess in that respect the requirement for NOTCam calibration is/can be less stringent...* in a similar way to how it is illuminated by light coming from the telescope.

In principle, the lamps can be included in the calibration unit for the SCS (see Sect. 2.9), but the number of slots for calibration lamps should then be increased by 3 and a way should be included for the light from these lamps to illuminate the slits in NOTCam (e.g., adding a mirror plus lens to the adapter unit; see Sect. 2.8).

4 Standby Lucky Imager

Should there be a separate requirement to allow for the light to be diverted to a standby Lucky Imager, or for that matter any other (simple) instrument at a folded Cassegrain focus? The main requirement would be that switching to such a separate focus should be simple and quick. and the adapter unit should allow for it to be modified.

5 Autoguider

A permanent autoguider system should be included in the design. It should be possible to use this system, i.e., to be in focus, within the tolerance allowed by the SCS and NOTCam. The system should be able to provide a suitable guide star over 99.5% *???* of the sky.

A simple design is envisioned consisting of a permanent mirror installed off-axis on a side of the field of view provided by the telescope that deflects the light towards a direct imaging camera with a Peltier-cooled CCD.

I believe it would also be good to require a filter system, specifically to reduce the effect of differential diffraction on long exposures. In principle I would think of requiring 5 filter slots for an Open position and blue, green, red and a Grey filter...

6 Other Cassegrain instruments

Is there any requirement for the possibility to mount a different instrument than NOTCam at Cassegrain? As it is now, the requirements imply that any instrument that fits in the envelope filled by NOTCam can be mounted as long as its focal plane is within the focus movement of the secondary. If also the guide camera is needed than the focal plane of the instrument should be within the focus movement of the guide camera (see Sect. 5). The main is that it should be possible to remove the adapter unit and any polarimetry optics from the light path to the Cassegrain focus.