LIRIS: A Long-Slit Intermediate Resolution Infrared Spectrograph for the WHT

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LIRIS is an Instituto de Astrofísica de Canarias (IAC) project that consists in a near-infrared (0.9–2.4 microns) intermediate resolution spectrograph, conceived as a common user instrument for the WHT.

LIRIS will have imaging, long-slit and multi-object spectroscopy observing modes ($\Re$~1000–3000). Coronography, and polarimetry capabilities will eventually be added. Image capability will allow easy target acquisition for spectroscopy.

Focal station	Cassegrain
Array format	Rockwell Hawaii 1024×1024 HgCdTe
Scales at detector	0.25 arcsec/pixel
Observing modes	Imaging, long-slit spectroscopy, multi-object spectroscopy, coronography with apodization masking and polarimetry
IMAGING MODE	
Field of view	4.2×4.2 arcmin
Sensitivity	K=22.13, H=23.68, J=24.75, Z=25.24 for t=1h, S/N=3, 0.5” seeing
SPECTROSCOPY MODE	
Available slits	Long slit: (0.5, 0.75, 1, 2.5, and 5) arcsec×4.2 arcmin Multi-object: 10 multislit masks available (up to 24 slits per mask)
Spectral coverage and sensitivity*	$\Re$=1000 Bands Z and J (0.887–1.531 mm). Limiting magnitudes J=21.3, Z=22.0 Bands H and K (1.388–2.419 mm). Limiting magnitudes K=18.6, H=19.9 $\Re$=3000 Bands Z (0.997 to 1.185 mm). Limiting magnitude Z=21.2 Bands J (1.178 to 1.403 mm). Limiting magnitude J=20.3 Bands H (1.451 to 1.733 mm). Limiting magnitude H=19.5 Bands K (2.005 to 2.371 mm). Limiting magnitude K=18.0 *In all cases for the continuum and t=1hr, S/N=3, FWHM=0.5"

Table 1. Instrument features.

1. Scientific Drivers

Given its common-user status, it should be possible to use LIRIS for a wide range of astrophysical disciplines, including the areas of stellar, planetary, extragalactic and cosmological physics. We list below some of the most relevant potential scientific applications:

- Spectroscopy of proto-planetary nebulae.
- Detection of very low mass secondaries, planets and brown dwarfs.
- Spectroscopy of nearby and distant galaxies with massive star formation: nearby HII regions and distant starbursts.
- Stellar kinematics and populations in spiral galaxies.
- Physical conditions of the gas, and the stellar kinematics and populations of starburst galaxies and AGNs.
- Ultraluminous infrared galaxies.
- The fundamental plane of high-redshift elliptical and S0 galaxies.
- Redshift measurements of infrared sources.

2. General Description

The optical system is based on a classical collimator/camera design (Figures 1, 2 and 3). The expected throughput (averaged across the wavelength range) for the optics is 80% and 64% in imaging and spectroscopic modes, respectively. The total throughput including filters, grisms and detector is 35% and 30% in imaging and spectroscopic modes, respectively. Grisms are used as the dispersion elements (the grism transmission is assumed to be 80%). Low resolution grisms are manufactured in Corning 9754 (Figure 4) while medium resolution will be manufactured in ZnSe. A set of filters (broad band, Z, J, H, K_s and narrow band Br-α, K-continuum, H-continuum, [FeII], H_2 (v=1–0), H_2 (v=2–1), CH_4 and HeI) have been acquired through a consortium headed by Alan Tokunaga.

The mechanical design is based on a modular concept, integrated by the following modules: the aperture

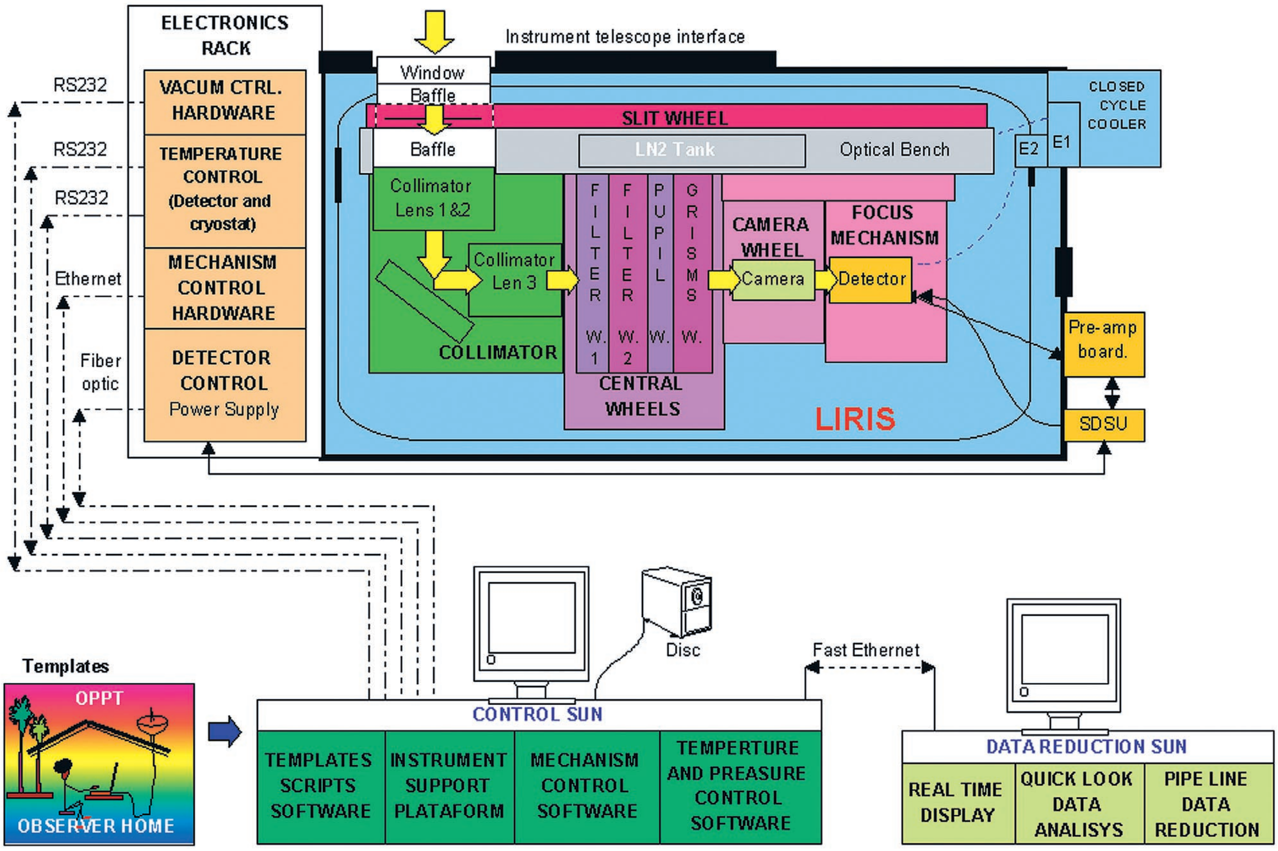


Figure 1. LIRIS schematic representation.

wheel (slit wheel), the collimator assembly, the central wheel assembly (formed by two filter wheels, the pupil wheel and the grism wheel), the camera wheel and finally the detector assembly with its focussing mechanism. The detector will be mounted in a cold translation mechanism to compensate for non-achromaticity along the observing spectral range.

The detail optical design and the conceptual mechanical design were subcontracted to the ROE (Royal Observatory of Edinburgh).

The slit wheel (Figure 5) contains 16 positions: one blank position, five long slits and ten multislit positions. The two filter wheels contain 12 positions each, and will hold the filters and the Wollaston prisms. The pupil wheel (Figure 6) contains 12 positions and will hold the pupil masks, plus an optional apodization mask with rotation mechanism for coronography capabilities. The grisms wheel has 10 positions for grisms. The camera wheel (Figure 7) has four positions and will carry the camera and the optics to re-image the pupil onto the detector plane, as well as an aperture and a black aperture. All mechanisms use Phytron cryogenic stepping motors and the control system is based on a VME system.

The instrument is pre-cooled with LN_2, and the cooling system is a two-stage closed-cycle refrigerator (Figure 8) (CTI model 1050C), which works on the Gifford-McMahon cycle.

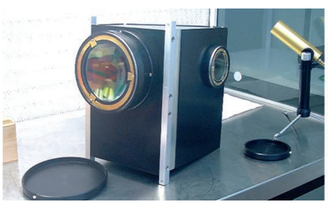
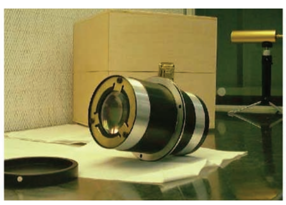
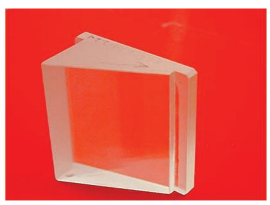
The detector is a Hawaii 1024×1024 HgCdTe array using a SDSU controller, which communicates with the control computer (SUN workstation) using the SBUS card.

An agreement has been established between the IAC and the ING to develop jointly the detector control system and the Mechanism Control Software for the two infrared instruments (LIRIS/IAC and INGRID/ING).

The LIRIS Software system is being designed to be fully integrated in the observer environment available at the WHT. A common observer will have access to the following software packages: Instrument Simulator Software, Templates Generator Software, Instrument Support Platform User Interface, LIRIS Mechanism and Thermal Control Software, Real Time Display, Quick Look Data Analysis and Pipeline Data Reduction.

3. Current Status

At present LIRIS is in the calibration phase at IAC. Assembly, integration

From left to right: Figure 2. Collimator. Figure 3. Camera. Figure 4. Corning 9754 Gris.

and verification phases were carried out in summer 2001.

The collimator, camera, slits wheel mechanism and the main central wheel (filter 1 and the pupil wheel) mechanism have been successfully tested at test cryostats (Figure 9) in cryogenic conditions. They have also been pre-integrated on LIRIS to check the interfaces (Figures 10, 11 and 12).

Test multi-slits masks have been manufactured by Electric Discharge Machining (EDM) and successfully tested achieving a roughness of 1.15±0.15 microns.

The engineering and the scientific detectors have been tested in cryogenic conditions on a purpose-built detector test bench (Figures 13 and 14). The main characteristics of the science degree array at 80 K are as follows: readout noise ~20 e^-, dark current 0.065 $e^- s^{-1}$, bad pixels <1.5% and the detector behaves linearly within 2% up to 50% of the full-well (175,000 e^-). The signal offset was found to vary 670 e^-/K with the detector temperature. The current temperature controller permits a stability of better than 0.005 K, which implies a signal offset variation of less than 4 e^-.

In November 2001 the LIRIS Cryostat integration was started (vacuum tank, optical bench, closed-cycle cooler, radiation shields, etc.) (Figures 15, 16, 17 and 18) and in December the first cool-down was successfully completed (Figures 19 and 20).

The following LIRIS cool-down took place in March and it included the slit wheel mechanism, collimator, central wheels mechanisms (two filter wheels, pupil and grisms wheels) and the camera mechanism. First light and commissioning at the telescope is expected at the beginning of 2003.

For on-line information about the LIRIS project, please visit our web site at: `http://www.iac.es/proyect/LIRIS/`. ¤

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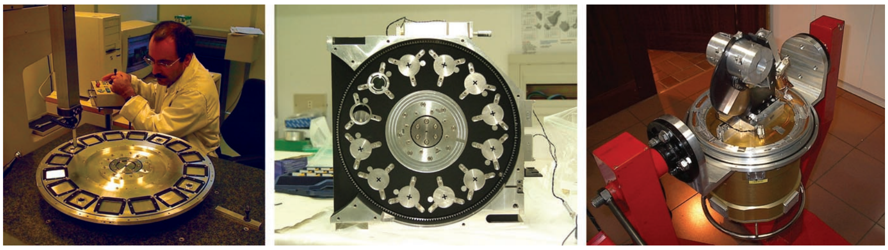
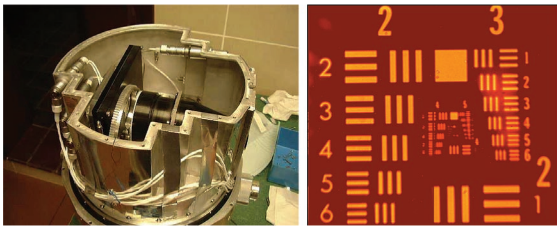


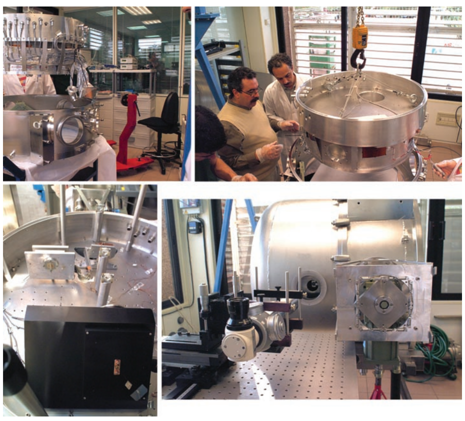
From left to right: Figure 5. Slit wheel. Figure 6. Pupil wheel. Figure 7. Camera wheel integrated in the test cryostat (dummy on camera position).

Left: Figure 8. Closed-cycle refrigerator with the two-stage thermal links integrated. Right: Figure 9. Mechanism cryostat on the Mitutoyo during the functional verification of the main central wheels module.

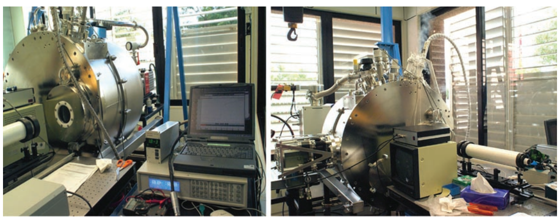
From left to right: Figure 10. Main central wheel module (filter wheel side) pre-integrated on LIRIS. Figure 11. Bottom view of the slit wheel mechanism. Figure 12. Pre-integration of the slit wheel on the LIRIS optical bench.



Left: Figure 13. Internal view of the detector test cryostat. Right: Figure 14. Image of an USAFSR pattern taken with the scientific grade detector, through the H-band filter.



From top to bottom: Figures 15 and 16. Positioning the optical bench on the trusses in the vacuum tank central ring (cables provisionally fixed for this cycle). Figures 17 and 18. Optical bench with the collimator and reticules placed in specific positions to check their behaviour during the first cycle (these reticules were visible at all time through a very useful cryostat auxiliary window, see Figure 18). A simulation of the detector module was placed outside the beam line to test the detector thermal control system.



Left: Figure 19. LIRIS cryostat ready for the first cycle. Right: Figure 20. Pre-cooling with liquid LN_2.