Southern African Large Telescope
High-Resolution Spectrograph

SALT HRS

3200AE0017 Instrument Description

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Issue History

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1 Scope

This document discusses the scientific case for the instrument and compares its capability to carry out these programmes with those of other large telescopes. It also provides an overview of the optical, mechanical, electronical and software design.

This replaces the PDR document with the same number except that it is Issue 2.

2 Science Case

SALT was primarily designed for spectroscopy. PFIS will cover resolving powers from 500 to ~10,000 with a wavelength range from 320 to 900 nm. The HRS we have designed complements PFIS by providing resolving powers from 16,000 – 70,000 and wavelength coverage from 370 - 890 nm.

2.1 Science Programmes

A list of more than 50 science drivers for HRS arose from a potential user survey, carried out in late 2000 and early 2001 by Glen Mackie, the New Zealand consortium's SSWG representative at the time. The results of this survey are contained within the October 2001 presentation by UC to the SALT Science Working Group at its Wisconsin meetings (see 3250AA0001 Background Documents from the R2 design). A wide range of science programmes was proposed, with the SALT community clearly requiring a general purpose instrument with high throughput over a broad wavelength range.

The broad categories of science to be addressed by this instrument will be:

- Element abundance studies in Local Group galaxies;
- Distance determinations to Local Group galaxies;
- Extrasolar planet detection;
- Stellar internal structure and dynamics;
- Star cluster and galaxy dynamics;
- Outflow and accretion studies;
- High- and moderate-redshift galaxy spectroscopy.

3 SALT HRS Design

3.1 Optical Design

The key elements of the optical design (see 3210AE0005 for details) are multiple fibre feeds to an R4 échelle spectrograph in which cross dispersion is achieved via volume phase holographic gratings. A dichroic beam-splitter divides the light into two separate cameras (or arms, see Figure 1). The échelle grating is a mosaic of two 204 x 410 mm R4 gratings onto a single substrate in a 200 mm beam.

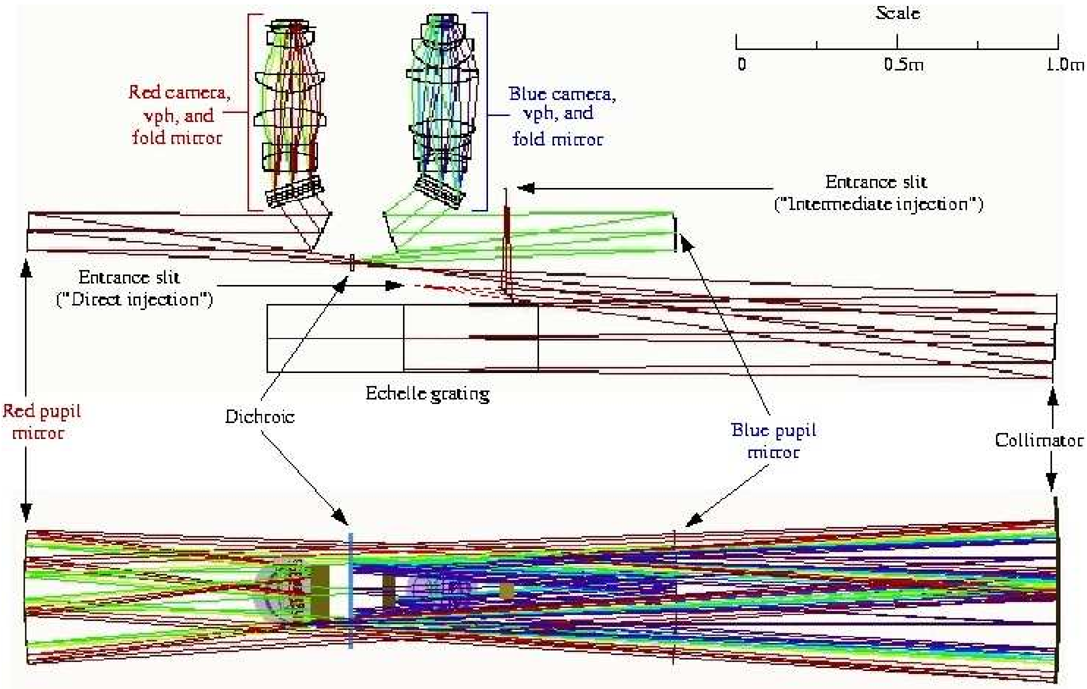

Figure 1: The ray diagram of SALT HRS R4. The input light is either by 'direct injection' or at 'intermediate injection' and deflected onto the collimator mirror by a fold mirror. The collimator serves as the first pupil mirror for both arms. A dichroic located just after the intermediate focus splits the spectrograph into its red and blue arms. Each arm has its own VPH cross-disperser and camera.

The fibre feeds are via 3 pairs of fibres, where each pair of fibres is used to simultaneously acquire the object and adjacent sky. For medium and high resolving power modes image slicers, located at the spectrograph's intermediate injection entrance slit, will be employed. The resolving powers to be provided are summarised in Table 1.

A nod and shuffle mode will be provided for precision sky subtraction at the lowest resolving power by 'nodding' the fibres between the object and sky in the focal plane of the telescope, while charges are "shuffled" simultaneously on the blue and red detectors. The detectors are a single 2k x 4k CCD for the blue camera and a 4k x 4k CCD for the red camera, with their long axes (columns) oriented perpendicular to the direction of échelle dispersion to enable charge shuffling.

Pair fibres (microns)	# Slices	Fixed Object & Sky	Nod & Shuffle
500	0	16,000	16,000
500	3	37,000	-
350	3	65,000	-

Table 1: Resolving powers from various combinations of pairs of fibres and image slices.

Figures 2 and 3 show the échelle spectrum as imaged onto the detectors. The combination of blue and red cameras will mean that in a pair of simultaneous exposures there will be complete wavelength coverage from 370 to 890 nm.

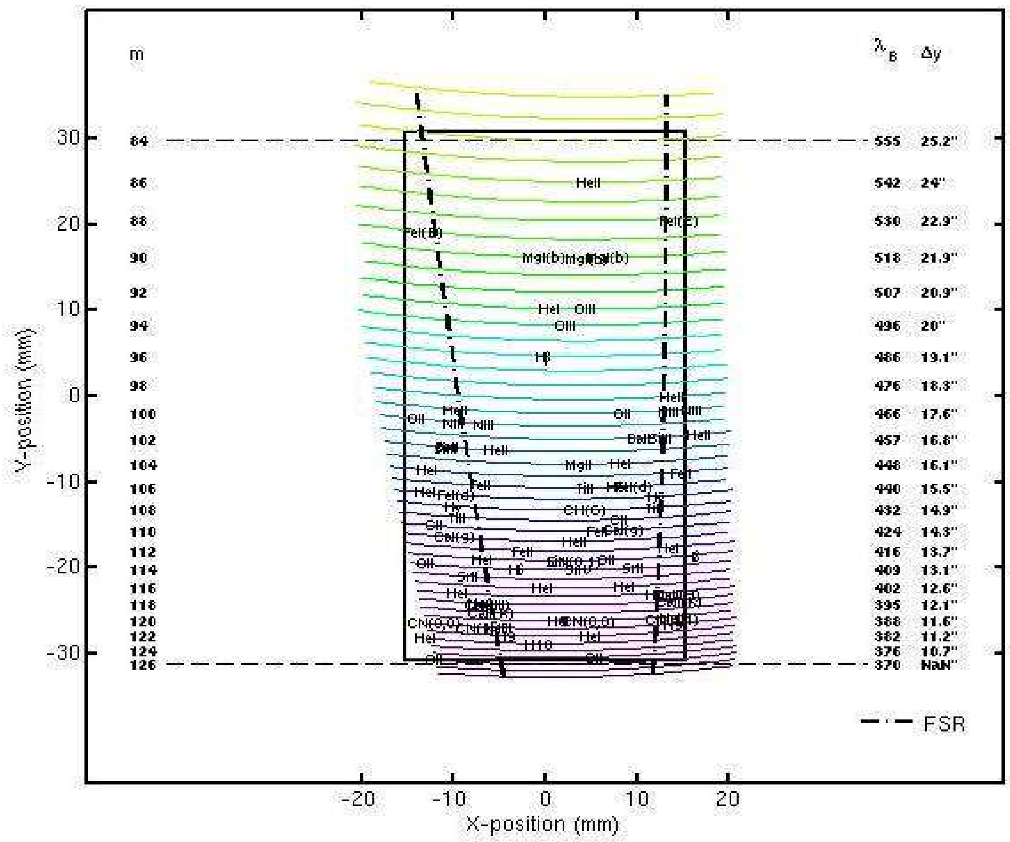

Figure 2: The SALT HRS blue camera spectral format. The dot-dashed line shows the extent of one free spectral range (FSR). The central blaze wavelength (λ_B) for alternate orders (m), and the spatial separation (in arcsecs) between each orders projected onto the sky are also indicated. The outline of a single 2k by 4k CCD with 15μm pixels is shown.

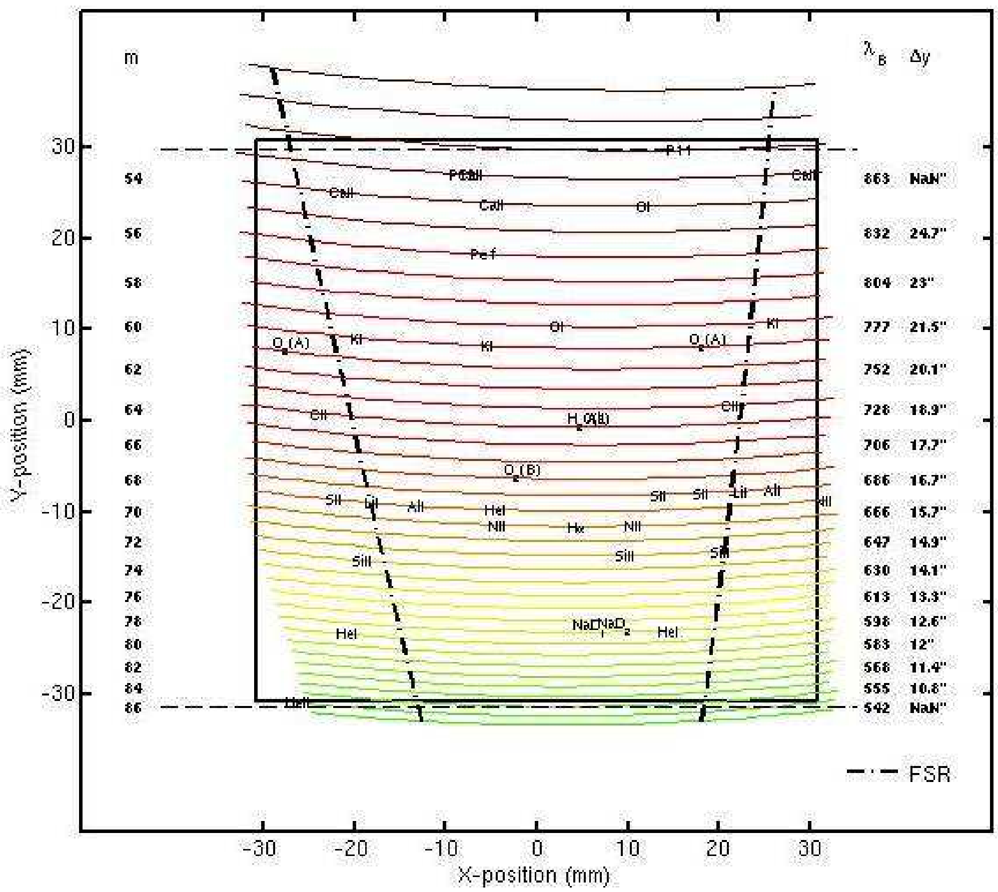

Figure 3: The SALT HRS red camera spectral format. The outline of a mosaic of a 4k by 4k CCD with 15μm pixels is shown.

3.2 Mechanical Design

The mechanical design (see 3220AE0004 and an example in Figure 4) provides a rigid enclosed framework to ensure mechanical and thermal stability. The whole spectrograph will be evacuated to enable precise wavelength calibration and a clean environment. The entire instrument will be enclosed in an insulated room to provide additional thermal stability.

The optical bench weldment (Figure 5) provides the central hub for the instrument, with all the optical elements, with the exception of the collimator, being placed on the optical bench. The collimator mirror is attached to the optical bench through a truss structure (see Figure 4).

Light enters the spectrograph via optical fibres from the Fibre Instrument Feed (FIF) and is either by direct injection at the lowest resolving power (16,000) or through the 'slit pocket' (see Figure 6). This 'pocket' (see 3230AE0030 for details) contains two pairs of image slicers on a rotating stage to produce the medium and high resolving powers, 37,000 and 65,000 respectively.

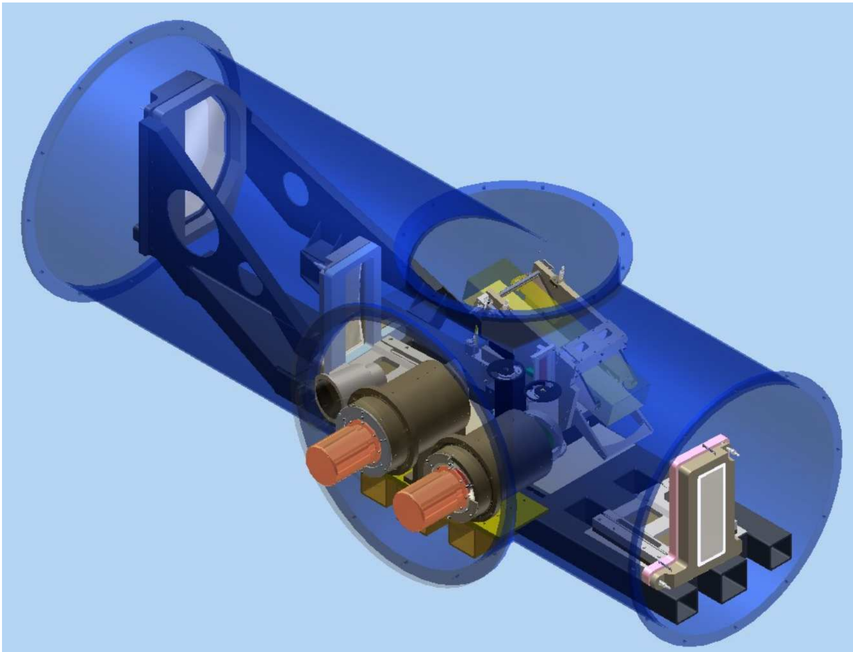

Figure 4: Layout of the whole spectrograph.

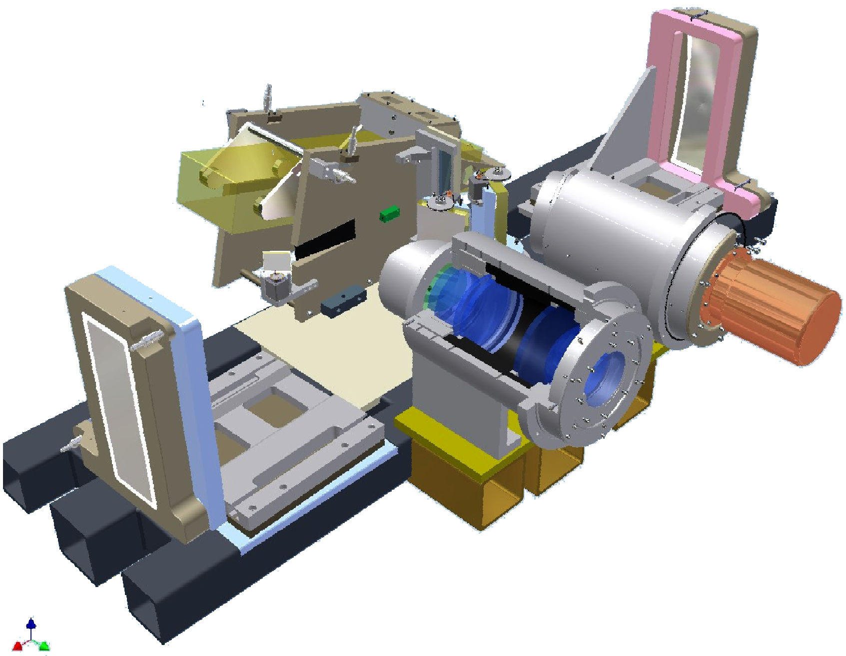

Figure 5: The spectrograph components on the optical bench viewed from the blue pupil mirror end. (The collimator, with its truss extension at the blue mirror end, is not shown.)

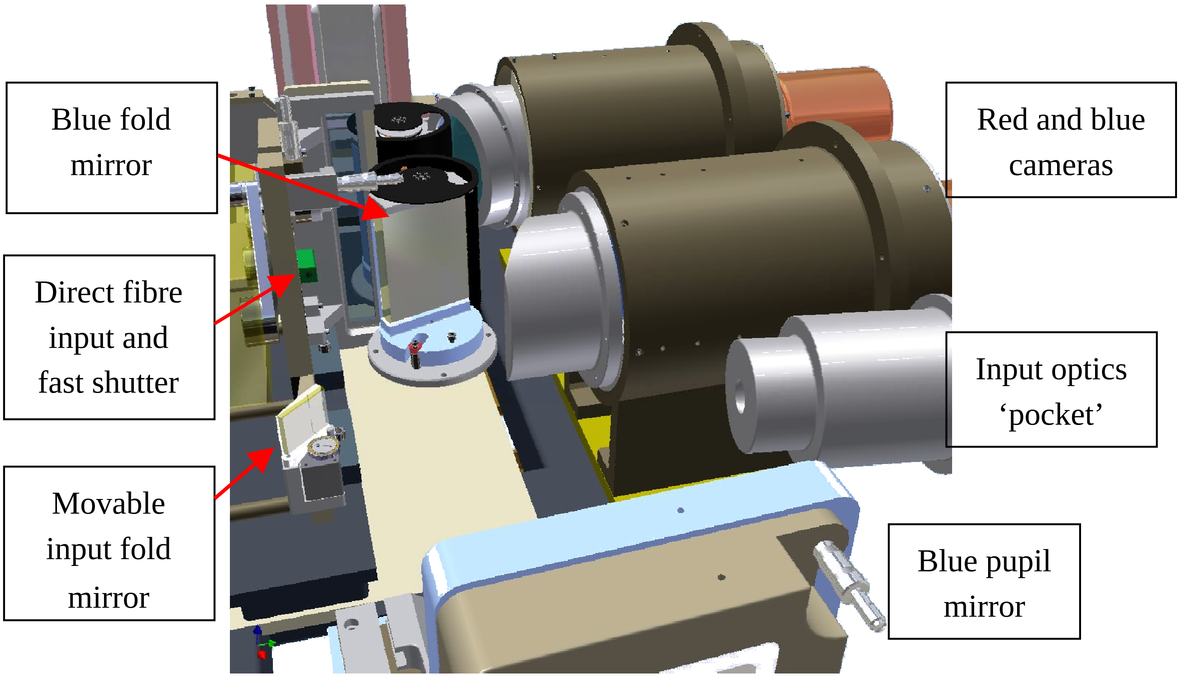

Figure 6: Input optics ‘pocket’ (centre right), movable input fold mirror (left), direct fibre input (centre left), blue pupil mirror (foreground) and blue fold mirror with red and blue cameras (middle and top right).

3.3 Electrical design

The electronics control system (see 3250AE0029) enables the HRS computer to control all of the electro-mechanical functions (fibre selector, fast and slow shutters, fold mirror, camera focus, flat-field and wavelength calibration lamps, temperature and pressure monitoring) of the spectrograph. It acts as an interface between the control computer and the devices. The electronics control system performs all the low level tasks associated with positioning actuators and reading temperatures and pressure. Also associated with the electronics control system is the slit-viewing camera and the exposure meter.

3.4 Software

The HRS software (see 3240AE0002) will provide the capability to control the electro-mechanical mechanisms described above as well as the Detector subsystems, enforce any conditions required by the electronic and electromechanical systems to prevent damage to the instrument, provide status information for each electronic subsystem, control the slit viewing camera and exposure meter, provide data from each temperature and pressure sensor and error recovery operations for each system.

4 Comparison with other Telescopes

Efficiency calculations indicate that this spectrograph will have a throughput comparable to similar instruments on other large telescopes but with considerably better wavelength coverage (see Table 2 for SALT HRS and Table 3 for other instruments).

	Blue arm	**Red arm**
Wavelength range:	370-555	555-890nm
Resolution/slit product:	27,000	
Maximum resolution:	70,000	
Camera:	f/1.5	f/1.8
Echelle:	R4, 41.6 gv/mm	
Beam size:	200mm	
Pupil mag:	1.8	1.8
Cross-dispersion:	VPH grating	VPH grating
	1850 ln/mm	855 ln/mm
Max λ coverage:	520 nm	
Total efficiency: telescope, fibre, spectrograph, detector:	13% (450nm)	17% (650nm)

Table 2: Key parameters for SALT HRS.

Telescope:	VLT		Keck	Subaru	HET	Gemini S.	LBT	
Spectrograph:	UVES		HIRES	HDS	HRS	bHROS	PEPSI	
D_{tel}	8.4 m		10 m	8.2 m	9.2 m	8.4 m	2×8.4 m	
Wavelength range (nm):	300–500	420–1100	320–1100	320–1100	420–1100	400–1000	390–580	580–1050
Echelle:	R4	R4	R2.8	R2.9	R4	R2	R4	
gv/mm:	41.59	31.6	52.6	31.6	31.6	87.0	31.6	
Beam size (mm):	200	200	305	305	260	200	200	
Resolution-slit product:	41 400	38 700	39 000	38 000	30 000	21 000	40 000	
Maximum Resolution	80 000	110 000	67 000	165 000	120 000	150 000	120 000	120 000
Pupil mag.:	1	1	n/a	n/a	1	n/a	1.5	1.5
Cross-dispersion	SR grating 1000 gv/mm 660 gv/mm	600 gv/mm 312 gv/mm	SR grating ?? gv/mm 250 gv/mm	SR grating 400 gv/mm 250 gv/mm	SR grating 600 gv/mm 316 gv/mm	Prism 2 × silica 60°	VPH grisms 940 l/mm 15.5°	460 l/mm 13.6°
Camera:	dioptric $f/1.8$	dioptric $f/2.5$	catadioptric $f/1.0$	catadioptric $f/0.96$	dioptric $f/2.8$	reflecting $f/0.96$	dioptric $f/2.3$	dioptric $f/2.3$
CCD:	EEV	EEV & MIT/LL	SITe	EEV	Marconi	Marconi	EEV	EEV
Format:	2k × 4k	2k × 4k	2k × 2k	2×(2k × 4k)	2k × 4k	2k × 4k	4k × 4k	4k × 4k
Pixels:	15 μm	15 μm	24 μm	13.5 μm	15 μm	15 μm	15 μm	15 μm
Max. λ coverage:	85/126 nm	200/403 nm	~250 nm	~400 nm	380 nm	~160 nm	660 nm	
DQE:	12%	14%	10%	13%	~7%	12.6%	–	–
λ	400 nm	600 nm	600 nm	600 nm	600 nm	600 nm		

DQE's are from top of telescope with "wide slit".
HET HRS predicted efficiency.
bHROS coverage not continuous.
PEPSI parameters based on 8 arcsec order separation and complete wavelength coverage.

Table 4: Comparison of high resolving power spectrographs on large telescopes.