Centro de Estudios de Física del Cosmos de Aragón

TECHNICAL REQUIREMENTS FOR THE SLOAN-r AND SLOAN-i FILTERS FOR JPCAM SUPPLY CONTRACT

TABLE OF CONTENTS

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 telescope 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.

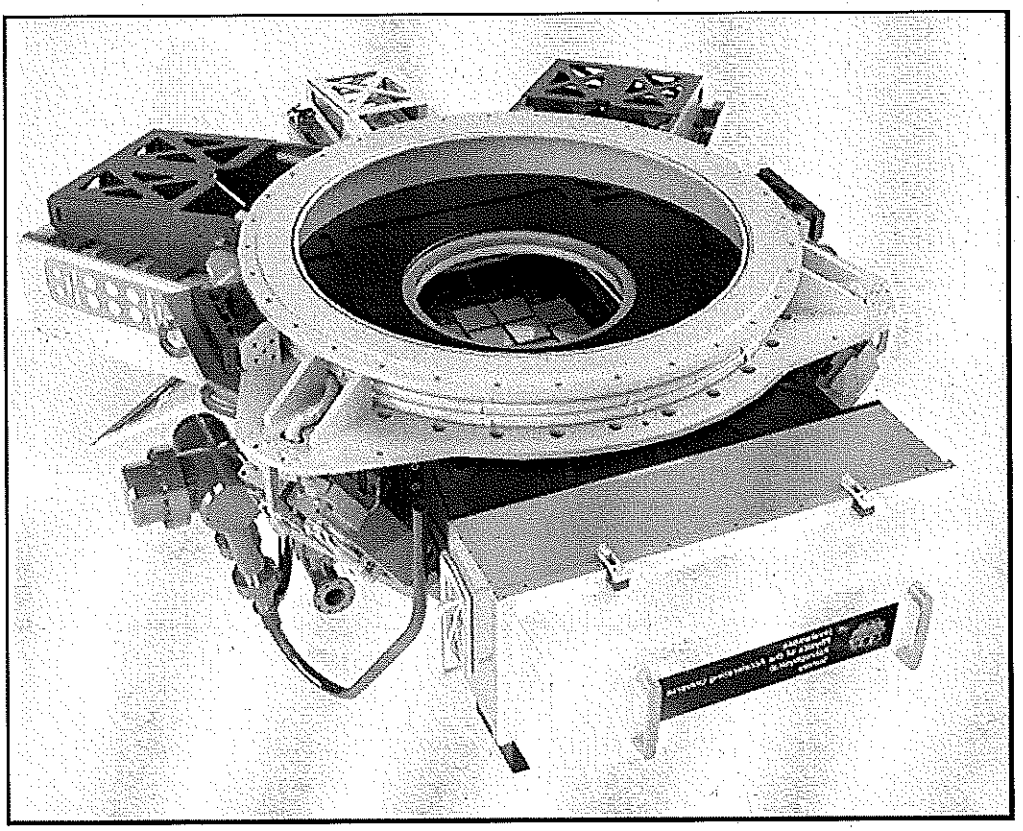


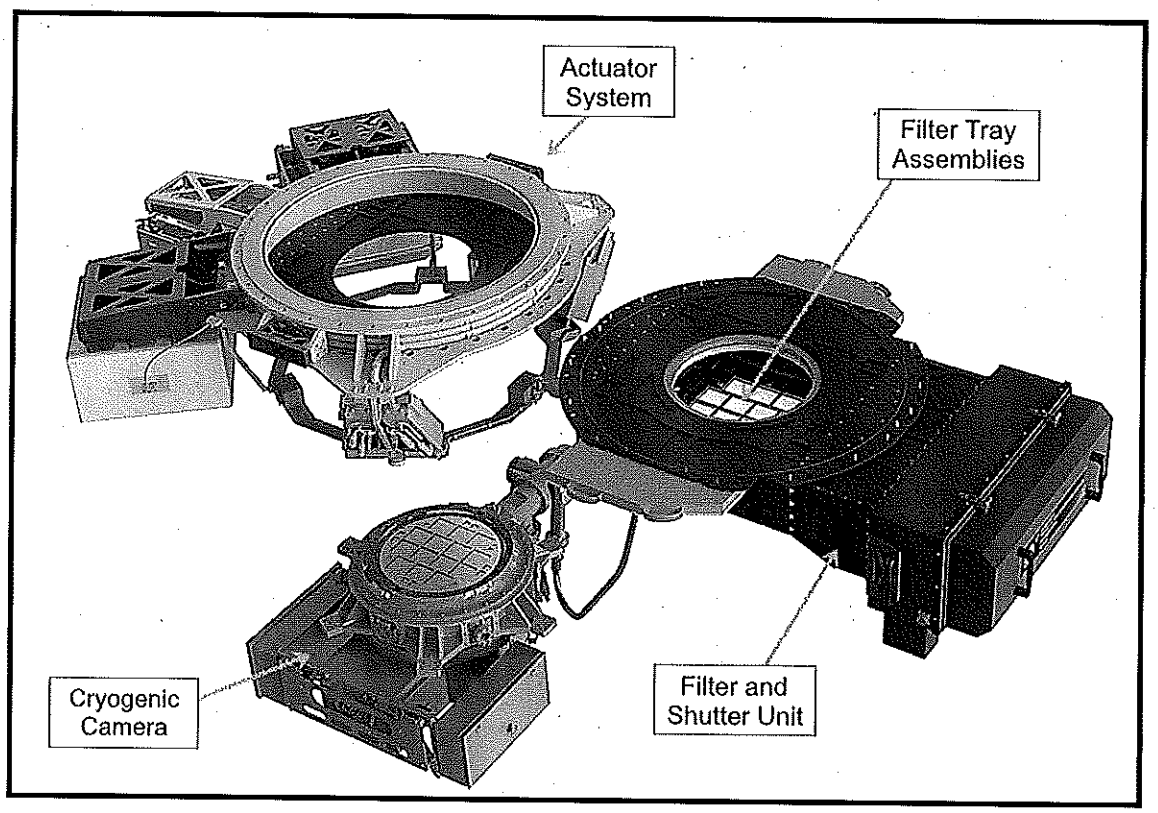
Figure 1: JPCam final design.

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.

The OAJ was declared an Spanish "*Instalación Científico Técnica Singular (ICTS)*" in 2014. As ICTS, the OAJ is offering open access to its telescopes and cameras since July 1, 2016. To date, JPCam is equipped with a complex filter system designed for the J-PAS project. As part of this filter system, a broad-band filter tray integrating 7 SDSS-r,



4 u-JAVA and 3 SDSS-g filters is available.

The filter distribution within this tray has been optimised for the J-PAS Survey. However, this distribution is not optimum is a Survey of a region of the sky in one or two bands is planned. For the SDSS-r band, and due to the filter's distribution in the broad-band filter tray, if a tray populated with 14 identical filters would be available then a gain of at least 50% in observing time and a significant improvement in data homogeneity in termos of depth would be achieved. In the case of the SDSS-i band, as it is not currently available, a new observing window will be opened.

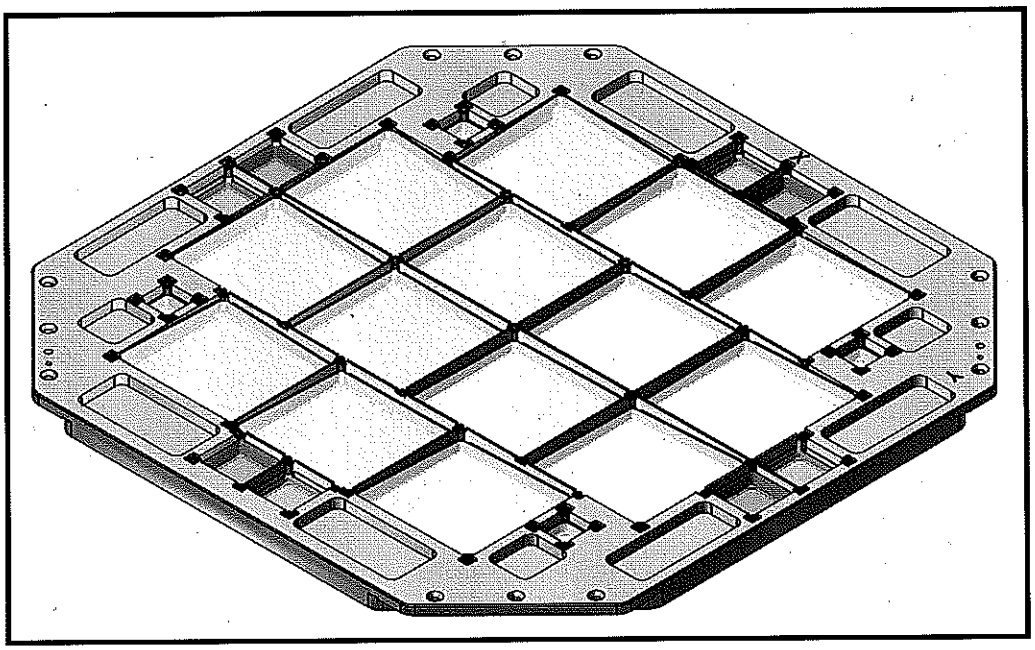


Figure 3: JPCam filter tray final design. The 14 science filters are shown in light green. AG filters and WFS filters are shown in yellow and red/blue, respectively. JPCam has 5 filter trays.

5. SCOPE OF THE DOCUMENT AND SCOPE OF WORK

The OAJ was declared an Spanish *Instalación Científica Técnica Singular* (ICTS) in 2014. In order to increase the observing capabilities through "*Open Time*" beyond currently available J-PAS Survey filter set, this contract has been defined to provide JPCam at the JST/T250 with two new broad-band filter trays (filters SDSS-r and SDSS-i).

This document shows the requirements of Sloan filters for JPCam. In particular, to populate two JPCam filter trays, 14 SDSS-r and 14 SDSS-i filters are requested, as shown in Table 1. The contractor shall design, manufacture, verify and deliver the requested Sloan filters for JPCam. Filters shall be delivered in appropriate transport packages and together with the necessary storage supports.

Filter	Number of filters
r_{sdss}	14
i_{sdss}	14
Total number of required filters	28

Table 1: Number of required Sloan filters for JPCam.

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 a broad-band filter. 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. The specified filter transmission curves correspond to the filter working conditions, so the **filters shall be designed to fulfill the following requirements when placed on a f/#=3.64 converging beam with the chief ray being perpendicular to the filter**.

The interference layer technology shall be optimized in order to reduce the sensitivity of the central wavelength versus the incidence angle.

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

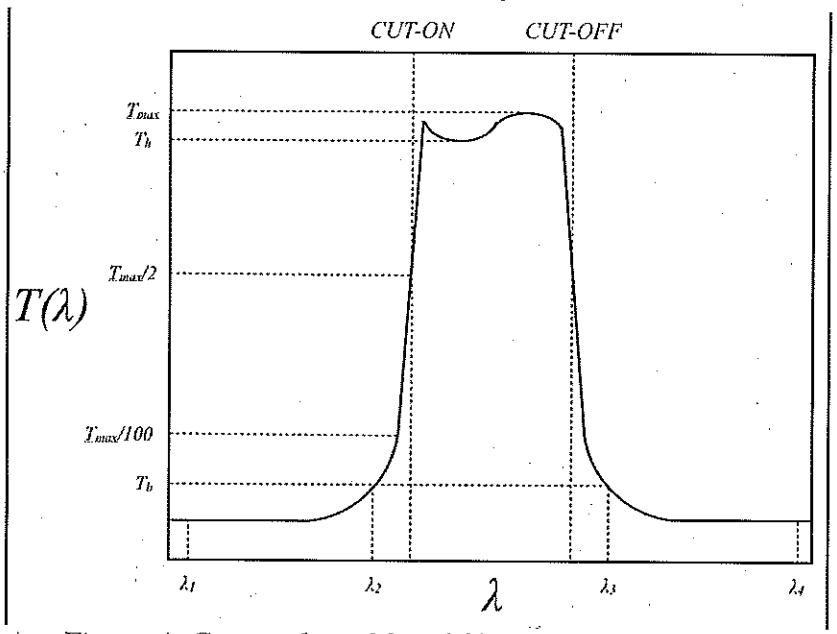


Figure 4: Generic broad-band filter transmission curve.

6.1.1. Functional requirements

6.1.1.1. Cut-on wavelength

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

Filter name	CUT-ON (nm)	CUT-OFF (nm)
r_{sdss}	550	700
i_{sdss}	695	850

Table 2: Cut-on and Cut-off wavelengths for the Sloan filters[1].

6.1.1.2. Cut-on wavelength tolerance

Cut-on wavelength tolerance for the Sloan filters shall be ±3nm.

6.1.1.3. Cut-on Slope

Cut-on slope, defined as *ABS[lamda80%(peak)-lambda5%(peak)/lambda5%(peak)]*100*, shall be around 1%. This slope shall agreed during the design phase

6.1.1.4. Cut-off wavelength

Table 1 lists the required cut-off wavelength for the Sloan filters.

6.1.1.5. Cut-off wavelength tolerance

Cut-off wavelength tolerance for the Sloan filters shall be ±3nm.

6.1.1.6. Cut-off Slope

Cut-off slope, defined as *ABS[lamda80%(peak)-lambda5%(peak)/lambda5%(peak)]*100*, shall be around 1%. This slope shall agreed during the design phase

6.1.1.7. Peak Transmittance (T_{max})

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

6.1.1.8. Peak Transmittance Uniformity

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

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[1] *Definition and design notes for the SDSS filters can be found at Fukugita et al (1996), AJ, 111, 1748*

6.1.1.9. Transmittance Flatness

The filters transmission function within the bandpass shall vary (peak-to-valley) less than 7% of T_{max}, with a goal of 5%.

6.1.1.10. 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 $\lambda_{100} < CW$.

6.1.1.11. 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 $\lambda'_{100} > CW$.

6.1.1.12. Out of band blocking

The upper transmittance limit within the short- and long-wave blocking ranges (T_b) shall be, on average, lower that $10^{-5} * T_{max}$.

6.2. Physical Requirements

6.2.1. Filters Substrate Material

The reference filters substrate material shall be suprasil 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 suprasil.

6.2.3. Filters Total Reflectivity

Total reflectivity shall be lower than 5% (goal 2.5%) within the filter's bandpass.

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 rectangular, with a dimension of 101.7mm x 96.5mm (see figure 9).

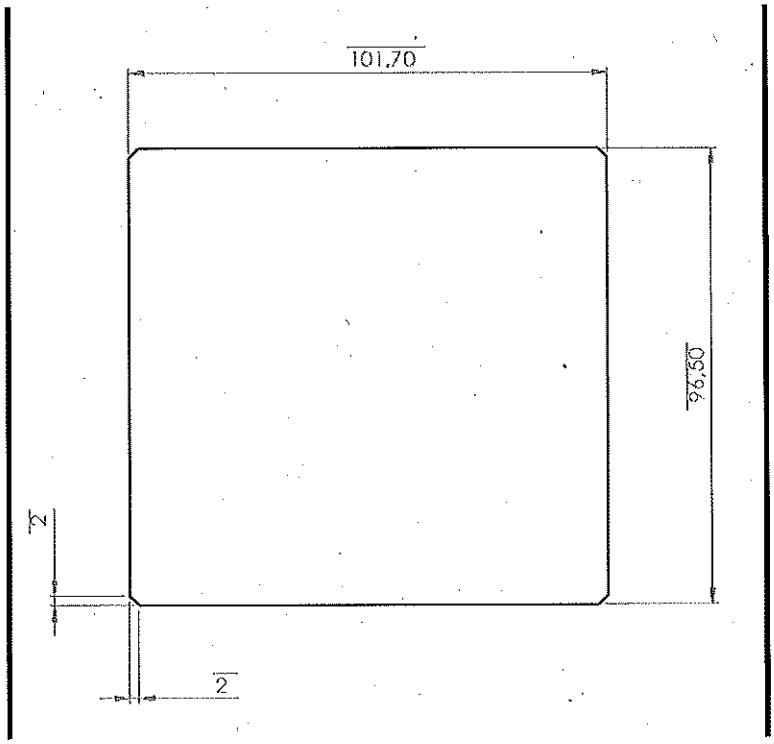

Figure 9: Filters physical dimensions. Units are in mm.

6.2.6. Filters Physical Dimension Tolerance

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

6.2.7. Bevels

Filters shall have 0.1 mm bevels on all edges, 45°.

6.2.8. Bevels tolerance

The tolerance in the bevels +0/-0.05 mm.

6.2.9. Corner Chamfer

Filters shall have corner chamfers of 2 mm, 45° (see figure 9).

6.2.10. Clear aperture

The clear aperture shall be equal to the filter's physical size minus the size of the bevel described in requirement 6.2.7.

Note: Filters shall operate in a fast converging beam so the clear aperture in operating conditions is driven by the filter's upper surface (incident light cone). Lower surfaces have less impact in the effective clear aperture.

6.2.11. Substrate Thickness

The substrate thickness shall be 8 mm if the filter's effective refractive index (RI) is equal to that of Suprasil. If the filter's effective RI (including coatings) differs from that of Suprasil then the filter thickness shall be computed for each filter type to warrantee image quality on final science images. In this case, the contractor shall provide the detailed filters' design (including number of coating layers, their thickness and RI, the substrate RI...). Based on each filter's design, CEFCA will perform the system optical analysis and will provide the contractor with the required substrate's thickness.

6.2.12. Substrate Thickness Tolerance

The substrate thickness tolerance shall be ±40 μm, with a goal of ±20 μm.

If the filter design includes more than one substrate then the accumulated tolerance of the different substrates shall be ±40 μm, with a goal of ±20 μm.

6.2.13. Filter Thickness

The thickness of the whole filter, including substrates, coatings and any additional component shall be less than 8.0mm.

6.2.14. 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.

6.2.15. 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.

6.2.16. 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.

6.2.17. 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.

6.2.18. Maximum Wedge

The wedge shall be lower than 30 arcsec.

6.2.19. *Total Transmitted Wavefront Error*

Transmitted wavefront RMS error shall be λ/2 at 632.8 nm over its whole clear aperture (goal λ/4).

6.2.20. *Local Transmitted Wavefront Error*

Transmitted wavefront RMS error shall be λ/8 at 632.8 nm in each sub-aperture of 25mm x 25mm (goal λ/16).

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 10. 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.

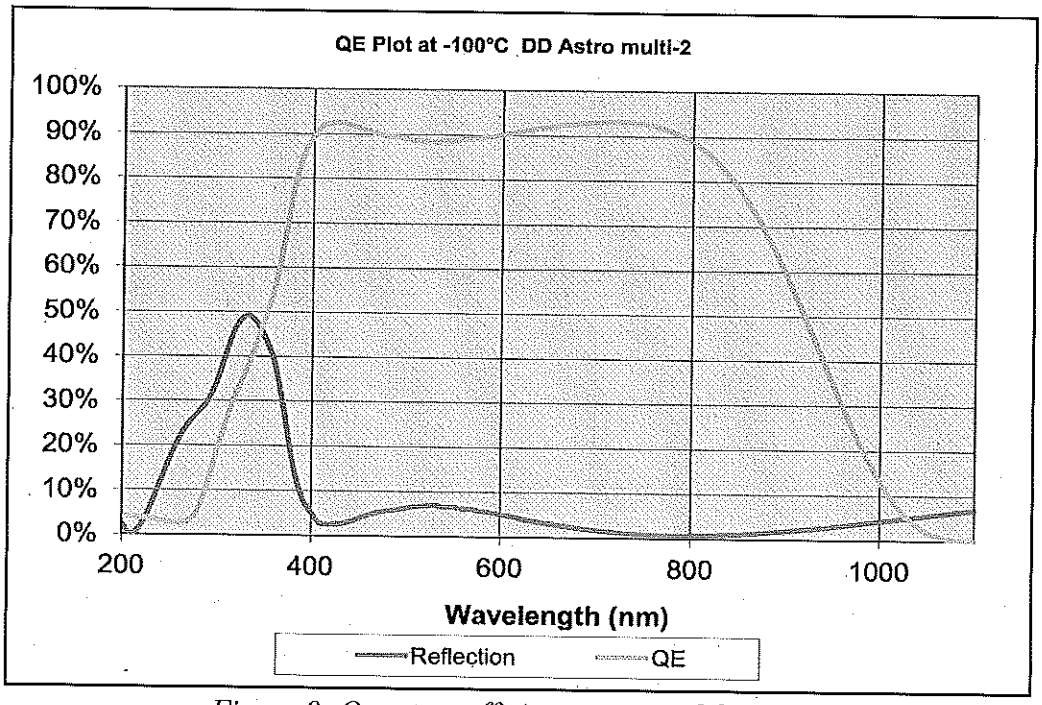

Figure 9: Quantum efficiency curve of the CCD.

6.3.4. Packaging, Storage and Transportation Requirements

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 the manufactured filters to the CEFCA headquarters: in 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 file with the spectrophotometric trace of filter's transmission band under working conditions (f/#=3.64) in %T. Transmission data shall be measured at several locations over the filter's usable area (see verification plan).
- ASCII file with the spectrophotometric trace of filter's reflectivity under working conditions (f/#=3.64) in %R. Reflectivity data shall be measured at several locations over the filter's usable area (see verification plan).
- Certificate of acceptance.
- Procedure for cleaning the filters.

7. WORKING PLAN

There are 3 phases identified during the process of manufacturing the filters:

- ***Phase 1. Design***. During this phase the contractor shall produce a detailed design of the filters to fulfill 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 fulfillment 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. The filters should arrive at CEFCA in no more than 2 weeks after the Preliminary Acceptance. CEFCA shall make all tests to verify the integrity and functionality of the filters.

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 fulfillment of requirements. This verification matrix shall be agreed by CEFCA. Verification tests shall be accomplished following the agreed verification methods.

Zaragoza, a 27 de abril de 2016
La PRESIDENTA DEL PATRONATO

Fdo: Pilar Alegría Continente