Southern African Large Telescope
High-Resolution Spectrograph

SALT HRS

3200AE0018 Operational Concepts Definition Document

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Issue History

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	MDA	2.1	13 March 2005	Minor revisions
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TABLE OF CONTENTS

1 Introduction

This document replaces version 1.1 of the SALT HRS R4 PDR Operational Concepts Definition Document.

2 Overview of SALT HRS Operation

SALT HRS is a cross-dispersed échelle spectrograph to be located in the spectrograph room below the telescope and fed by optical fibres from the telescope prime focus. The only moving parts within the spectrograph itself are for focus of the cameras, mechanisms to operate shutters in each of the two cameras and in front of the internally mounted fibres and a mechanism to move the input fold mirror to select light input from either the internally or externally mounted fibres. SALT HRS is explicitly designed for single-object (plus simultaneous sky) spectroscopy. Different spectral resolving powers are achieved through a choice of two image slicers or an unsliced fibre. Very accurate sky subtraction is available for the low resolving power fibre by invoking a nod and shuffle observing mode.

2.1 Focal plane mechanism

The SALT Fibre Instrument Feed (FIF) will individually position object and sky fibres in the telescope focal plane. The operations of the FIF are described in the FIF CDR document set.

2.2 Calibration mechanisms

A module within the spherical aberration corrector (SAC) will provide uniform focal plane illumination by thorium-argon and smooth-spectrum sources when required for calibration. The module will be programmable to duplicate the far-field illumination pattern of arbitrary telescope exposure tracks.

Additional to the on-telescope calibrations, the spectrograph can be fed at high resolution by a laboratory ThAr source for long term monitoring of internal drifts in image position. A laboratory flat field source will be available to near-uniformly illuminate the CCDs for the routine monitoring of pixel relative sensitivity and cosmetic defects.

2.3 Spectrograph feed

At any one time, the spectrograph will be fed by a pair of optical fibres, one each for object (F1) and sky (F2). For the medium and high resolving power modes, selectable via a turntable, each fibre exit pupil is reformatted into a pseudoslit by a Bowen-Walraven image slicer. Focal conversion optics project the pseudoslit image onto a physical slit located at the intermediate (folded) collimator focus. For the low resolving power mode, fibres with focal conversion microlenses are positioned at the direct collimator focus.

2.4 Dispersive optics

Primary dispersion is by means of a mosaic of two échelle gratings in R4 configuration imprinted on a single substrate. A dichroic is used to separate the dispersed collimated beam into blue (370 – 560nm) and red (550 – 890nm) wavelengths. Cross dispersion is by means of volume phase holographic (VPH) gratings, located at the entrances of the two cameras.

2.5 Camera optics

There are two fully refractive cameras, one for the blue and one for the red wavelengths. The blue and red cross-dispersed echellograms are imaged onto their respective detector via a field-flattening lens that forms the entrance window to the detector housing.

2.6 Camera Shutters

There are independent slow shutters at the entrance to each of the cameras to provide for different length exposure times for each detector. Fast shutters are located at the two spectrograph feed positions.

2.7 Exposure Meter

An exposure meter sensor (fibre fed photomultiplier located outside the spectrograph insulated room) will measure the first order light reflected off the gap between the two échelle gratings to enable real-time calibration of exposure signals.

2.8 Detectors

The detector subsystems are Spectral Instruments cameras containing a thinned back-illuminated 4k x 4k Fairchild CCD486 detector for the red channel and a 2k x 4k E2V 44-82 for the blue channel (both with 15 μm pixels). The CCD columns are arranged perpendicular to the échelle dispersion direction. The CCD systems are capable of vertical charge shuffling along columns to operate in conjunction with telescope nods for high-quality sky subtraction.

3 Description of Operational Modes

SALT-HRS is designed to operate in only a few modes as detailed below. These modes can be described in terms of the spectrograph feed, light source and whether or not the fibres are moved during an exposure. Permutations of these options (some of which are mutually exclusive) give a range of exposure types as given in the following tables.

Table 1. Operational modes available.

Spectrograph feed	***Illumination source***				
	Telescope			**Spectrograph**	
	Arc	**Flat**	**Sky**	**Camera flat**	**Arc**
1 High res IS	✓	✓	✓		
2 Med res IS	✓	✓	✓		
3 Low res	✓	✓	✓		
4 High res fibre					✓
5 Camera flat				✓	

Table 2: Formats for the 3 telescope fibre feeds.

Spectrograph feed	D_{fibres} ***(µm)***	N_{slices}	W_{slices} ***(µm)***	H_{slices} ***(µm)***	***Resolving power***	***Nod & shuffle available***
High res IS	350	3	80	333	65,000	
Med res IS	500	3	160	333	37,000	
Low res	500	0			16,000	✓

3.1 Fixed position observing

For most applications the spectrograph will accept light from 2 fibres, F1 and F2, individually positioned in the telescope focal plane by the Fibre Instrument Feed (FIF). Normally the second of these fibres will be used to for simultaneous measurement of background sky flux.

3.2 Nod and shuffle observing

This is available for low resolving power science exposures where very accurate sky subtraction is required. During an exposure, the FIF will execute a series of ‘nods’, repositioning the F1 and F2 entrances at two discrete positions in the focal plane. Initially the target object will be positioned on F1, with F2 acquiring sky to one side of the target. After the first nod (and subsequent odd-numbered nods), the target object will be positioned on F2, with F1 acquiring sky at a position with the same separation from the target but at an angle of 180° from the initial position of F2 relative to the target. The second nod (and subsequent even-numbered nods) of the FIF will return to the initial position.

Simultaneous to each of the FIF nods, the CCDs will shuffle charges back and forth along columns by a given number of pixels equal to the separation of the corresponding F1 and F2 order profiles on the detector. In this way, background light can be measured from positions at a fixed angle on either side of the target. Nod and shuffle observing will also equalise the target and background exposure lengths through the two fibres, thus correcting the measured background signal for differences in transmission between the fibres.

Each nod of the FIF will take less than 5 seconds to execute, while charge shuffling will take less than 0.15 seconds. The spectrograph direct feed fast shutter will be closed while nods and shuffles are executed. The nod frequency will be selectable by the user.

3.3 Calibration

The telescope thorium-argon arc and flat illumination sources are located below the spherical aberration corrector on the prime focus payload and are designed to illuminate the FIF focal plane with the same far field pattern as sky exposures.

The high resolution fibre (spectrograph feed 4) is a single 100 μm diameter fibre located at the direct collimator focus and fed by a ThAr lamp located outside the spectrograph insulated housing. This can be used to monitor internal spectrograph radial velocity drift.

The camera flat feed consists of a smooth spectrum lamp, mounted on the fibre input selection wheel, that is imaged onto a pair of fibre bundles adjacent to the slit plate that pipe the light to the camera entrances.

4 Typical sequences of operations

4.1 Fixed position observing

Acquire field using SALTICAM
Position target star and sky on fibre entrance fiducial positions
Move guide probe to guide star fiducial position
Insert 45 degree FIF feed mirror
Begin guiding
Adjust fibre positions to maximise exposure metre signal

Optionally: Deploy SAC calibration module
Switch on smooth-spectrum lamp
Open fast shutters and expose CCDs
Close fast shutters and read out CCDs
Switch off lamp and stow SAC calibration module

Optionally: Deploy SAC calibration module
Switch on Th-Ar lamp
Open fast shutters and expose CCDs
Close fast shutter and read out CCDs
Switch off lamp and stow SAC calibration module

Open fast shutters and expose CCDs
Close fast shutters and readout CCDs

Optionally: Deploy SAC calibration module
Switch on Th-Ar lamp
Open shutter and expose CCD
Close shutter and read out CCD
Switch off lamp and stow SAC calibration module

Note that smooth-spectrum calibrations are unlikely to be necessary (or requested) during observing time. Wavelength calibration during observing time is likely to be necessary only when radial velocity precision better than 100 m/s is required.

4.2 Nod and shuffle mode

As in 4.1 above except that the target exposure sequence is:

Fine adjustment of FIF probe positions
For each nod {
  Open shutter and expose CCD
  Close shutter
  Move fibre entrance probes to alternate positions and simultaneously shuffle charge
        on CCD up or down to alternate position
}
Close shutter
Read out CCD