Centro de Estudios de Física del Cosmos de Aragón

TECHNICAL REQUIREMENTS SPECIFICATION FOR THE JPCam AUTOGUIDE AND WAVEFRONT SENSOR FILTERS SUPPLY CONTRACT

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1. REFERENCE DOCUMENTS

	Doc title	Doc Number
RD1	OAJ T250 Optical Analysis	OAJ-TRE-AMO-1000-009-is5.pdf
RD2	Update on JPCam window prescription	2126_01_04_is3.pdf

2. LIST OF ACRONYMS AND ABBREVIATIONS

CEFCA	Centro de Estudios de Física del Cosmos de Aragón
JPCam	Wide Field Mosaic Camera for the JST/T250 telescope.
FoV	Field of View
OAJ	Observatorio Astrofísico de Javalambre
JPAS	Javalambre PAU Astrophysical Survey
JST/T250	OAJ 250cm aperture telescope
FWHM	Full Width Half Maximum
AG	Autoguide
WFS	Wavefront sensor

TBC: "To Be Confirmed" by the CEFCA during Contract negotiations or at an agreed date during Contract duration.

TBD: "To Be Defined" and agreed between the CEFCA and the Contractor at the time of Contract signature or at an agreed date during Contract duration.

3. DEFINITIONS

Contractor	Refers to the Company entrusted with the design and manufacture of the JPCam AG and WFS filters
Temperature of Reference	The temperature of reference for all the dimensions and tolerances, unless otherwise specified, shall be 21° C.

4. INTRODUCTION

The Observatorio Astrofísico de Javalambre (OAJ) is a new astronomical facility located at the Sierra de Javalambre (Teruel, Spain) whose primary role will be to conduct all-sky astronomical surveys. The OAJ facility will have two wide-field telescopes: the JST/T250; a 2.55-m telescope with a 3° diameter field of view (FoV), and the JAST/T80; an 0.83-m telescope with a 2° diameter FoV. The Fundación Centro de Estudios de Física del Cosmos de Aragón (CEFCA) is responsible for the definition, construction, operation and scientific exploitation of the OAJ.

The JST/T250 has a plate scale of 22.67"/mm and a f/# = 3.6. The 3° diameter FoV corresponds to 476.4mm [*RD1*]. The main scientific instrument for JST/T250 is JPCam (figure 1), a 14 science CCD mosaic camera using the new large format e2v 9k-by-9k 10μm pixel detectors. The focal plane will be completed with a set of 12 auxiliary detectors: 4 autoguide (AG) and 8 wavefront sensor (WFS) CCDs. JPCam will be installed at the Cassegrain focus of the JST/T250 and will cover a large fraction of the telescope's FoV with a pixel scale of 0.2267 "/pixel.

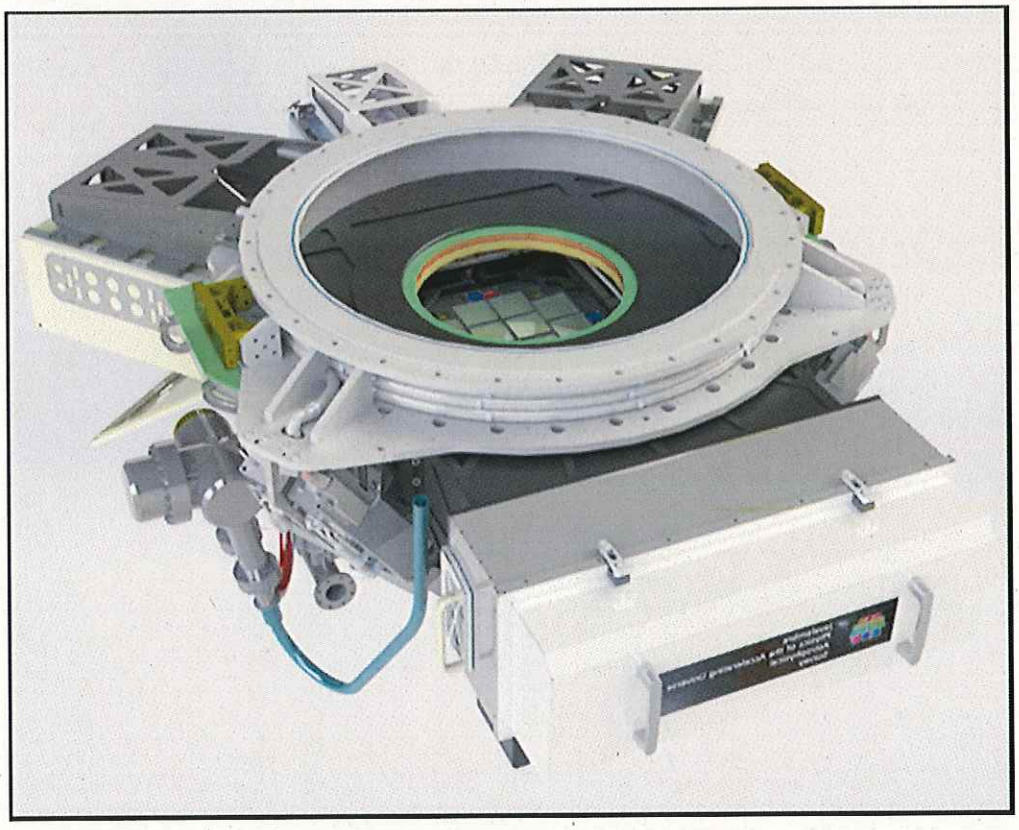


Figure 1: JPCam final design.

JPCam is broken down into four subsystems, named: actuator system (supplied by *NTE-Sener*, Spain), filter and shutter unit (supplied by *The Vacuum Projects*, Spain), filter tray assemblies (supplied by *Jaguar Precision Machine*, USA) and the cryogenic camera (supplied by *e2v Technologies*, UK). All four subsystems have passed their final design reviews and are now completing different stages of manufacturing, integration and testing.

The filter and shutter unit has been designed to admit 5 filter tray assemblies. Each one of the filter trays shall mount 14 science, 4 AG and 8 WFS filters corresponding to the 14 scientific, 4 AG and 8 WFS CCDs of the focal plane mosaic. Each CCD will view only its corresponding filter without any cross-talk between them. Figure 3 shows the final design of a JPCam filter tray.

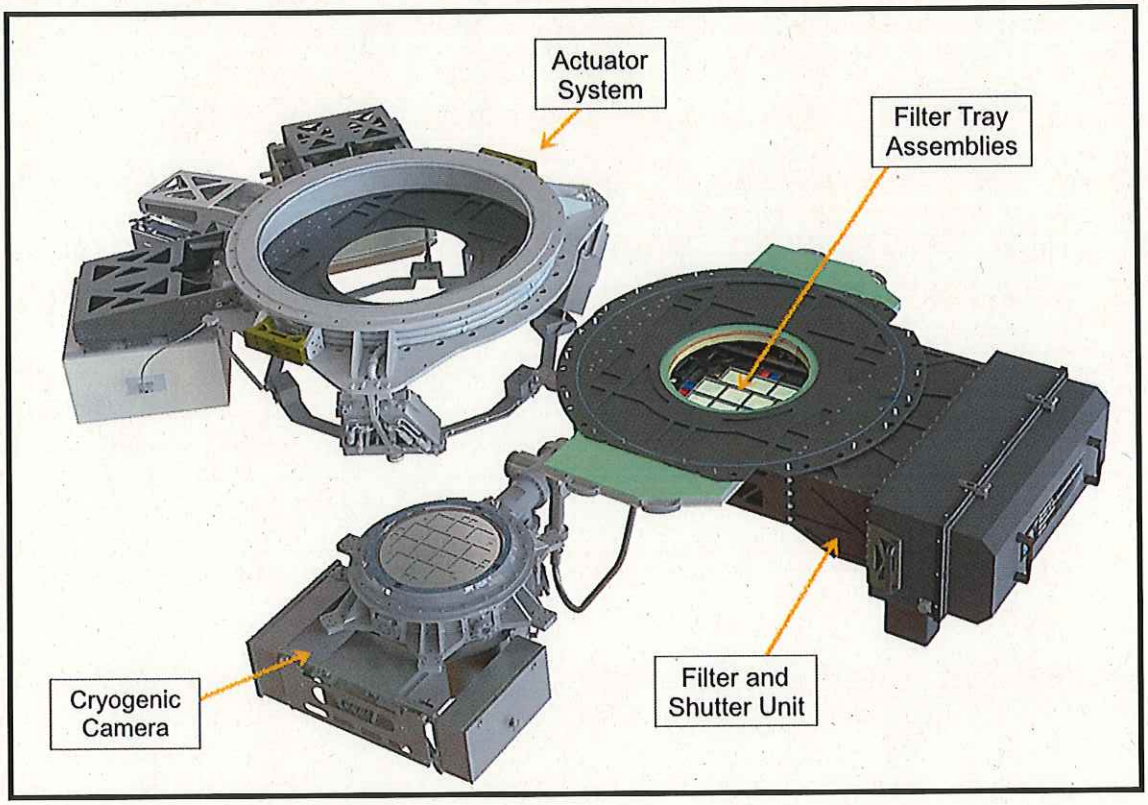


Figure 2: JPCam main subsystems.

JPCam has been designed to perform the Javalambre-PAU Astrophysical Survey (J-PAS), an innovative photometric survey of more than 8000 square degrees of northern sky using the following system of 59 science filters (being produced by *SCHOTT Suisse SA*):

- 56 main filters, 54 narrow-band (FWHM=14.5 nm) filters continuously populating the spectrum between 370 to 920 nm with 10.0 nm steps, plus 2 broad-band filters.
- A custom $u_{J\text{-}PAS}$ broad band filter.
- Two Sloan filters (g_{SDSS} and r_{SDSS}).

Apart form the science filters, each one of the filter trays will be populated with a set of 4 AG and 8 WFS filters (4 "*intra*" and 4 "*extra*"). AG and WFS filters will operate close to, but up-stream from the dewar window in a fast (F/3.6) converging optical beam.

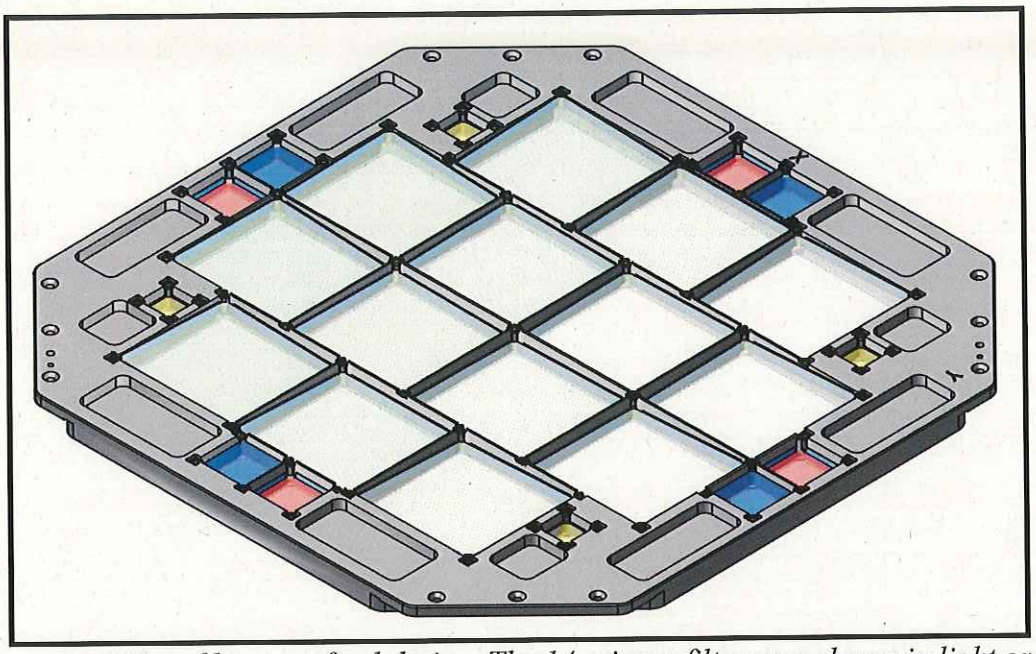


Figure 3: JPCam filter tray final design. The 14 science filters are shown in light green. AG filters and WFS filters are shown in yellow and red/blue, respectively. JPCam has 5 filter trays.

5. SCOPE OF THE DOCUMENT AND SCOPE OF WORK

This document gives the requirements for the JPCam AG and WFS filter set. The contractor's scope of work and the project's maximum cost and timescale are also presented. The aim of this contract is to supply the AG and WFS filters required to properly operate the JPCam. Five J-PAS filter trays plus two additional trays conceived for a future integration of additional filters in the instrument shall be populated. The auxiliary filter set is then composed by 84 filters, 28 AG and 56 WFS filters. A set of spares (2 filters of each type) is also included in the present contract, as shown in table 1 below. The contractor shall design, manufacture, test and deliver the specified AG and WFS filters. These shall be delivered in the appropriate delivery boxes and together with the long-term storing boxes/supports.

Filter name	Number of filters per tray	Total
AG	4	28 (+2 spares)
WFS-Intra	4	28 (+2 spares)
WFS-Extra	4	28 (+2 spares)
Total number of requested filters		**90**

Table 1: Number of required J-PAS AG + WFS filters.

6. OVERALL REQUIREMENTS

6.1. *Functional Requirements*

The temperature of reference for all dimensions and tolerances during manufacturing of components shall be 21 °C.

Figure 4 shows the generic filter transmission function for the JPCam AG and WFS filters. Filters specified in this document shall be standard r-SDSS filters. Definition and design notes for the r-SDSS filters can be found at Fukugita et al (1996), AJ, 111, 1748. The detailed filter transmission function is specified bellow.

Once mounted on JPCam, the filters will operate close to the detector, in a fast converging beam. When used, the interference layer technology shall be optimised in order to reduce the sensitivity of the central wavelength versus the angle of incidence.

Filter's mechanical design shall be optimised to minimise stress induced by temperature changes and gradients.

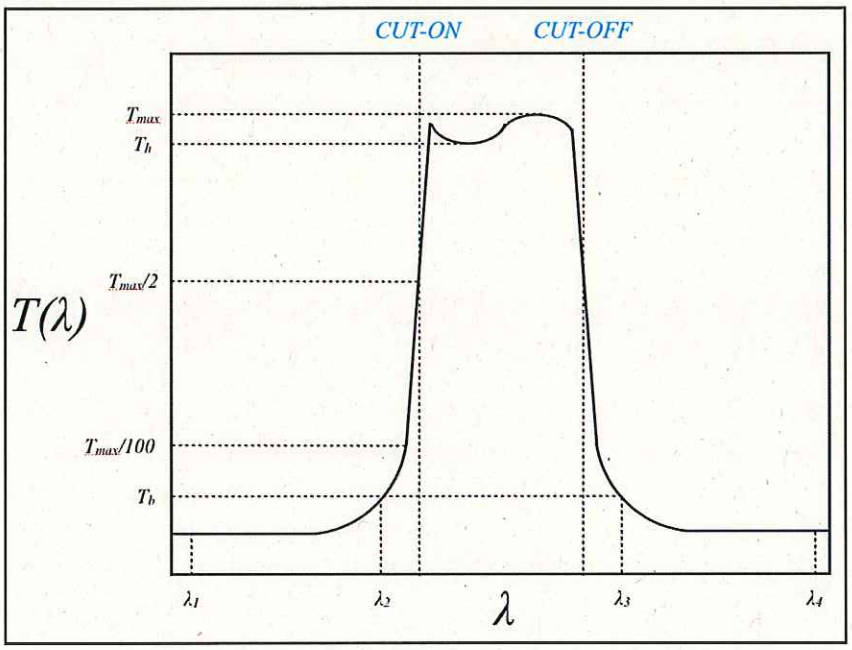


Figure 4: Generic broad-band filter transmission curve.

6.1.1. *WFS-Intra and -Extra transmission curves*

As far as practical, each pair or WFS-intra and -Extra filters shall have identical transmission curves. The use of substrates from the same batch is encouraged.

6.1.2. *Cut-on wavelength*

Table 2 lists the required cut-on wavelength for the JPCam AG and WFS filters.

Filter name	CUT-ON (nm)	CUT-OFF (nm)	Comments
AG	550	700	r-SDSS filter

Filter name	CUT-ON (nm)	CUT-OFF (nm)	Comments
WFS-Intra	550	700	r-SDSS filter
WFS-Extra	550	700	r-SDSS filter

Table 2: Cut-on and cut-off wavelength specifications for the AG and WFS filters.

6.1.3. Absolute cut-on wavelength tolerance

Cut-on wavelength tolerance shall be ±15nm.

6.1.4. Relative cut-on wavelength tolerance for WFS filters

WFS filters will operate in pairs (Intra and Extra). The two filters of each pair shall have the same cut-on wavelength, with a tolerance of ±3nm.

6.1.5. Cut-on slope

Cut-on slope, defined as *ABS[lamda80%(peak)-lambda5%(peak)/lambda5%(peak)]*100*, shall be around 5%. This slope shall agreed during the design phase

6.1.6. Cut-off wavelength

Table 2 lists the required cut-off wavelength for the broad-band filters.

6.1.7. Absolute cut-off wavelength tolerance

Cut-off wavelength tolerance shall be ±15nm.

6.1.8. Relative cut-off wavelength tolerance for WFS filters

WFS filters will operate in pairs (Intra and Extra). The two filters of each pair shall have the same cut-off wavelength, with a tolerance of ±3nm.

6.1.9. Cut-off Slope

Cut-off slope, defined as *ABS[lamda80%(peak)-lambda5%(peak)/lambda5%(peak)]*100*, shall be around 5%. This slope shall agreed during the design phase

6.1.10. Central Wavelength Uniformity

The central wavelength shall be uniform across the filter's usable area within ±1.25nm.

6.1.11. Peak Transmittance (T_{max})

The peak transmittance within passband shall be higher than 85% (goal >90%).

6.1.12. Peak Transmittance Uniformity

The peak transmittance T_{max} shall vary less than ±4% (goal ±2.5%) across the filter's usable area.

6.1.13. Transmittance Flatness

The filters transmission function within the bandpass ($T>0.9*T_{max}$) shall vary (peak-to-valley) less than 7% (goal 5%) of T_{max}, that is, $T_{max} - T_h < 0.07*T_{max}$.

6.1.14. Short-Wave Blocking Range

The filters shall block light with wavelength in the interval $[\lambda_1, \lambda_2]$, where $\lambda_1 = 250$ nm and $\lambda_2 = \lambda_{100} - 0.5$ nm, being λ_{100} the wavelength at with the filter transmission is $T_{max}/100$, with $\lambda_{100} < CW$.

6.1.15. Long-Wave Blocking Range

The filters shall block light with wavelength in the interval $[\lambda_3, \lambda_4]$, where $\lambda_4 = 1050$ nm (goal 1100 nm) and $\lambda_3 = \lambda'_{100} + 0.5$ nm, being λ'_{100} the wavelength at with the filter transmission is $T_{max}/100$, with $\lambda'_{100} > CW$.

6.1.16. Upper Transmittance Limit Within Blocking Ranges

The upper transmittance limit within the short- and long-wave blocking ranges (T_b) shall be, on average, lower that $3*10^{-4}*T_{max}$.

6.2. Physical Requirements

6.2.1. Filters Substrate Material

The reference filters substrate material shall be Fused Silica or B270.

6.2.2. Filters Effective Refractive Index

The filters effective refractive index shall be in the range [1.45, 1.56], the goal being a refractive index as close as possible to that of Fused Silica.

6.2.3. Filters Total Reflectivity

In order to reduce undesired ghosts in the final images, the filters shall be designed to minimise reflectivity. In particular, filter's total reflectivity shall be <4% average (goal 2%) for wavelengths lower than 500nm.

6.2.4. Filters Internal Reflections

Filters shall be designed to avoid internal reflections susceptible of creating perceptible ghosts on the final images. The intensity of the parasitic light shall at least six orders of magnitude smaller than the incident light.

6.2.5. Filters Physical Dimension

The filters shall be square, with a dimension that depends on the filter type as shown in table 3 and figure 5 below:

Filter type	Dimensions (X side * Y side * Thickness, in mm)
AG	25.0 * 25.0 * 8.05[(i)]
WFS-Intra	40.1 * 40.1 * 4.88[(i)]
WFS-Extra	40.1 * 40.1 * 11.21[(i)]

Table 3: AG and WFS filters' physical dimensions.

[(i)] Filters' thickness is valid for the case of a Fused Silica filter. If the filters' effective RI differs from that of Fused Silica then the filter thickness shall be computed to warrantee image quality on final images. In this case, the contractor shall provide CEFCA with the substrates included in the filters' design and, based on the substrate average RI, CEFCA will provide the contractor with the required substrate's thicknesses.

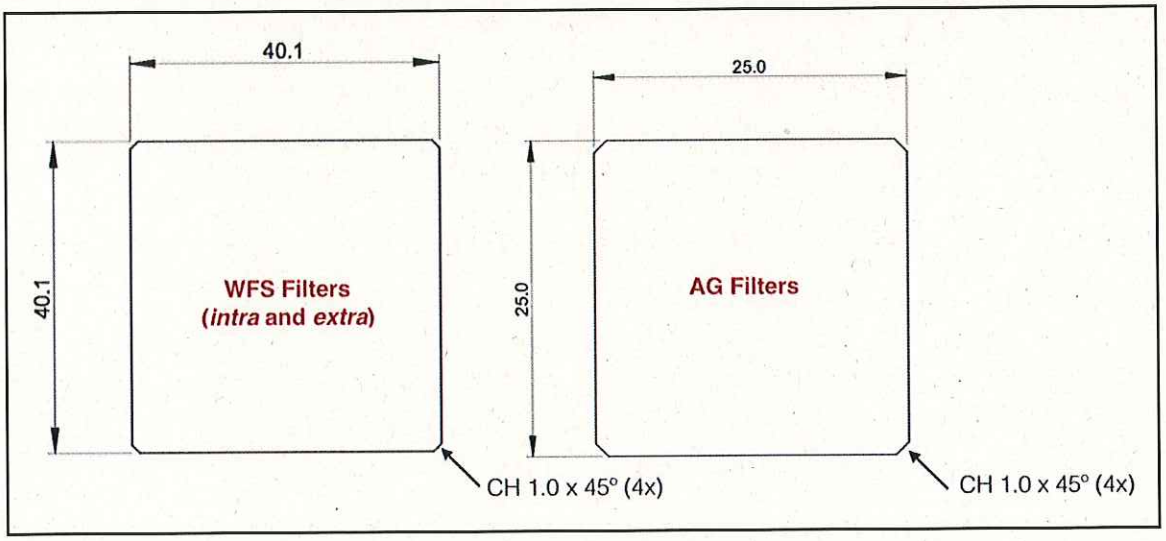


Figure 5: AG and WFS filters' physical dimensions

6.2.6. Filters Side Dimension Tolerance

The tolerance in the filters side dimension is ±0.1 mm.

6.2.7. Filters Thickness Tolerance

The tolerance in the filters thickness is ±0.1 mm (goal ±0.05mm).

6.2.8. Bevels

Filters shall have 0.3 mm bevels on all edges, 45°.

6.2.9. Bevels tolerance

The tolerance in the bevels ±0.2 mm.

6.2.10. Corner Chamfer

Filters shall have corner chamfers of 1 mm, 45°.

6.2.11. Clear aperture

The clear aperture shall be equal to or larger than:

- For the AG filters: 23.5 x 23.5 mm (centered).
- For the WFS filters: 38.6 x 38.6 mm (centered).

6.2.12. Surface Roughness

The filter substrate shall be polished to a residual surface roughness of 2 nm R.M.S. or better over its whole clear aperture. Coating blemishes shall be included in the allowable surface roughness.

6.2.13. Surface Imperfections

Surface quality shall meet the 60/40 scratches/digs MIL-C-13830A specifications. Coating blemishes shall be included in the allowable surface imperfections.

6.2.14. Pinhole restriction

No pinhole shall be visible to the unaided eye in viewing chamber defined by Mil-O-13830A. Coating blemishes shall be included in the allowable pinhole restrictions.

6.2.15. Bubbles restriction

The total cross-section of all bubbles/inclusion $\geq$ 0.03 mm shall be less than 0.5 mm^2 per 100 cm^3 of glass volume.

6.2.16. Maximum Wedge

The wedge shall be lower than 60 arcsec.

6.2.17. Total Transmitted Wavefront Error

Transmitted wavefront RMS error shall be λ/2 at 632.8 nm over its whole clear aperture.

6.3. Operational Requirements

6.3.1. Environmental Requirements

The filter set shall be designed to operate and survive in the general conditions of the OAJ. In particular, it shall operate in the conditions given in the table below.

The filter requirements shall be fulfilled under the Nominal conditions. The filters shall be able to operate up to the Limit of operation conditions but the filters specifications do not need to be fulfilled to this level. Under Survival conditions the filters are assumed not to be in operation.

	Nominal conditions	Limit of operation	Survival limit
Temperature	-15°C to +10°C	-20°C to +20°C	-25°C to +25°C
Thermal variation (at night) in 15 minutes	0°C to 0.9°C	N/A	N/A
Thermal variation (at night) in 1 hour	0°C to 1.8°C	N/A	N/A
Thermal variation (at night) in 2 hours	0°C to 2.4°C	N/A	N/A
Relative humidity	2% to 90%	95% (or condensation)	0% to 100% with condensation

6.3.2. Autofluorescence

If the filters show a level of autofluorescence, it shall occur in a wavelength out of the CCD sensitivity range [250nm, 1050nm] (goal [200nm, 1100nm]). The CCD sensitivity curve is shown in figure 6. If the autofluorescence occurs at a wavelength within the CCD sensitivity range, the filter design shall block this autofluorescence avoiding its impact on the CCD.

6.3.3. Edge Marking

The filters edge shall be marked with the customer's name, filter's description, filter's orientation and the manufacturing trace code.

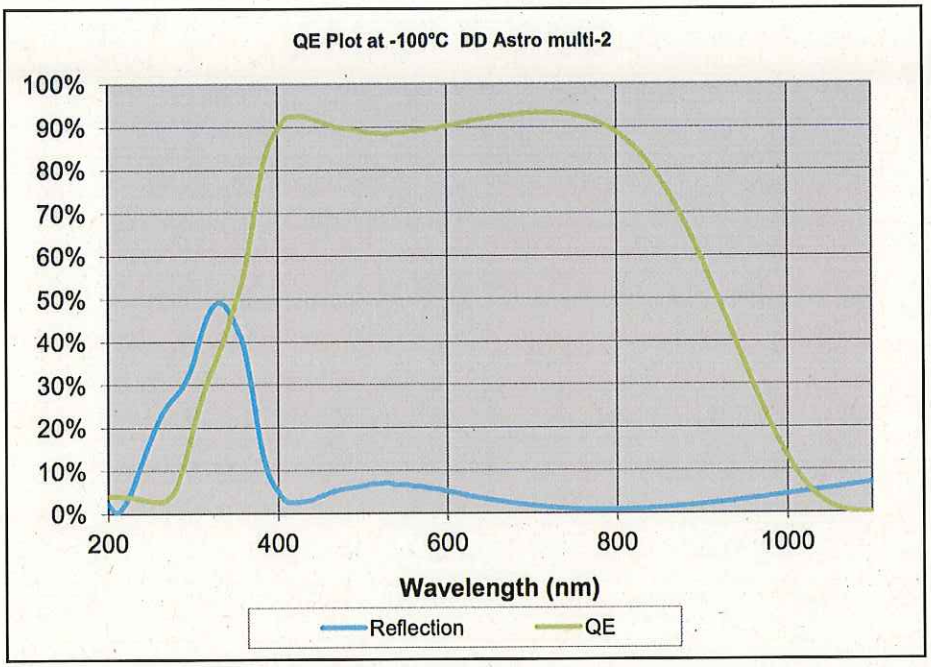


Figure 6: Quantum efficiency curve of the CCD.

6.3.4. Packaging, Storage and Transportation

The equipment supplied under the resulting contract shall be cleaned and prepared in the workshop prior to shipping. The shipping package shall be designed to support normal air and sea transport conditions. The package shall be also designed to be used for preventive and maintenance tasks and in case of reparation. It shall be designed to support at least 10 packing and 10 unpacking operations keeping all its performances.

The filters shall be also delivered with the appropriate long term storing boxes or filter supports. The design of these items shall prevent the filters from being damaged under the conditions at the OAJ clean room environment during a period of time larger than 5 years.

6.3.5. Delivery

The contractor shall deliver a set of JPCam auxiliary filters (as defined in table 1) to CEFCA headquarters: Plaza San Juan 1, planta 2, E44001, Teruel.

6.4. Reliability Requirements

6.4.1. Filters Lifetime

The filters shall be designed for a minimum lifetime of 10 years of operation.

6.4.1. AR coating durability

The minimum AR coating durability shall meet the MIL-C-48497A specifications.

6.5. Documentation

For each filter, the following documentation shall be provided:
- ASCII or excel file with the spectrophotometric trace of filter's transmission band under working conditions (f/#=3.64) in %T.
- ASCII or excel file with the spectrophotometric trace of filter's reflectivity under working conditions (f/#=3.64) in %R.
- Certificate of acceptance.
- Procedure for cleaning the filters.

7. WORKING PLAN

The maximum delivery time is 14 weeks, with the following working plan:

- ***Phase 1. Design***. During this phase the contractor shall produce a detailed design of the filters to fulfil the requirements. The detailed design shall be agreed and approved by CEFCA.

- ***Phase 2: Manufacturing and Verification.*** In this phase, the contractor shall manufacture the filters. The filters will be tested for functionality and verification at the contractor's premises. People from CEFCA will be invited to participate in the testing in order for CEFCA to certify the fulfilment of the requirements. This will constitute the Preliminary Acceptance of the filters.

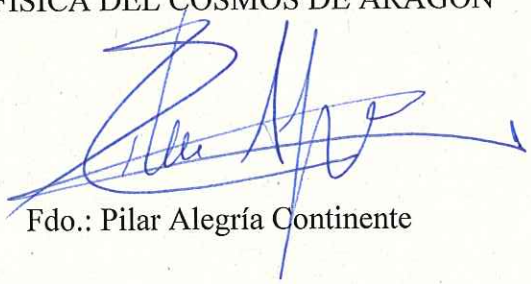
- ***Phase 3: Packing, shipping to CEFCA and verification***. After the Preliminary Acceptance, the filters will be packed and shipped to CEFCA, in Teruel. Filters shall be delivered clean. The contractor shall be responsible, in cost and risk, to transport the equipment manufactured from its facilities to the CEFCA facilities. CEFCA shall make all tests to verify the integrity and functionality of the filters. The process will be terminated with the Final Acceptance certificate.

8. VERIFICATION PLAN

The filter requirements shall be measured and validated at the contractor premises. The contractor shall provide a verification matrix designed to demonstrate fulfilment of requirements. This verification matrix shall be agreed by CEFCA. Verification tests shall be accomplished following the agreed verification methods.

En Teruel a 8 de abril de 2016

LA PRESIDENTA DEL PATRONATO DE LA
FUNDACIÓN CENTRO DE ESTUDIOS
DE FÍSICA DEL COSMOS DE ARAGÓN



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