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Dpt. 92

Scientific grade cameras and spectrometers

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Table of Content

1. Introduction	4
1.1. Purpose	4
1.2. Scope	4
1.3. Terms, Definitions and Abbreviations	4
1.4. References to standards	5
2. Functional, Performance and Design requirements	6
2.1. Tender part A - Imaging spectrometers	6
2.1.1. General requirements for all the spectrometers	6
2.1.1.1. Software and computer interface requirements	6
2.1.1.2. Power supply	6
2.1.1.3. Turret interface	6
2.1.2. Turret and grating requirements for all the spectrometers	7
2.1.2.1. General requirements	7
2.1.2.2. Turret #1	7
2.1.2.3. Turret #2	7
2.1.3. Imaging Spectrometer #1	8
2.1.3.1. Focal length	8
2.1.3.2. Wavelength accuracy	8
2.1.3.3. Wavelength repeatability	8
2.1.3.4. Input port	8
2.1.3.5. Output ports	8
2.1.3.6. Optics	8
2.1.4. Imaging Spectrometer #2	9
2.1.4.1. Focal length	9
2.1.4.2. Wavelength accuracy	9
2.1.4.3. Wavelength repeatability	9
2.1.4.4. Input port	9
2.1.4.5. Output ports	9
2.1.4.6. Optics	9
2.1.5. Imaging Spectrometer #3	10
2.1.5.1. Focal length	10
2.1.5.2. Wavelength accuracy	10
2.1.5.3. Wavelength repeatability	10
2.1.5.4. Input port	10
2.1.5.5. Output ports	10
2.1.5.6. Optics	10
2.1.6. Camera for the Spectrometers	11
2.1.6.1. General requirements	11
2.2. Tender part B – sCMOS scientific imaging camera	12
2.2.1. General requirements	12
2.2.1.1. Software and computer interface requirements	12
2.3. Tender part C – Large field-of-view imaging camera	13
2.3.1. General requirements	13
2.3.1.1. Software and computer interface requirements	13
3. Delivery requirements	14
4. Safety Requirements	14
5. Quality Requirements	15
5.1. General Quality Requirements	15
5.2. Specific Quality requirements	15

1. Introduction

1.1. Purpose

This Requirements Specification Document (RSD) lists the technical requirements and constraints on products being purchased for the department 92 of ELI Beamlines project.

1.2. Scope

The RSD contains all of the technical requirements: functional, performance and design, delivery, safety and quality requirements for the following products: **Imaging spectrometers and scientific grade cameras** (PBS code: E.E3.P3DG.3).

These products are in product **Category A** according to the ELI Beamlines RSD categories of products. The Category A is an Off-the-shelf Product without necessity of modifications and necessity to be subjected to a verification program (review of design, inspection and testing) for ELI applications by the actual project specifications. All verification activities performing by a supplier shall be executed in accordance with the supplier's plan of outgoing inspection and tests. Internal Acceptance Procedure of the product Category A shall be established and applied before the product implementation (operation phase).

1.3. Terms, Definitions and Abbreviations

For the purpose of this document, the following abbreviated terms are applied:

Abbreviation	Meaning
AC	Alternating current
ADC	Analog-to-Digital Converter
CA	Contracting Authority (Institute of Physics AV CR, v. v. i.)
CCD	Charge-Coupled Device
CMOS	Complementary Metal Oxide Semiconductor
ELI	Extreme Light Infrastructure
EM	Electron multiplication
EMCCD	Electron Multiplying CCD
GigE	Gigabit Ethernet
PBS	Product Breakdown Structure
RSD	Requirements Specification Document
sCMOS	Scientific CMOS technology
SDK	Software Development Kit

Abbreviation	Meaning
TTL	Transistor–Transistor Logic
USB	Universal Serial Bus
UV	UltraViolet

For the purpose of this document, the following terms and definitions are applied:

Term	Definition
Wavelength accuracy of a spectrometer	Wavelength accuracy of a spectrometer is defined as the difference between the predicted position of an emission line (as predicted by the spectrometer control software) and the measured peak position of the atomic emission line.
Wavelength reproducibility of a spectrometer	Wavelength reproducibility is defined as the maximum deviation in measurement of centroid of a particular spectral line during multiple scans (20 times). The wavelength range of the spectrometer shall be set moving from low wavelength to high wavelength (10 times) and moving from high wavelength to low wavelength (10 times).

1.4. References to standards

If this document includes references to standards or technical documents the CA allows/permits also another equal solution to be offered. If the Supplier offers another equal solution the CA shall not reject its bid, once the Supplier by appropriate means in the bid proves that the offered supplies, services or works meet in an equivalent manner the requirements including references to standards or technical documents.

2. Functional, Performance and Design requirements

2.1. Tender part A - Imaging spectrometers

2.1.1. General requirements for all the spectrometers

2.1.1.1. Software and computer interface requirements

REQ-021493/A

The Supplier shall provide the required software for the spectrometers control, data acquisition and display.

REQ-021494/A

The software shall be able to run on Windows 10 operating system (or newer versions).

REQ-021598/A

The Supplier shall provide a software development kit (SDK) allowing programmatic control of full range of spectrometers settings and regimes and undepreciated raw image data acquisition.

NOTE 1: The SDK shall be compatible with Windows 10 and Centos 7 operating systems (or newer versions).

NOTE 2: The SDK shall be delivered in form of 64-bit linkable library binaries (.dll for Windows, .so for Linux), C/C++ header includes and full-scale documentation of all public library objects.

REQ-021495/A

The CA shall be able to install the software in any number of computers without incurring any additional costs.

REQ-021496/A

The control interface of the spectrometers shall be compatible with USB 3.0.

REQ-021498/A

The Supplier shall provide a cable in the range of 2 m to 3 m long for the control of the spectrometer.

2.1.1.2. Power supply

REQ-021497/A

All the spectrometers shall have power supply compatible with input Voltage in the range of 210–245 V AC at 50–60 Hz.

2.1.1.3. Turret interface

REQ-021508/A

The turret control of all the spectrometers shall be motorized.

REQ-021509/A

All the spectrometers and the turrets shall be designed such that the CA can replace/install a different turret in the future.

2.1.2. Turret and grating requirements for all the spectrometers

2.1.2.1. General requirements

REQ-021499/A

The Supplier shall provide 2 turrets that shall comply with the following specifications:

- **Turret #1** shall be compatible with imaging spectrometer #1;
- **Turret #2** shall be compatible with imaging spectrometers #2 and #3 (see chapters 2.1.4 and 2.1.5).

REQ-021500/A

The gratings shall be plane ruled reflectance grating.

2.1.2.2. Turret #1

REQ-021501/A

The turret shall house two gratings.

REQ-021502/A

The gratings shall have the following specifications:

- (A) **Grating 1A** shall have a groove density of 150 lines/mm, blazed for 500 nm;
- (B) **Grating 1B** shall have a groove density of 300 lines/mm, blazed for 422 nm.

REQ-021503/A

*The gratings **1A** and **1B** shall be coated with Aluminum coating.*

2.1.2.3. Turret #2

REQ-021504/A

The turret shall house three gratings.

REQ-021505/A

The gratings shall have the following specifications:

- (A) **Grating 2A** shall have a groove density of 150 lines/mm, blazed for 500 nm;
- (B) **Grating 2B** shall have a groove density of 300 lines/mm, blazed for 750 nm;
- (C) **Grating 2C** shall have a groove density of 1200 lines/mm, blazed for 1000 nm.

REQ-021600/A

*The gratings **2A**, **2B** and **2C** shall be coated with Aluminum coating.*

2.1.3. Imaging Spectrometer #1

2.1.3.1. Focal length

REQ-021506/A

The spectrometer shall be designed in Czerny Turner configuration.
The focal length of both the curved mirrors shall be between 175 ± 25 mm.

REQ-021507/A

The focusing optics and grating shall be such that the f-number at the input shall be between $f/3.5$ and $f/4.1$.

2.1.3.2. Wavelength accuracy

REQ-021510/A

The wavelength accuracy of the spectrometer #1 shall be equal or less than 0.25 nm, when used with a grating with groove density 1200 l/mm.

2.1.3.3. Wavelength repeatability

REQ-021511/A

The wavelength repeatability of the spectrometer #1 shall be less than 75 pm, when used with a grating with groove density 1200 l/mm.

2.1.3.4. Input port

REQ-021512/A

The spectrometer shall have one input port with motorized slit assembly.

2.1.3.5. Output ports

REQ-021513/A

The spectrometer shall have single output port.

REQ-021514/A

The output port shall be able to provide an imaging aperture of 25 x 10 mm.

REQ-021515/A

The Supplier shall provide a mechanical slit that can be attached to the output port.

2.1.3.6. Optics

REQ-021516/A

The optics within the spectrometer shall be $\text{Al}+\text{MgF}_2$ coated to enhance transmission in ultra violet region.

2.1.4. Imaging Spectrometer #2

2.1.4.1. Focal length

REQ-021517/A

The spectrometer shall be designed in Czerny Turner configuration.
The focal length of both the curved mirrors shall be between 500 ± 50 mm.

REQ-021518/A

The focusing optics and grating shall be such that the f-number at the input shall be between $f/6$ and $f/7$.

2.1.4.2. Wavelength accuracy

REQ-021521/A

The wavelength accuracy of the spectrometer #2 shall be equal or less than 0.2 nm, when used with a grating with groove density 1200 l/mm.

2.1.4.3. Wavelength repeatability

REQ-021522/A

The wavelength repeatability of the spectrometer #2 shall be less than 4 pm, when used with a grating with groove density 1200 l/mm.

2.1.4.4. Input port

REQ-021523/A

The spectrometer #2 shall have one input port with motorized slit assembly.

2.1.4.5. Output ports

REQ-021524/A

The spectrometer #2 shall have 2 output ports. The output port shall be selectable with a motorized mirror inside the spectrometer.

REQ-021525/A

Each of the spectrometer #2 output port shall be able to provide an imaging aperture of 30 x 14 mm.

REQ-021526/A

The Supplier shall provide a mechanical slit that can be attached to one of the output ports.

2.1.4.6. Optics

REQ-021527/A

The optics within the spectrometer #2 shall be silver coated to enhance transmission in Visible and Near Infra-red region.

2.1.5. Imaging Spectrometer #3

2.1.5.1. Focal length

REQ-021528/A

The spectrometer shall be designed in Czerny Turner configuration.
The focal length of both the curved mirrors shall be between 750 ± 50 mm.

REQ-021529/A

The focusing optics and grating shall be such that the f-number at the input shall be between $f/9.0$ and $f/10.5$.

2.1.5.2. Wavelength accuracy

REQ-021532/A

The wavelength accuracy of the spectrometer #3 shall be equal or less than 0.2 nm, when used with a grating with groove density 1200 l/mm.

2.1.5.3. Wavelength repeatability

REQ-021533/A

The wavelength repeatability of the spectrometer #3 shall be equal or less than 10 pm, when used with a grating with groove density 1200 l/mm.

2.1.5.4. Input port

REQ-021534/A

The spectrometer #3 shall have one input port with motorized slit assembly.

2.1.5.5. Output ports

REQ-021535/A

The spectrometer #3 shall have 2 output ports. The output port shall be selectable with a motorized mirror inside the spectrometer.

REQ-021536/A

Each of the output port shall be able to provide an imaging aperture of 30 x 14 mm.

REQ-021537/A

The Supplier shall provide a mechanical slit that can be attached to one of the output ports.

2.1.5.6. Optics

REQ-021538/A

The optics within the spectrometer shall be silver coated to enhance transmission in Visible and Near Infra-red region.

2.1.6. Camera for the Spectrometers

2.1.6.1. General requirements

REQ-021539/A

The parameters of all the cameras for the spectrometers (see chapters 2.1.3, 2.1.4 and 2.1.5) shall correspond to the requirements given in table 1 below.

Item N°	Parameters	Minimum Requirements
1.1	Anti-reflection coating	UV coating (QE \geq 35 % at 250 nm)
1.2	Sensor type	Back illuminated EMCCD with fringe suppression technology
1.3	Fringe suppression	Intensity fluctuation resulting from interference should be reduced to max. $\pm 20\%$ (peak-to-peak) in the wavelength range 250 nm – 1000 nm
1.4	Pixel format	1600 x 400 pixels
1.5	Pixel size	16 x 16 μm
1.6	Sensor area	25.6 x 6.4 mm
1.7	Linearity	$\geq 99\%$ at 1MHz readout rate
1.8	Quantum efficiency	$\geq 95\%$ at maximum (peak located in 500-800 nm range), $\geq 35\%$ at 250 nm
1.9	Spectrometric well capacity	$\geq 200,000$ electrons
1.10	Readout noise	≤ 25 electrons/pixel/s (typical) in EM mode at 1MHz readout rate
1.11	Dark current	< 0.01 electrons/pixel/s
1.12	Clock-induced charge	< 0.02 electrons/pixel/frame
1.13	Binning	Should be selectable
1.14	Readout interface	USB version 2.0 or higher, or GigE
1.15	Trigger input	Fiber optic or TTL
1.16	ADC resolution	≥ 16 bit
1.17	Cooling	Thermoelectric

Table 1: Functional and performance parameters of the cameras for spectrometers.

2.1.6.1.1. Camera interface requirements

REQ-021614/A

The Supplier shall provide the relevant hardware required to install the camera on any of the spectrometers described in the previous sections.

2.2. Tender part B – sCMOS scientific imaging camera

2.2.1. General requirements

REQ-021540/A

The parameters of all the sCMOS scientific imaging cameras shall correspond to the requirements given in table 2 below.

Item N°	Parameters	Minimum Requirements
2.1	Sensor type	sCMOS
2.2	Pixel format	2048 × 2048 pixels
2.3	Pixel size	6.5 × 6.5 μm
2.4	Sensor area	13.3 × 13.3 mm
2.5	Linearity	≥ 99 %
2.6	Quantum efficiency	≥ 80 % (peak)
2.7	Full well capacity	≥ 30,000 electrons
2.8	Readout noise	< 1.0 electrons (median)
2.9	Dark current	< 0.02 electrons/pixel/s
2.10	Dynamic range	≥ 33,000:1
2.11	Readout interface	USB3.0
2.12	ADC resolution	≥ 16 bit
2.13	Trigger input	Fiber optic or TTL
2.14	Optical interface	C-mount
2.15	Cooling	Thermoelectric

Table 2: Functional and performance parameters of the sCMOS scientific imaging camera.

2.2.1.1. Software and computer interface requirements

REQ-021615/A

The Supplier shall provide the required software for camera control, data acquisition and display.

REQ-021616/A

The software shall be able to run on Windows 10 operating system (or newer versions).

REQ-021617/A

The Supplier shall provide a software development kit (SDK) allowing programmatic control of full range of camera settings and regimes and undepreciated raw image data acquisition.

NOTE 1: The SDK shall be compatible with Windows 10 and Centos 7 operating systems (or newer versions).

NOTE 2: The SDK shall be delivered in form of 64-bit linkable library binaries (.dll for Windows, .so for Linux), C/C++ header includes and full-scale documentation of all public library objects.

REQ-021618/A

The CA shall be able to install the software in any number of computers without incurring any additional costs.

REQ-021619/A

The Supplier shall provide a cable between 2 m to 3 m long for the control of the camera.

2.3. Tender part C – Large field-of-view imaging camera

2.3.1. General requirements

REQ-021541/A

The parameters of all the large field-of-view imaging cameras shall correspond to the requirements given in table 3 below.

Item N°	Parameters	Minimum Requirements
3.1	Sensor type	CCD or sCMOS
3.2	Pixel format	$\geq 4096 \times 4096$ pixels
3.3	Pixel size	$9 \times 9 \mu\text{m}$
3.4	Sensor area	$\geq 36.8 \times 36.8 \text{ mm}$
3.5	Linearity	$\geq 99 \%$
3.6	Quantum efficiency	$\geq 60 \%$ (peak)
3.7	Full well capacity	$\geq 90,000$
3.8	Readout noise	< 10 electrons
3.9	Dark current	< 0.02 electrons/pixel/s
3.10	Dynamic range	$\geq 9,800:1$
3.11	Readout interface	USB or Ethernet
3.12	ADC resolution	≥ 16 bit
3.13	Cooling	Thermoelectric

Table 3: Functional and performance parameters of the large field-of-view imaging camera.

2.3.1.1. Software and computer interface requirements

REQ-021620/A

The Supplier shall provide the required software for camera control, data acquisition and display.

REQ-021621/A

The software shall be able to run on Windows 10 operating system (or newer versions).

REQ-021622/A

The Supplier shall provide a software development kit (SDK) allowing programmatic control of full range of camera settings and regimes and undepreciated raw image data acquisition.

NOTE 1: The SDK shall be compatible with Windows 10 and Centos 7 operating systems (or newer versions).

NOTE 2: The SDK shall be delivered in form of 64-bit linkable library binaries (.dll for Windows, .so for Linux), C/C++ header includes and full-scale documentation of all public library objects.

REQ-021623/A

The CA shall be able to install the software in any number of computers without incurring any additional costs.

REQ-021624/A

The Supplier shall provide a cable between 2 m to 3 m long for the control of the camera.

3. Delivery requirements

REQ-021602/A

The transportation to the final destination shall be conducted by the Supplier.

4. Safety Requirements

REQ-021603/A

The Supplier shall supply a Declaration of Conformity or any other equivalent document legally recognized and accepted in the Czech Republic for each product type if the appropriate legislation determines the Supplier's obligation to have a Declaration of Conformity (or the equivalent document) for the purposes of a Device sale in the Czech Republic to fulfil the requirements of 2001/95/EC directive or applicable Czech law.

5. Quality Requirements

5.1. General Quality Requirements

REQ-021604/A

The Supplier shall provide the Product User Manual as part of the delivered Product. The Manual shall include the instructions and descriptions regarding the following procedures:

- transport, handling and storage;
- installation, cleaning and calibration;
- user manual for the software;
- safe operation and maintenance procedures.

NOTE 1: The Product technical data sheet shall be part of manual.

NOTE 2: The scope of the User Manual shall be agreed with the CA before Product delivery.

REQ-021605/A

The Supplier shall establish and maintain a non-conformance control system compatible with ČSN EN ISO 9001 (equivalent to EN ISO 9001).

5.2. Specific Quality requirements

REQ-021606/A

In case of the spectrometer repair by the Supplier within the validity of warranty, the Supplier shall recalibrate and verify the spectrometer once the repair is completed. The results of these processes shall be provided to the CA.

REQ-021607/A

All the spectrometers shall be delivered with documented results of the Supplier's outgoing check (e.g. test protocols, inspection report and etc.).

NOTE 1: These results shall demonstrate that the spectrometers comply with technical requirements stipulated herein.

NOTE 2: The test equipment used for performing the tests shall have valid metrological confirmation.

