A unique infrared spectropolarimetric unit for CRIRES+

Nikolai Piskunov[1], Eric Stempels[1], Alexis Lavail[1], Michael Escuti[2], Andrei Dolgopolov[1], Artie Hatzes[3], and the CRIRES+ consortium

1: Uppsala University, 2: ImagineOptix, 3: Thüringer Landessternwarte Tautenburg

UPPSALA UNIVERSITET

https://crir.es

Introduction

CRIRES+ is the upgrade of the ESO high-resolution infrared spectrometer for the Very Large Telescope (Dorn et al. 2016). One of its new component is the full Stokes vector spectropolarimetry unit (SPU). Positioning the SPU directly after the tertiary mirror of the VLT minimizes instrumental polarization but creates compatibility issues with the adaptive optics (AO) system down the optical path. A double image of a point source as produced by a traditional beam-splitter makes AO operation unstable.

Design

The solution is to construct beam-splitters using a pair of polarisation gratings (PGs; Packham et al. 2010) with transition wavelength set at the boundary of AO and science spectral range. In this configuration, most of the light in the visible continues as through a plane-parallel glass plate. In the infrared most of the light is separated by polarization into two parallel beams. PGs were optimized for YJ and HK bands. The designed SPU needs to measure both linear and circular polarisation components, across two operational bands: YJ and HK. Measuring linear polarisation is made possible by inserting an additional λ/4 retarder in front of the beam-splitter. In CRIRES+, these different observing modes are implemented by mounting four beam-splitters on an octagonal turret. Rotation of the turret selects the operation band and corresponding circular/linear beam-splitter.

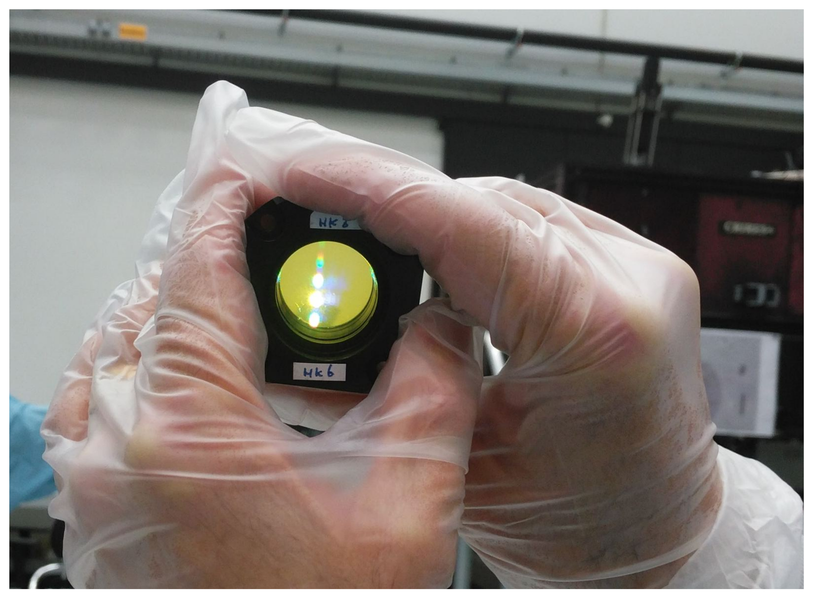

Fig. 1: Optical spotlight shone through a beam-splitter optimized for the HK-bands

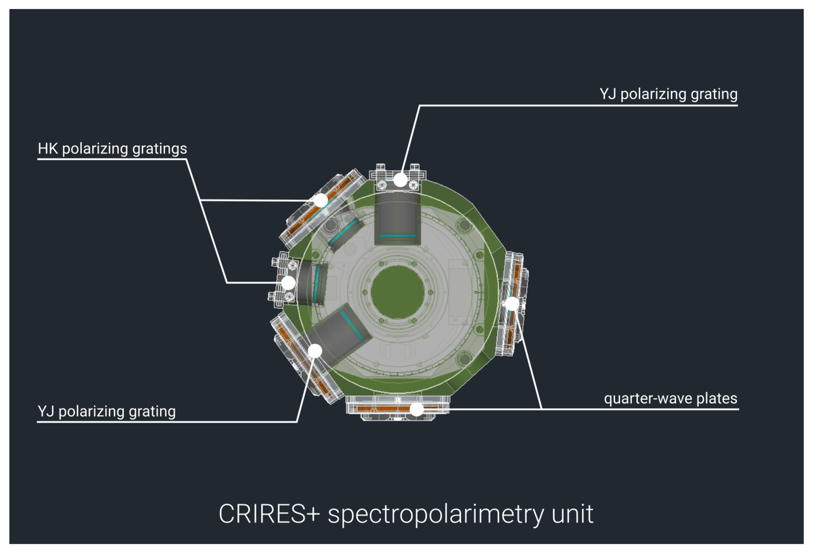

Fig. 2: Top view of the schematic design of the spectropolarimetry unit for CRIRES+ with its four beam-splitters

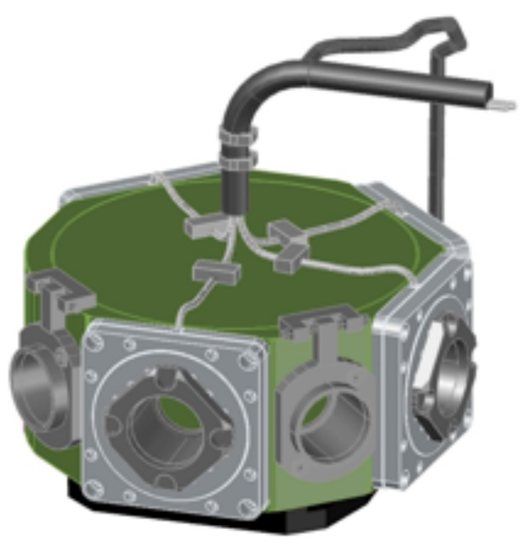

Fig. 3: 3D view of the schematic design of the spectropolarimetry unit for CRIRES+

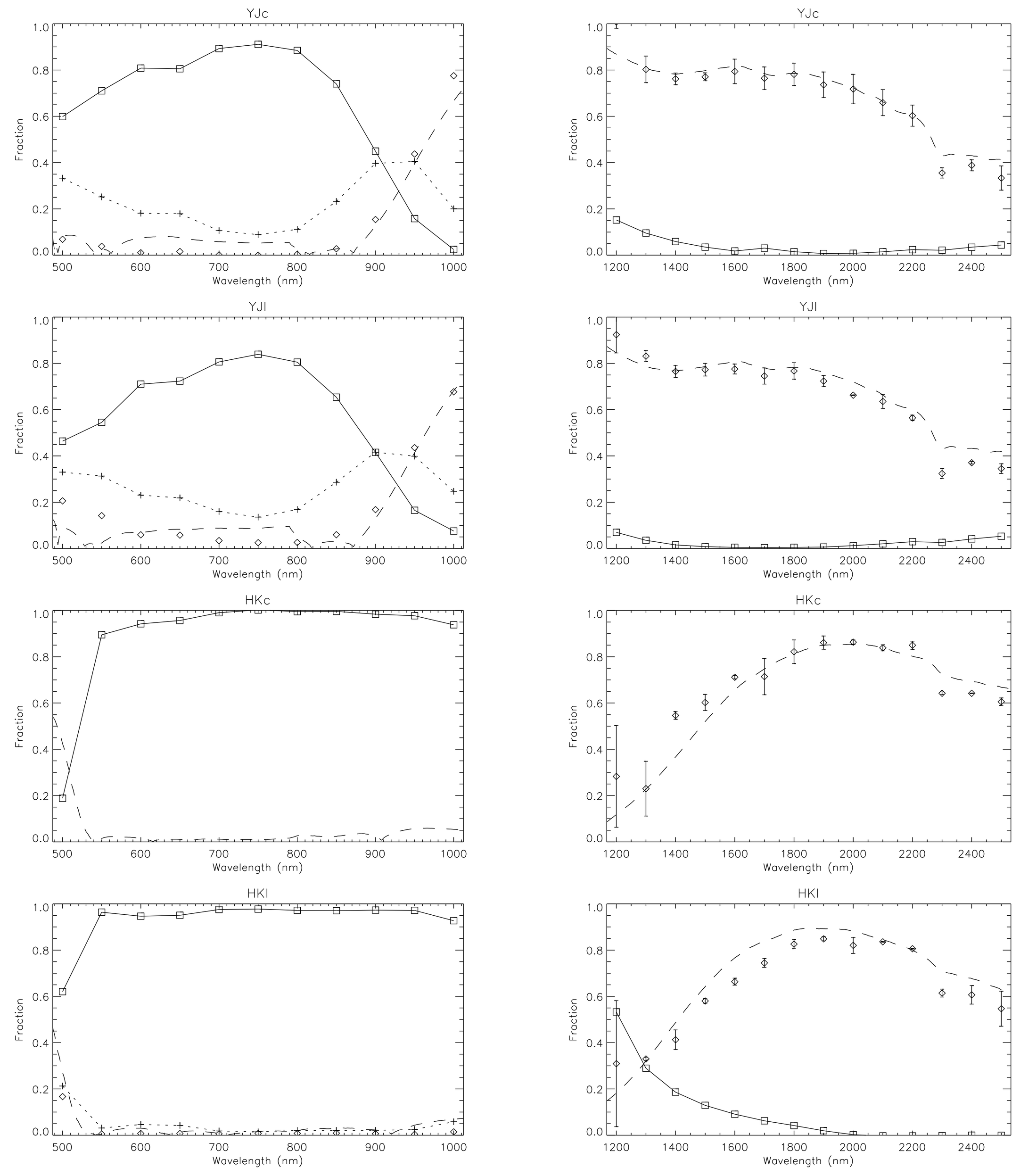

Fig. 4: Measured throughput in the optical (left column) and near-infrared (right column) of different beam-splitters. Solid line with squares: undeviated unpolarized beam, dashed line with rhombi: sum of the two polarized beams, dotted line with plus: polarisation ghosts.

Fig. 5: Surface plots of the measured intensity of the polarized beams after a beam-splitter

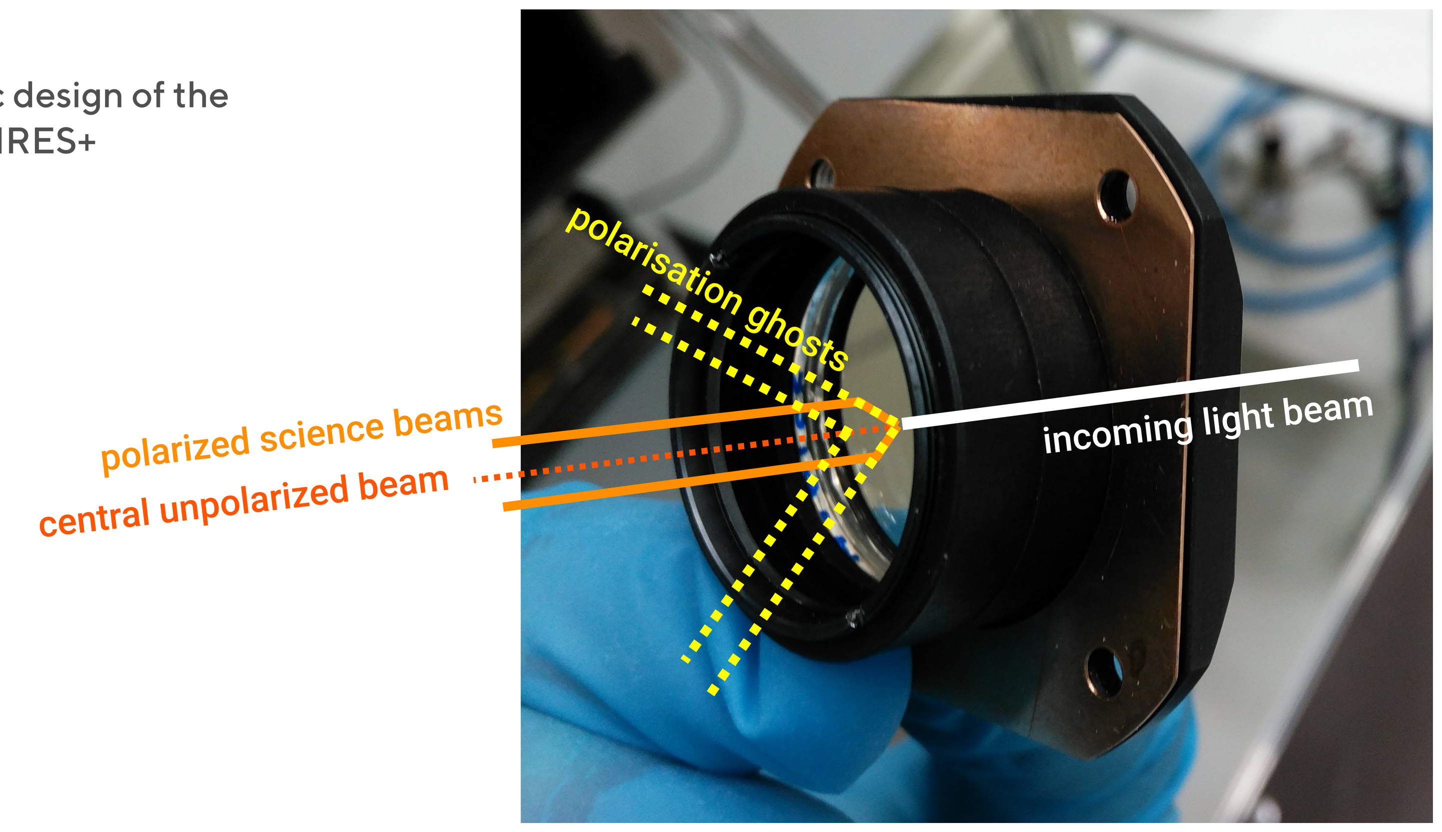

Fig. 6: Picture of a beam-splitter with schematic ray-tracing

Throughput and operation

Polarisation gratings were designed and manufactured by ImagineOptix, then assembled and tested at Uppsala University. The PGs are chromatic, which means that the dispersion angle of the polarized beams depends (slightly) on wavelength. In our beamsplitters this leads to a variable beam separation. Therefore, it is important to align the beamsplitter along the entrance slit of CRIRES+. The measured throughput reaches well above 30% of the incoming light in each of the polarized beams. A two-hole decker on the entrance slit minimizes contamination and blocks the remains of undeviated light. Beam switching for circular polarization is achieved by rotating the beam-splitters. For linear polarization, beam switching is achieved by rotating the λ/4 retarder in front of the beam-splitter.

Conclusions

The SPU was assembled and integrated with the CRIRES+ calibration unit in Garching. Its operation was implemented in the instrument control system and the compatibility with the AO system was tested using telescope and turbulence emulator. The tests confirm the efficiency of our design solutions.

References

Dorn, R. J., Follert, R., Bristow, P., et al. 2016, in Ground-based and Airborne Instrumentation for Astronomy VI, Proc. SPIE, 9908, 99080I

Packham, C., Escuti, M., Ginn, J., Oh, C., et al. 2010, in Publications of the Astronomical Society of the Pacific, 122, 1471.