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JPCam: Development of a 1.2 Gpixel Camera for the J-PAS Survey

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Abstract

To carry out J-PAS survey, the JST/T250 telescope at the Observatorio Astrofísico de Javalambre (OAJ) is equipped with JPCam, a panoramic camera designed to exploit survey capabilities of the telescope. JPCam is a direct imaging instrument designed to work in a fast convergent beam at the telescopes Cassegrain focus. It is based on state-of-the-art, high efficiency, low noise 9.2k-by-9.2k, 10μm pixel CCDs specially developed by e2v for JPCam. The instrument is equipped with a 1.2Gpixel mosaic of 14 CCDs providing a useful FoV of 4.7 deg2 (67% focal plane coverage) with a plate scale of 0.2267 arcsec/pix. Moreover, JPCam includes 12 auxiliary detectors for auto-guiding and wave front sensing purposes. JPCam is completed with an innovative set of 59 optical filters specifically designed to perform accurate BAO measurements, main science driver of J-PAS.

1 Introduction

The main scientific instrument for JST/T250 is JPCam, a 1.2 Gpixel camera that will be installed at the Cassegrain focus of the JST/T250 telescope. JPCam has been designed to perform the J-PAS survey, so maximising FoV and wavelength coverage while guaranteeing a high image quality over the whole focal plane and providing low read noise images have been the main instrument design drivers.

JPCam is a wide field, direct imager equipped with a mosaic of 14 CCD290 9.2k-by-9.2k, 10μm pixel backside illuminated, low noise detectors from e2v. Each science CCD is read from 16 ports simultaneously, allowing in its nominal operational mode a read out and data download of the whole focal plane in 19s (full frame) or 8.5s (2x2 binning) with a read noise of 5.4 electrons (RMS).

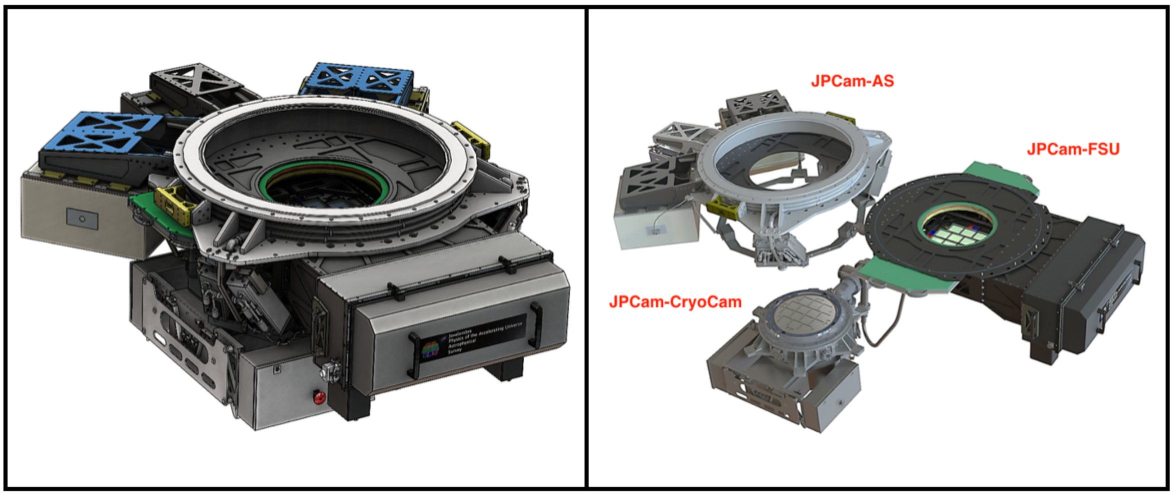

Figure 1: JPCam 3D model design. Left panel shows a fully assembled JPCam while in the right panel shows a deployed view identifying the three main subsystems.

The instrument is broken down into three main subsystems: cryogenic camera (CryoCam), Filter and Shutter Unit (FSU) and Actuator System (AS), described below. Table 1 summarises JPCam performances and figure 1 shows the instrument 3D model design with its three main subsystems identified. The definition and procurement of JPCam is lead by CEFCA and the J-PAS Collaboration. The instrument has been funded by a consortium of several institutions from Spain (CEFCA and IAA-CSIC) and Brazil (ON, IAG/USP, and CBPF).

2 JPCam-CryoCam

The CryoCam comprises the powered dewar entrance window, the CCD mosaic and their associated controllers, the cooling and vacuum systems and the image acquisition electronics and control software. The JPCam-CryoCam has been supplied by e2v (Chelmsford, UK).

Table 1: JPCam performances

FoV	4.7 deg2 (14 x) 0.58deg x 0.58deg
CCD format	(14x) 9,216 x 9,232 pix, 10 μm/pix 1.2 Gpix camera
FoV coverage	4.7 deg2 (fill factor 67%)
Pixel scale	0.23 arcsec/pix
Read out + data download time (633kHz) Read out noise (633kHz)	19.3s (full frame) – 8.5s (2x2 binning) 5.4 e- (RMS)
Read out + data download time (400kHz) Read out noise (400kHz)	24.7s (full frame) – 11.3s (2x2 binning) 4.5 e- (RMS)
Full well	123,000 e-
QE	40% (350nm), 86% (400nm), 93% (500nm), 93% (650nm), 61% (900nm)
Minimum exposure time	0.1s
Exposure homogeneity	1 ms
Dark current	0.001e-/pixel/s
Number of filters	56 + BB (J-PAS filters)

The heart of the camera is the focal plane mosaic, composed by a total of 26 CCDs, 14 large format, science detectors plus 12 auxiliary CCDs for autoguiding and wavefront sensing. The flatness of the focal plane is one of the most challenging and important requirements on JPCam as it directly impacts on final image quality. The achieved science CCD mosaic flatness is 27m peak-to-valley, measured at operating temperature.

The data from the sensors is gathered in the Detector Electronics Box and transmitted via four Camera Link ports to two PCs, the science PC and the AG & WFS PCs Two fibre optic channels are used to transmit the Science CCD data to reduce the data transmission time. The proximity drive electronics achieves total system level noise performance of 5.4e- from the 224-channel CCD system when reading out the system at 633kHz. This allows a read out and data download of the whole CCD mosaic in 19s (full frame) of 8.5s (2x2 binning).

The cryostat is cryo-cooled with liquid nitrogen. Two LN2 tanks, mounted on the telescope fork, will feed the cryostat through routing of the flexible cooling lines via the telescope cable wraps, as required to accommodate both Cassegrain and altitude rotation. The cooling system controls the focal plane to a temperature of -100degC with a variation across the focal plane of better than 2.5degC and a stability of better than +/- 0.5degC over the long periods of operation required. The chamber will be evacuated to a level of 10-6 Torr using a serviceable turbo-pump and pressure will be maintained during operation using sorption pump material.

The camera entrance window is in fact the forth element of the JST/T250 field corrector, and together with the filters, it is part of the telescope optical design optimization. The

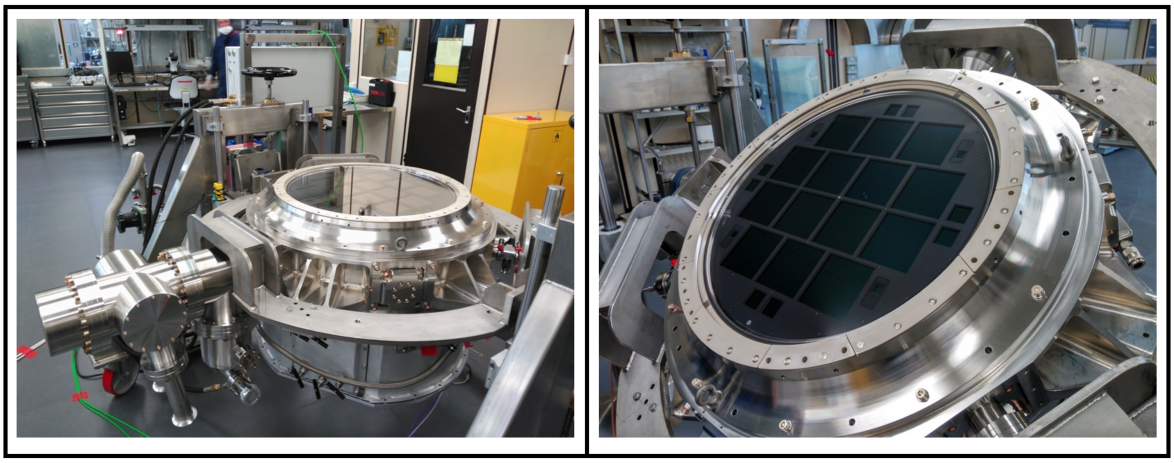

Figure 2: JPCam-CryoCam and focal plane pictures taken during the final acceptance of the system at e2v's clean room.

window is a 580mm diameter and 29mm thick, weakly powered field-flattener with an 8mm distance between its inner surface and the focal plane mosaic. The dewar window has been supplied by Glyndwr Innovations Limited (St. Asaph, UK).

Figure 2 shows a picture of the JPCam-CryoCam at e2v clean room during the final acceptance review of the system. This figure also shows a closer picture of the focal plane, where the 14 science and the 12 auxiliary CCDs can be clearly seen.

3 JPCam-AS

Because of the JST/T250 telescopes very wide FoV combined with the confirmed excellence of the OAJs intrinsic site seeing, JPCam is required to fully optimise and maintain the image quality across the full focal plane of the mosaic. Optical analysis revealed that it is necessary, not only to guide the telescope and keep it optically aligned by adjusting the position of its secondary mirror, but also of the focal plane itself. To perform this task JPCam includes the JPCam-AS, an hexapod that is controlled thanks to a set of wavefront sensors included in the periphery of the cryogenic camera focal plane FoV. The JPCam-AS attach the cryogenic camera to the telescope and provides the required focus and tilt adjustments to the focal plane. The JPCam-AS has being supplied by Sener (Barcelona, Spain). The JPCam-AS is able to position the JPCam-Cryocam, whose weight is about 600Kg, with an accuracy of +/-4μm (focus) and +/-20 arcsec (tip-tilt). The JPCam-AS is controlled by a Drive Motion Controller (GeoBrick Drive) and monitored through a set of linear, absolute encoders. The system has been designed to perform one movement in less than 2 seconds.

4 JPCam-FSU

The FSU comprises the filter tray exchange mechanism and the shutter. The JPCam-FSU has been designed to admit 5 filter trays, each mounting 14 square filters corresponding to the 14 CCDs of the mosaic. Each CCD will view only its corresponding filter avoiding optical cross-talk from their neighbors. The filters will operate close to, but up-stream from, the dewar window in a fast converging beam. With this configuration, JPCam will cover 4.7 deg2 (67% focal plane coverage) with a plate scale of 0.2267 arcsec/pix and will allow all the 70 required filters (59 J-PAS filters plus several copies of the broad-bands) to be permanently installed on the camera, so no night-to-night filter exchange will be required. JPCam-FSU has being designed in collaboration with Astro-EME, USA, and has been supplied by The Vacuum Projects (Spain) and Jaguar Precision Machine (USA). The massive 515mm aperture shutter is from Bonn-Shutter UG.

The 5 filter trays are selectable remotely so the FSU will include the motors and encoders and the control system needed for their operation. Each filter tray is designed to be easily and manually removable and exchangeable from the closed frame. Individual filters can be manually removable from their tray once the tray has been removed from the module. Figure 3 shows the JPCam-FSU during its integration at CEFCA's lab.

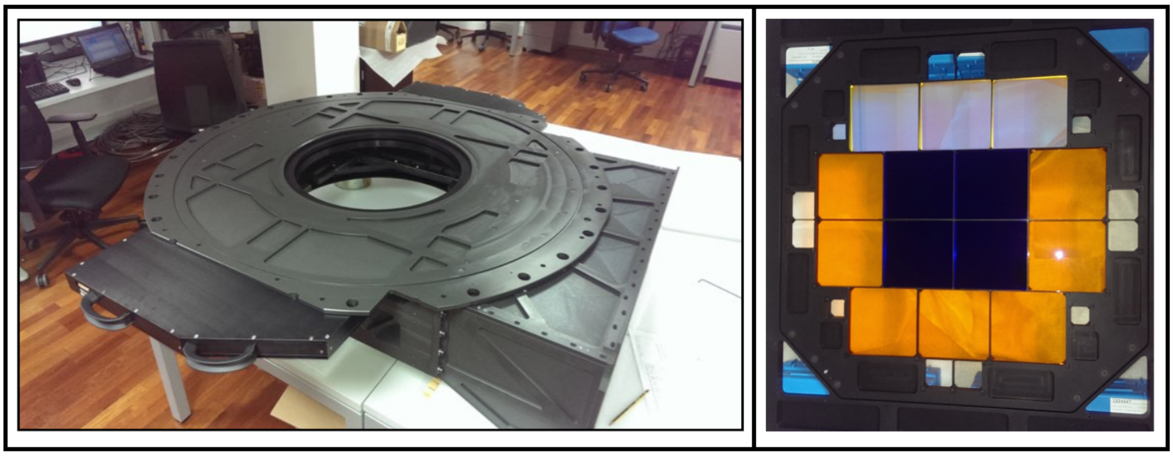

Figure 3: Left panel: JPCam-FSU during its integration at CEFCAs premises. Right panel: a filter tray unit fully populated with broad-band filters.

The JPCam has a 515mm diameter aperture and is supplied by Bonn-Shutter AG. It is a 'two-curtain' shutter that guarantees an homogeneous illumination of the focal plane. It allow for exposures as short as 10ms with an exposure uniformity better than 1ms over the full FoV.

Finally, in order to prevent frost and/or condensation from forming on the large (about 550mm diameter) dewar window, the FSU will be sealed and slightly over-pressured with N2.

5 J-PAS filter system

The J-PAS filter system is defined by the following set of 59 filters (figure 4):

- 56 main filters, 53 narrow-band (FWHM=14.5 nm) filters continuously populating the spectrum between 390 to 910 nm with 10.0 nm steps, plus 3 medium to broad-band filters. Adjacent filters have a certain overlap ensuring a spectral measurement over the whole spectrum from about 320 nm to > 1050 nm with 56 different spectral channels with very low light-loss.
- A custom uJ-PAS broad band filter.
- Two Sloan filters (gSDSS and rSDSS)

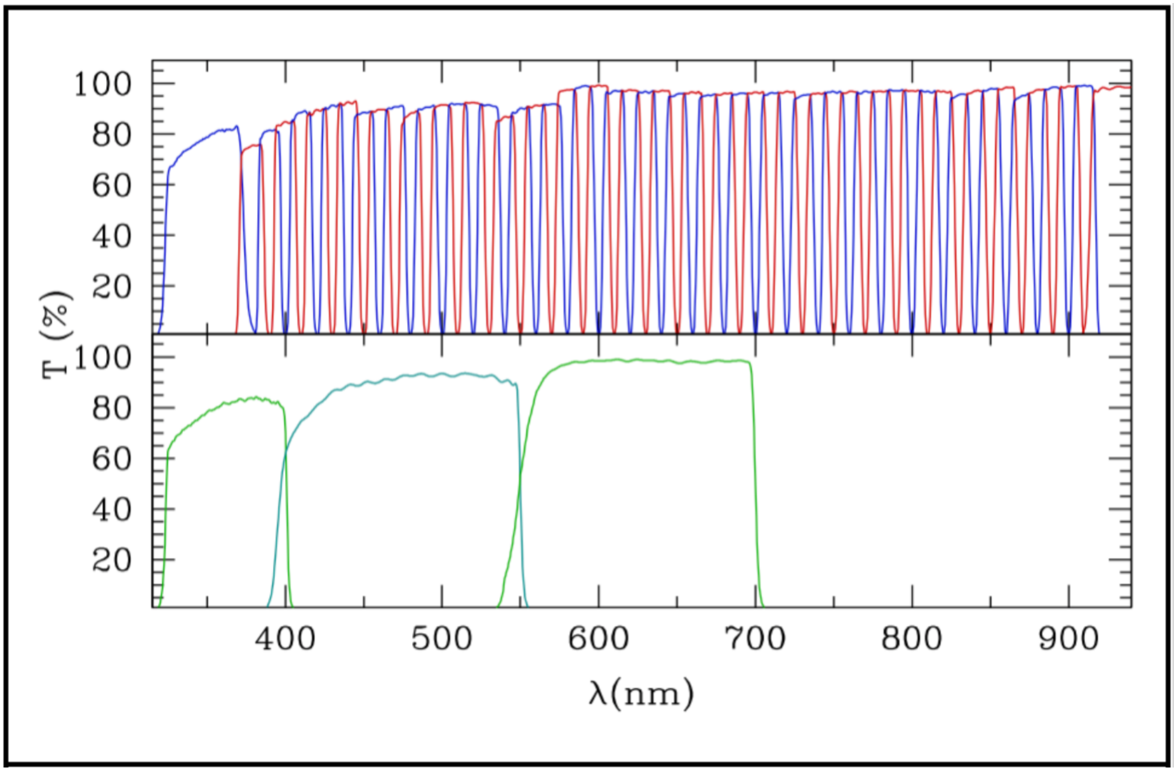

Figure 4: As designed J-PAS filter transmission curves.

6 Conclusions

JPCam design has been driven by the main science goal defined by the J-PAS collaboration, that is, the J-PAS survey. The JPCam different subsystems have been completed and accepted. The AI&V of the complete instrument has just started at the OAJ clean room and commissioning at telescope is planed for mid 2017.