

ANNEX 3  
TECHNICAL SPECIFICATIONS

Authors

Tomáš Skála, Kevin Prince, Nataliya Tsud, Luca Poletto

## Table of contents

Table of contents.....	2
List of sub-annexes.....	3
1 Introduction.....	4
2 Subject of the supply.....	6
2.1 General conditions.....	6
2.2 Responsibilities of the contractor.....	6
2.3 Responsibilities of CERIC.....	8
2.4 Indications for the development of the project.....	8
2.5 Time Schedule.....	9
2.5.1 Design.....	9
2.5.2 Construction and FAT.....	10
2.5.3 Delivery and installation.....	10
2.5.4 SAT and compliance checks.....	10
2.7 Vacuum system tests and checks.....	10
2.8 Dimensional tests and verifications.....	12
2.9 Tests and controls related to motion.....	12
Basic checks.....	12
2.10 Optical tests and checks.....	12
Gratings.....	12
Mirrors.....	13
2.11 Tests relating to the vibration modes of mechanical systems.....	13
2.13 Testing of fluid circuits.....	13
2.14 Protection and transport.....	13
2.15 Installation and Site Acceptance Test (SAT) at Elettra.....	14
2.16 Warranty.....	14
2.17 Documentation.....	15
3 Technical specifications.....	17
3.1 General requirements.....	17
3.1.1 Chambers and connecting vacuum tubes.....	18
3.1.2 Optical elements.....	19
3.1.3 Cooling system.....	19
3.1.4 Pumping system and vacuum monitoring.....	19
3.1.5 Pneumatic components.....	20
3.1.6 Bake-out system.....	20

3.1.7	Actuators.....	20
3.1.8	Connections.....	21
3.1.9	Pre-alignment .....	21
3.2	Pre-focusing mirror ( <i>PFM</i> ) .....	21
3.3	Transfer line 1 ( <i>TL1</i> ).....	22
3.4	Plane grating monochromator ( <i>PGM</i> ).....	22
3.5	Transfer line 2 ( <i>TL2</i> ).....	24
3.6	Exit slit ( <i>ES</i> ) .....	24
3.7	Filters ( <i>F</i> ).....	24
3.8	Refocusing mirror ( <i>RFM</i> ) .....	25
4	Special and spare parts.....	26

#### List of sub-annexes

3A	pdf	Suggested component list
3B	pdf	Manufacturing and Cleaning. Technical Specification for ultra-high vacuum chambers and components
3C	pdf	Installation and Alignment of Beamlines at Elettra
3D	pdf	Technical Specification Document: Controls
3E	pdf	List of instruments for which TANGO control devices are already available at Elettra-Sincrotrone Trieste
3F	pdf	Electrical system of a beamline
3G	dwg	Scheme of the beamline
3H	pdf	Technical specifications for grouting machine supports
3I	pdf	Elettra stability principles and guidelines
3J	pdf	Optical elements

In sub-annexes, wherever Elettra is mentioned as customer with rights of inspection or other requirements, CERIC is to be substituted.

## 1 Introduction

A new laboratory named Charles University Beamline for Electron Spectroscopy (hereinafter CUBES) will be installed at the upgraded Elettra 2.0 synchrotron light source. The beamline will be constructed by the Central European Research Infrastructure Consortium (hereinafter CERIC), <https://www.ceric-eric.eu/>, and operated by one of its members, the Charles University, <https://cuni.cz/>, which will provide also the end-station, partly inherited from the Materials Science Beamline (hereinafter MSB), [https://www.elettra.eu/elettra-beamlines/material\\_science.html](https://www.elettra.eu/elettra-beamlines/material_science.html), operated by the Charles University from 2002 until the present. The CUBES will be dedicated mainly to surface science studies of solid materials, thin films, surfaces and interfaces, including sample preparation, and analysis by photoelectron spectroscopy and X-ray absorption in the XUV and soft X-ray photon energy range. Based on extensive calculations, a new optical layout has been designed, see Fig. 1.

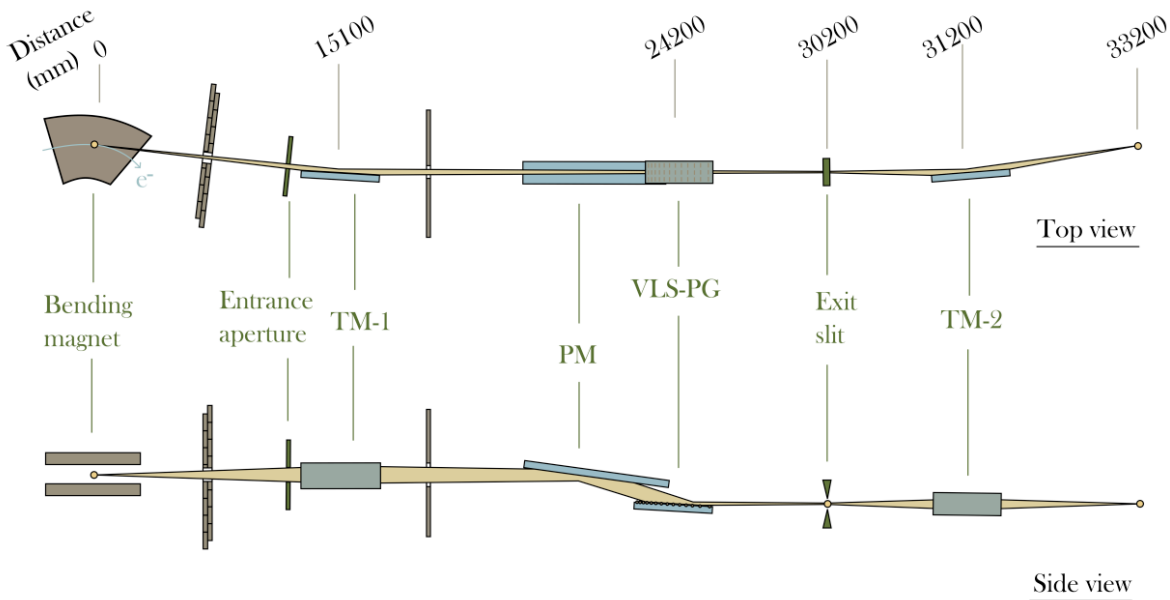


Figure 1: Proposed optical layout.

Results of the calculations show that the parameters will be significantly improved with respect to the MSB, mainly in terms of broader photon energy range (towards higher energies), higher resolution and higher photon flux. For details see Table 1:

		<b>MSB at Elettra</b>	<b>CUBES at Elettra 2.0</b>
operation		2002–2025	from 2028 on
source		bending magnet 6.1	bending magnet 5.6
electron beam energy/current		2.0 GeV/310 mA 2.4 GeV/160 mA	2.0 GeV/400 mA 2.4 GeV/400 mA
magnetic field		1.45 T	1.46 T
radius		5.52 m	5.48 m
critical energy		5.55 keV	5.59 keV
angular acceptance (hor×vert)		3.44×3.44 mrad <sup>2</sup>	2.4×3.5 mrad <sup>2</sup>
photon energy range		22–1000 eV	20–2000 eV
resolution	at 100 eV	30 meV	100 meV
	at 1000 eV	1000 meV	300 meV
	at 1500 eV	–	450 meV
	at 2000 eV	–	750 meV
photon flux	at 100 eV	10 <sup>10</sup> ph/s	3×10 <sup>12</sup> ph/s
	at 1000 eV	5×10 <sup>9</sup> ph/s	2×10 <sup>11</sup> ph/s
	at 1500 eV	–	2×10 <sup>11</sup> ph/s
	at 2000 eV	–	2×10 <sup>10</sup> ph/s
optical elements		toroidal mirror entrance slit plane mirror plane grating spherical mirror exit slit toroidal mirror	toroidal mirror  plane mirror 2 selectable plane gratings  exit slit toroidal mirror

Table 1: Comparison of MSB and CUBES

## 2 Subject of the supply

The subject of this call for tender is for the design, manufacture, testing, delivery and installation of a system for beam transport and monochromatization of synchrotron light of the CUBES beamline at Elettra 2.0, based on the layouts shown in figures 1 and 2. The system consists of a cleanup mask, a prefocusing mirror, a plane mirror, two variable line space gratings and a refocusing mirror. The tender will include construction of the necessary mechanical systems to align and manipulate the optics, construction of the UHV vacuum systems and supports, factory testing, on-site installation, pre-alignment, as well as vacuum and mechanical testing. Pre-alignment is defined as the positioning, in the experimental hall of Elettra 2.0, of the vacuum chambers containing optical elements using a laser tracker or similar instruments, so that the optical elements are at pre-determined positions with respect to reference points supplied by Elettra.

### 2.1 General conditions

All of the following is to be understood as the "minimum required performance" and, therefore, does not limit the adoption of more suitable technologies to achieve higher quality manufacturing and management standards, nor does it exempt the supplier from all the broader responsibilities inherent in compliance with applicable national and international regulations.

In order to correctly evaluate the design and construction solutions, the technical proposals for the different components of the beamlines must be as detailed and complete as possible, in particular for the instrumentation critical for their performance and the elements of them considered of greater technical value, highlighting the differences and the innovative/improving aspects compared to the initial solutions reported below.

The Contractor and his subcontractors should have suitable and current quality certificates issued by a relevant Quality Assurance Organization, such as ISO 9001:2008 or its equivalent with respect to design, production and testing of all the systems and equipment provided by it.

An indicative list of possible components is attached in sub-annex 3A.

### 2.2 Responsibilities of the contractor

- compliance with the timetable referred to in paragraph 2.5, through the development of a detailed time plan for the contract; including, but not limited to, the following essential constituent elements: preliminary meeting at Elettra (kick-off meeting), realization of the project and drawings, approval of the project and drawings by CERIC (Final Design Review Meeting) procurement of material, mechanical processing, fabrication, assembly, factory acceptance tests (FAT), shipping, installation and commissioning, site acceptance tests (SAT), etc.;
- definition and sizing of the various mechanical and vacuum components, including the management of the thermal load on the various elements and the minimization of mechanical vibrations, in particular of the most critical optical elements;
- optimization of the optical layout and physical parameters of the related elements;
- creation of the construction drawings (prepared and delivered in STEP/DWG format for approval and including all the elements of the complete system) which will be issued to CERIC;
- procurement of materials and commercial parts necessary for the construction of the beamline, except as explicitly stated differently;
- construction and assembly of components and systems;
- cleaning and protection procedures of the components during manufacture;
- execution of cleaning and vacuum tests, which must be consistent with the specifications described in sub-annex 3B;
- calibration and testing of moving parts;

- dimensional verification of all components and fiducialization of systems;
- execution of all the tests necessary for the testing of the chambers and movements in the required vacuum conditions;
- production of documentation and certifications attesting to the real performance and compliance of the mechanical and optical components with the established requirements;
- packaging and transport from the Contractor's premises to Elettra's premises;
- completion of the documentation: executive drawings, quality assurance documents, certification of the acceptance tests, documentation of any software implemented, list (by component) and certificate of the materials used in compliance with the UNI EN ISO 10204 standard;
- CE certification of the instrumentation supplied;
- installation, commissioning and performance testing of the beamline at Elettra;
- certification of leak tests on all hydraulic circuits dedicated to cooling equipment.

The Contractor must also provide CERIC:

- manufacturing drawings in STEP format and a file with the description of the assembly step by step;
- certification of the dimensional verification of the system delivered with compliance reports in digital form with the values of fiducialization of the components, see sub-annex 3C;
- characterization and certification of optical elements (gratings, mirrors) and of the materials exposed to the beam (masks, slits, etc.);
- documents describing the operating logic and reporting the calculations and/or simulations of any improvements to the various components such as optical elements, vacuum components, cooling, controls, etc.;
- diagrams of the electrical systems (DWG), the various wiring and junction boxes present (sub-annex 3D);
- diagrams of the hydraulic circuits of the cooling (DWG format) with indications of the nominal flow rates, the maximum heat load disposed of and pressure losses;
- dimensions of the equipment, providing detailed technical diagrams of the dimensioned mechanical drawings (or 3D drawings in STEP format);
- description of the sheets constituting the control electronics supplied (or CAD/DWG drawings) or manuals and datasheets used for the design;
- results of vacuum tests and handling;
- certification of the materials used for each component of the system;
- a final report with all the technical documents and test results to be sent to CERIC at least 2 (two) weeks before delivery. CERIC reserves the right to reject the delivery in case the requested documentation is not provided.

Each element of the beamline must be supplied with the technical drawings and the reference to the assembly to which it belongs. In addition, a document must be provided showing the characteristics of the various components, provided with the mechanical and assembly drawings necessary for installation and routine maintenance. The description must also include the controllers, the connections for their hardware and any custom software that the supplier develops for interfacing and remote control. In particular, for each section of the beamline, the project shall include, where applicable, the following elements:

- general description;
- general vacuum requirements;
- arrangement and placement of the vacuum elements;
- pumping system;
- vacuum measurement system;
- cooling requirements;

- accuracy and precision in translations and rotations, characteristics of the encoders used;
- locking systems;
- supports and alignment systems;
- any beam diagnostic devices in the sections;
- cooling system and temperature monitoring devices;
- electrical diagrams relating to signals and power supplies;
- connections (wiring) with controllers;
- hardware connections for alarms;
- materials used;
- bake-out system;
- any reports of risks associated with the use and maintenance of the instrumentation.

### 2.3 Responsibilities of CERIC

- Radiation shielding of the safety hutches.
- PLC for the management of the elements of the beamline related to the safety of people (stoppers, access systems, monitors, etc.) linked to the presence of radiation (including the relevant racks). The necessary PLC software will also be provided by CERIC.
- PLCs relating to the instrumentation protection system and the computers making up the control system (including the related racks). The necessary PLC software will also be provided by CERIC.
- PLCs for operation of the gate valves separating beamline sections.
- Infrastructures serving the beamline, i.e. CERIC will install in the immediate vicinity of the beamline all the services necessary for:
  - computer network (and related distribution channel);
  - electricity (and related distribution channels);
  - demineralized cooling water including flow meters (the supply will end with valves on the supply and return);
  - compressed air (the supply will end with a valve on the delivery);
- Drivers, controllers and control software (tango devices) of the motors, if compatible with what is described in sub-annex 3E.
- 19" racks for electronics

### 2.4 Indications for the development of the project

The Contractor shall specify within 9 (nine) months from the signature of the contract all the laboratory services required for the operation of the system (e.g. power requirements, gas/compressed air, chilled water, etc.).

The control system of each beamline will consist of a PLC-based instrumentation protection system and a high-level control infrastructure based on the TANGO framework. The computers and PLCs making up the control system will be supplied by CERIC and must be able to manage all logic states, positions, temperatures, pressures and flows, movements, etc. Each controller supplied with the instrumentation must therefore be equipped with analog or digital interfaces in order to be integrated into the PLC-based instrumentation protection system. For software control, each controller not listed in sub-annex 3E must be supplied with a TANGO software interface, and communication must take place via serial or Ethernet hardware interface. For each user, the supply of wiring up to the relative controllers, generally located in dedicated racks according to Elettra's internal standards, is required.

All electrical equipment in the system must meet the following requirements: 230 V, 50 Hz and CE compliance. The Elettra electrical system is served by two own MV/LV substations, connected to the national medium voltage (MV) grid at a nominal voltage of 20000 V ("normal power line") and to two cogeneration and absolute continuity plants ("priority power line"). The earthing system is unique and its impedance is about 1 ohm. The electrical distribution circuits are divided between "normal" and

"priority" energy and converge on dedicated electrical distribution panels, located in the experimental hall of Building S. The detailed characteristics of the plant and its possible developments are given in sub-annex 3F. All the laws of the Italian State in force and applicable to electrical systems must be complied with: in particular, Ministerial Decree 37/2008 and Legislative Decree 81/2008. The electrical works must be designed and built in a "workmanlike manner" pursuant to Law no. 186 of 1 March 1968 and therefore in compliance with all the technical standards of the Italian Electrotechnical Committee (C.E.I.), of the Italian Standardization Body (U.N.I.) in force and applicable. The materials must comply with the European regulations for construction products (such as the CPR Regulation - EU 305/2011) in addition to those of CE marking of the product.

As far as compressed air is concerned, the maximum available pressure is 7 bar (Elettra department classification according to ISO 8573-1=3-4-1).

Demineralized water (conductivity <math><10 \mu\text{S}/\text{cm}</math>, temperature 20–25 °C) will be used for water cooling. The allowable pressure drop in the device being cooled is 3 bar and the maximum allowable speed in copper circuits is 1.2 m/s. Maximum supply pressure 10 bar, maximum return pressure 2 bar. Variations in water flow at the beamline and at specific critical elements will be monitored by means of flow meters, which will be equipped with an alarm if the flow values are outside specific ranges.

## 2.5 Time Schedule

The Contractor is required to provide a detailed description of the phases of the project, including milestones and deliverables, such as production of construction drawings, procurement of materials, vacuum testing, factory acceptance tests, installation, pre-alignment and final on-site acceptance tests. The suggested time schedule can be divided into the following four phases (scale in months). Faster delivery is acceptable and welcome.

### 2.5.1 Design

T0	Date of signature of the contract.
T0+1 (one)	By this date, the first meeting (kickoff meeting) will be organized at Elettra. The purpose of this meeting is the discussion of technical, administrative, etc. aspects related to the realization of the beamline.
T0+(1–4) (from one to four)	During this period meetings will be held in order to develop the optical design of the beamline and to define the various components.
T0+5 (five)	By this date, the optical elements and the layout of the beamline should be defined and approved by CERIC.
T0+6 (six)	By this date, the preliminary design should be produced with approval of the 3D drawing of the beamline; all motion and other encoders must be defined, and the delivery timelines of the materials should be determined, and the various phases of the installation planned.
T0+9 (nine)	By this date, the Contractor should send the executive technical drawings relating to the order for their acceptance by CERIC, which will take place during the Final Design Review Meeting, organized within 2 (two) weeks of their receipt. If necessary, CERIC may request further meetings for the discussion/definition of aspects that have not yet been clarified. The Contractor should indicate if there will be the need of (type and quantity) of motion controllers for the tests. Production will not begin until CERIC gives written notice in order to authorize the start of production.

### 2.5.2 Construction and FAT

T0+23 (twenty three)	Expected date for the Factory Acceptance Tests (FAT) described below.
-------------------------	---

### 2.5.3 Delivery and installation

T0+24 (twenty four)	Expected date for the delivery of the entire supply.
T0+28 (twenty eight)	Expected date for installation, commissioning and training of personnel at Elettra.

### 2.5.4 SAT and compliance checks

T0+29 (twenty nine)	Expected date for Site Acceptance Tests (SAT) described below.
Completion of verification of acceptance and compliance	The contract conclusion will occur after the successful completion of the SAT and beamline conformity checks.

Throughout the duration of the contract, the Contractor must produce a written report on the progress of the supply and installation works every two months. This report must contain, among other things, evidence of orders placed for materials and components, with related delivery times, and documentation of the construction in progress. CERIC reserves the right to send its personnel to the Contractor's premises at any time after giving due notice, to monitor the progress in fulfilling the contract.

## 2.6 Inspection and Factory Acceptance Test (FAT)

During the entire manufacturing, assembly and testing process, the Contractor shall carry out all the tests and controls provided for in the following paragraphs. In particular, the Contractor shall inspect and test the vacuum chambers, the supports, the mechanical parts necessary to implement the movements of all the elements, the electrical connections, the motors and encoders, the hydraulic circuits and the optical elements. CERIC reserves the right to actively participate in the acceptance tests at the Contractor's premises which, therefore, must communicate the dates of the tests at least 2 (two) weeks in advance. CERIC will approve the delivery of the products after the Contractor has demonstrated full compliance with the specifications; the Contractor must then send to CERIC a detailed report with the results of the tests. The Contractor will be notified of the acceptance or rejection of the system within 3 (three) weeks of receipt of the report.

## 2.7 Vacuum system tests and checks

The manufacturing, cleaning and vacuum testing procedures are indicated in sub-annex 3B. This document must be accepted and complied with by the Contractor at all points.

- At least 2 (two) weeks prior to production, the Contractor shall submit a Quality Assurance (QA) plan to CERIC for acceptance, which shall ensure that each part produced complies with the requirements contained herein. The Contractor shall wait for written approval from CERIC prior to the commencement of production.
- The Contractor shall ensure full compliance with the specifications in sub-annex 3B and further detailed herein. Any deviations must be submitted for approval to CERIC before any action is taken in this regard.
- Appropriate cleaning conditions of workspaces, tools and work clothing must be applied during all phases of construction and assembly of vacuum components.

- Finishing and cleaning surfaces exposed to vacuum are of paramount importance to achieve the required vacuum level. The materials used for cleaning and subsequent storage of the components must not leave residues on their surfaces that could compromise vacuum performance or mechanical functionality. Sandblasting and shot peening of vacuum-exposed surfaces is not permitted. Lapping or other mechanical polishing methods are not permitted, unless otherwise specified in paragraph 5.1.1 of sub-annex 3B. It is not permitted to handle these surfaces without the necessary protection (e.g. gloves, gowns, oversleeves) in order not to transfer organic residues from the operator to the surfaces themselves (e.g. natural skin grease in the form of fingerprints), in particular after cleaning the components for vacuum.
- The surfaces, internal and external, of all the components of the entire system must be free of obvious defects such as scratches, holes, variations in color and/or composition, inclusions, oxides, rust spots.
- Leak tests are required with helium of each individual vacuum component, possibly installed on the destination chamber. Losses must comply with class a) indicated in chapter 10 of sub-annex 3B. In the event of a leak above the threshold, the component identified as the source of the leak must be examined individually after having repaired the leak, and before being reinstalled on the destination chamber, if necessary.
- It is required to proceed with the controlled heating (bake-out) of each chamber and each component in vacuum, including bellows, connection tubes, slits and bellows, see sub-annex 3B. In addition, the chambers must be heated at least once to maximum temperature before inserting internal elements such as mirrors, gratings or sensors, which can subsequently limit the maximum temperature that can be reached. Please refer to paragraph 9.4 of sub-annex 3B for the complete specification.
- After bake-out, with the chamber at room temperature, the vacuum test must be carried out with a quadrupole residual gas analyzer (RGA), which allows one to check the type of residual gases present in the vacuum chamber and, therefore, the degree of cleanliness inside it.
- The mass spectrum shall cover the mass range from 1 to 200 a.m.u., and the instrument shall be capable of detecting partial pressures of less than  $5 \times 10^{-12}$  mbar. The test must be carried out in the various vacuum chambers of the system, once basic pressures of less than  $5 \times 10^{-9}$  mbar have been reached. A detector with a dynode electron multiplier or equivalent must be used; the use of the Faraday cup alone is not allowed. The instrument must be calibrated to peak nitrogen (28 a.m.u.) and the calibration factor must be reported in the documentation.
- In the case of a mass spectrum that shows the presence of air inside the vacuum chamber after bake-out, it is necessary to check again for any vacuum leaks and proceed to eliminate them, after written notification to CERIC. In this case, the bake-out process must be repeated after eliminating the loss. The final pressure 24 hours after the end of the bakeout must be below  $2 \times 10^{-10}$  mbar (for vacuum sections containing mirrors or gratings) or  $5 \times 10^{-10}$  mbar (other vacuum sections).
- The raw data, including pressure and temperature as a function of the bake-out procedure, must be saved in digital form in text format and delivered with the documentation. As indicated in chapter 9.5 of sub-annex 3B, the test is successful if the sum of the peak intensity values referred to masses higher than 28 a.m.u., excluding the peak mass intensity value 44 a.m.u., is less than 0.1% of the total sum of the values referred to all masses in the range 1–200 a.m.u. A CERIC representative must be allowed to attend the entire test.
- Once the vacuum tests have been successfully completed, each component or vacuum system consisting of several components shall be filled with dry nitrogen to equilibrate the external atmospheric pressure before being disassembled and packaged in accordance with paragraph 14 of sub-annex 3B.

- Prior to shipment, the Contractor shall provide a copy of the accompanying documentation indicating the results of the checks, analyses and tests to establish the conformity of the product with the requirements described herein.
- The beamline must be prepared for shipment in accordance with good business practice and in accordance with applicable rules and regulations relating to the packaging and transportation of goods, in order to prevent any damage to the parts.

## 2.8 Dimensional tests and verifications

- The mechanics must comply with the construction drawings previously approved by CERIC.
- It will be the responsibility of the Contractor to provide the data of the dimensional checks, obtained through the use of appropriate measuring devices.
- Alignment and dimensional checks will be carried out.
- The Contractor is responsible for the fiducialization of the components (see sub-annex 3C).

## 2.9 Tests and controls related to motion

All the planned movements will be subject to verification in terms of functionality, accuracy, precision. All the checks of the movements must be carried out by connecting the drive equipment to the so-called "junction box" (object of supply) which must have connections that comply with the CERIC requirements as described in sub-annex 3D.

### Basic checks

- verification of compliance of the "junction box";
- motor functionality check;
- checking the correct operation of the limit and reference switches (where present);
- verification of the correct reading of the encoders (where provided);
- detection of the minimum and maximum limits of the actuator and encoder stroke;
- verification of collision avoidance systems (where provided);
- verification of protections for operator safety.

Additional verifications, concerning the resolution, accuracy, repeatability, and stability of the positioning systems through repeated measurements of the position of one or more points with respect to a reference (if present) or limit switch signal.

## 2.10 Optical tests and checks

All optical elements (mirrors and gratings) must be accompanied by laboratory measurements certifying the required characteristics. Before their insertion into the respective vacuum chambers, these optics will be measured again for acceptance at the Elettra metrology room. The costs and organization of transport to and from Elettra are borne by the Contractor.

In particular, Elettra will carry out the following measurements:

### Gratings

- dimensional verification;
- check line density, groove depth, duty cycle and blaze angle;
- flatness verification with Fizeau interferometer at normal incidence;
- roughness verification;
- check for scratches on the surface.

### Mirrors

- dimensional verification;
- evaluation of slope error and radii with long-track profilometer;
- roughness assessment;
- check for scratches on the surface.

The Contractor will coordinate the testing of the optical elements and guarantee the results. One or more representatives of CERIC will be able to attend the tests. The Contractor shall agree with CERIC on the date and location of the tests at least 4 (four) weeks in advance.

### 2.11 Tests relating to the vibration modes of mechanical systems

The mechanical elements whose vibration modes are considered particularly critical (e.g. monochromator, mirrors,...) will be subjected to tests that evaluate their declared angular/positional stability and the vibration modes in a sufficiently wide range of frequencies (e.g. 0–2.5 kHz).

### 2.12 Tests related to instrumentation controllers

All the controllers envisaged will be subject to verification in terms of

- presence of analog or digital interfaces to be integrated into the PLC-based instrumentation protection system;
- presence of a TANGO interface, whose methods and attributes, in sufficient number to ensure good management of the instrumentation, will be subject to verification; communication with the controllers must take place via serial or Ethernet interface.

### 2.13 Testing of fluid circuits

Pressure tests of fluid circuits will be executed in accordance with the provisions of UNI EN 806-4:2010 standards, and in particular UNI 9182:2014 (water) and UNI CEN/TS 764-8:2016 (air and gas).

CERIC reserves the right to have tests and inspections carried out directly by its staff and with its own instrumentation, if it deems it necessary. In any case, the Contractor's obligation to find the equipment and measuring instruments necessary for the acceptance tests will remain valid.

Any failed checks should be discussed with CERIC. The Contractor shall provide CERIC with a corrective procedure which shall be implemented after approval in writing by CERIC.

The complete system can be delivered to Elettra only after the relevant acceptance tests have been successful and approved by CERIC.

### 2.14 Protection and transport

All components and mechanisms must be shipped properly, so as to prevent any damage or contamination during transport at any weather. 5G shock indicators must be attached to each package. Vacuum components must be filled with dry nitrogen to balance the external atmospheric pressure. To preserve the integrity of the sealing surfaces of flanges, they must be protected by a blind flange or mechanical protection.

Packing crates must be robust and suitable for lifting and transporting with a crane or forklift, without risk of damage.

All chambers and various subsystems, such as flanges with manipulators, mirrors, etc., which cannot be moved manually, must be equipped with eyebolts or similar systems for handling and positioning them. Any damage produced during transport must be repaired by the Contractor at no additional cost to CERIC.

## 2.15 Installation and Site Acceptance Test (SAT) at Elettra

The timeline of the various phases of the installation will be agreed in the first 6 (six) months of the project. It may include the staggered shipment of components and an installation divided into different times. The Contractor will take care of mounting the optical elements (i.e. mirrors, gratings) in the final location, trying to minimize operations in the experimental area.

Installation will be carried out by the Contractor. CERIC reserves the right to repeat at Elettra the tests and inspections previously carried out at the contractor's premises within 2 (two) months from the date of delivery of the beamline. Once installation and commissioning are completed, further functionality tests (vacuum, mechanical, hydraulic, electrical, software controls) will be carried out.

CERIC will notify the Contractor of the date of such tests at least 2 (two) weeks in advance. The Contractor, or his delegate, must be present at the SATs. At the end of the tests, an appropriate and detailed report will be drawn up certifying the correct performance of the same and the compliance of the instrumentation with the requirements of the supply. The minutes will be signed by the Contractor or his delegate present at the SATs and by CERIC's representatives.

In the event that the non-compliance of an element or system is detected and therefore the impossibility of use, CERIC reserves the right to refuse the system or any part of it, suspending the performance of the SAT until the problem is resolved. The Contractor shall therefore repair or reproduce the non-conforming system/component no later than 10 (ten) weeks after the defect is identified. If necessary, and upon written request from the Contractor, CERIC will ship the defective component/system to the Contractor's premises. No cost will be charged to CERIC for any shipping, repair or replacement costs. The Contractor is responsible for the movement of goods within the Elettra site and up to their installation. Elettra, on request, will be able to provide the overhead crane (maximum capacity 7.5 t) on free loan for use by adequately trained personnel, for handling inside the building S. Installation and commissioning must take into account the work schedule of other beamlines. CERIC undertakes to communicate to the Contractor the precise dates of the installation of the line at least 1 (one) month in advance.

The Contractor must communicate at least 2 (two) weeks before the aforementioned dates the list of personnel in charge of the installation and commissioning of the line to Elettra, and must prepare all the necessary documentation pursuant to Legislative Decree 81/08. The Contractor's personnel must read the "Safety Manual for External Companies" before starting work at the Elettra site. The document is available on the web at <http://www.elettra.eu/spp/info-ditte.html>.

Installation and commissioning must be carried out, at every stage, in accordance with the Italian laws and technical standards in force.

The tracing and alignment operations must be agreed in advance and will take place under the supervision of Elettra staff. At the end of the operations, the 3D drawing of the beamline must be provided in digital form, in the reference system of the machine.

## 2.16 Warranty

The Contractor shall guarantee the supplied equipment for both material quality and proper operation for a period of not less than twelve (12) months from the date of the conformity inspection. The warranty and support services shall include direct assistance for responding to inquiries and providing technical support.

By accepting these tender specifications, the Contractor further undertakes to indemnify and hold CERIC not liable from any direct or indirect damage arising from failures and/or functional defects of the supplied goods, for the entire duration of the warranty period.

## **2.17 Documentation**

Complete documentation including engineering drawings, 3D models (STEP files), manuals, safety declarations, CE compliance, reports of visual inspection, compliance of external dimensions, vacuum testing, and mechanical metrology reports will be supplied. For all components supplied by third parties, such as encoders and bake-out systems, the corresponding manufacturers' manuals will be supplied. The Contractor shall grant CERIC the right to use all supplied documentation (including drawings, 3D models, manuals, and reports) for the purposes of operation, maintenance, and possible future upgrades of the system, including cases where such activities are performed by third parties.

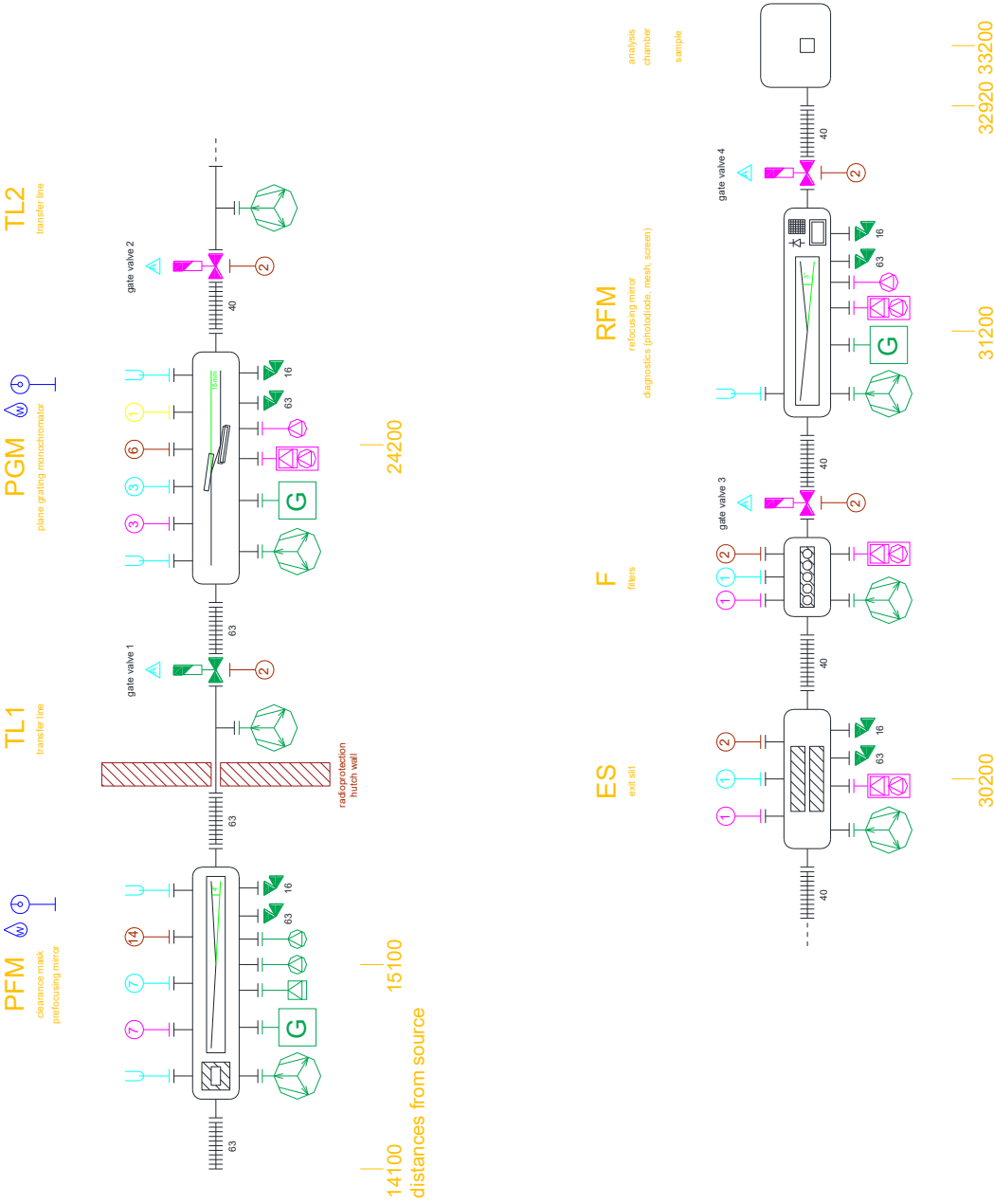
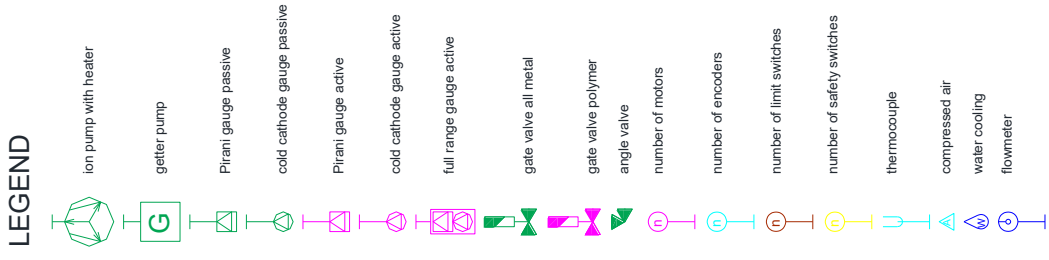


Figure 2: Scheme of the beamline, also in sub-annex 3G.

### 3 Technical specifications

Figure 2 and sub-annex 3G show the layout of the vacuum chambers and instrumentation. The system is divided into the following four vacuum sections with suitable electropneumatic valves separating them: Entrance optics, including the entrance aperture and prefocusing mirror. Monochromator. Exit slit and filters. Refocusing mirror.

#### 3.1 General requirements

In the following sections the beamline will be described in blocks corresponding substantially to the list of elements described in Figure 2. The quantities (e.g. number of ion pumps and their pumping speed, number of motors, limit switches, encoders, bellows, valves) reported are indicative and different and improved options can be proposed. Some parameters and/or figures of merit can be modified during the development of the final project with the aim of obtaining a better compromise in terms of flux, quality and stability of the beam in the experimental chamber of the end station located about 33 m from the source.

Before going into the details of the various components, some general observations are valid for all systems:

1. The beam from the bending magnet is located 1300 mm above the nominal level of the floor of the experimental hall.
2. The dimensions of each component are only estimated, as only the starting point (the DN100CF-F flange with tapped M8 holes of the last front-end valve at 14100 mm from the source) and the entrance of the end station (DN63CF-R flange with through holes of the experimental chamber at 32920 mm) are fixed.
3. All limit switches/status switches/zero markers and valves must be of the normally-closed type.
4. The valve status must be detected by two elements/sensors.
5. All systems must comply with the "Fail Safe" approach and all safety devices must follow the criterion of "redundancy with implementation of diversified technology".
6. For the alignment, at least four external references shall be provided in suitable positions for each chamber (see sub-annex 3C).
7. The supports of the various chambers must be as free from vibrations and as rigid as possible: where possible the use of granite supports is strongly encouraged. Each of them must be equipped with adjustment feet that allow an adjustment in the three coordinate axes (longitudinal, transverse and vertical) of at least  $\pm 25$  mm and a control of pitch, roll, and yaw. The feet must be attached, directly or indirectly, to the floor to provide a rigid connection for each foot, see sub-annex 3H. Concerning vibration issues, the mechanical design of the Contractor is required to conform to sub-annex 3I.
8. An appropriate mounting system or procedure for vacuum pumps must be provided for facilitate their installation and removal.
9. In the design of the various supports (including those for small components such as valves) the case in which one side of the component is in vacuum and the other in air at atmospheric pressure must be considered.
10. Each section into which the beamline can logically be divided (consisting of a single chamber or system of several elements positioned on the same support) must be equipped with one or more junction boxes that collect the signal and power cables necessary for the operation of the devices contained in that section.

11. The materials used in the construction of the various components must be approved by CERIC; in general, AISI 316L steel is the material of choice for the components of the prefocusing mirror chamber, whereas AISI 304 is allowed downstream.
12. All viewports situated outside of the radioprotection hutch must have X-ray screening (lead glass disks on the air side).
13. Metric units of measurements are preferred to imperial, e.g. for bolts, nuts, fluid tubing. Use of imperial measures where unavoidable must be discussed and approved by CERIC before use.
14. All vacuum components are required to conform to the specifications in sub-annex 3B.
15. The pressures in vacuum chambers containing mirrors or gratings must be below  $2 \times 10^{-10}$  mbar, measured 24 hours after bake-out, without beam. For other chambers, up to  $5 \times 10^{-10}$  mbar is allowed, measured 24 hours after bake-out, without beam.
16. Safety, Operation and Maintenance instructions should be provided for all supplied items, including the parts from external manufacturers.
17. Engineering drawings and 3D models as STEP files should be provided for all parts and assemblies.
18. The mechanics will be designed to facilitate maintenance operations, such as removal of optics for cleaning. The documentation supplied with the system will describe how this can be done.
19. The offer will include the period of the guarantee against defects in materials and workmanship.
20. A list of spare parts (such as bearings, electronics etc.) which are commercially available will be supplied. For parts which may be subject to wear and tear, and which are not commercially available, the Contractor is invited to include a quotation for spare parts.
21. The tender will specify the level of after sales support offered for the product, and the period.
22. The tender will enclose a list of references of soft X-ray or VUV beamlines, monochromators, manufactured by the Contractor, especially plane grating monochromators working with grazing incidence beam.

### 3.1.1 Chambers and connecting vacuum tubes

All components along the beamline must be UHV compatible with the vacuum levels indicated in this document and able to resist high radiation levels over time. The supply includes all pipes, valves, edge welded bellows, viewports, and blind flanges that make up the various chambers as well as the connections between them. Each chamber or group of chambers forming one vacuum section, in which a pumping system is installed, must be equipped, in addition to what is provided by the designer to ensure the required vacuum levels, with:

- at least one manual right angle all-metal valve of CF63 size for efficient pre-pumping of the vented chamber, mounted on a dedicated flange connected directly to the chamber;
- a DN16CF manual right angle all-metal valve for controlled venting of the chamber (at least one per vacuum section);
- a DN40CF flange with an all-metal valve, for mounting a mass spectrometer for He leak testing.

All pumping systems and vacuum measuring sensors must be connected directly to the flanges on the chamber but not directly pointing to the surfaces of the optical elements. The tubes and bellows may have a fixed flange (upstream), while the other (downstream) flange must be of the rotatable type. The required valves are all-metal type valves manufactured with CF type flanges (e.g. VAT series 48, 57, 54 or equivalent). Gate valves with metal bonnet seal and polymer closure (for example VAT series 01 and series 10 or equivalent) are allowed only in areas not subjected to ionizing radiation, i.e. outside of the radioprotection hutch. Gate valves must have a pneumatic actuator with double drive, without on-board distribution solenoid valve, with mechanical position indicator and with electrical contact closure for each

state (open valve and closed valve), and be free from electrical potentials. The distribution solenoid valve of the pneumatic actuator must be monostable and activated by 24 V DC.

### 3.1.2 Optical elements

All optical elements are described in sub-annex 3J, including the materials, dimensions, and corresponding thermal loads.

The axes are defined as shown in Figure 3.

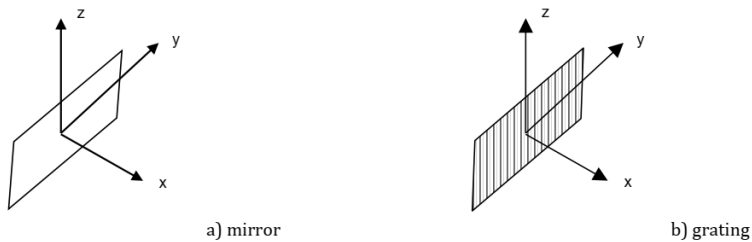


Figure 3: Axes definition for optical elements; a) mirror, and b) grating.  $x$ =optical surface normal,  $y$ =direction of the beam downstream.

### 3.1.3 Cooling system

The sizing, design and implementation of the cooling system of the various parts of the line are the responsibility of the Contractor who must ensure the stability and performance of the components for efficient use of the photon beam at the end station. In vacuum, no connections are allowed in the liquid transport system. The supply includes all internal parts for each component that needs cooling including type K-type thermocouples, internal wiring, feedthroughs, external wiring up to a junction box (dedicated to thermocouple signals, digital status signals, digital command signals, and analog signals (if present) and extension cables with an approximate length of 45 m. Particular attention must be paid to reducing vibrations produced by the circulation of the coolant. CERIC will supply flow switches and pressure switches for the cooling fluid, pipes and valves of the external circuit starting from the distribution box or from the connections on the chamber.

If the cooling requires water tubes inside the UHV chamber (probably the case of PFM, possibly also PGM), vacuum guard lines must be used. The vacuum guard line operates by means of a small membrane pump that keeps the guard line at a pressure of a few mbar, and is monitored by a low pressure vacuum gauge. The vacuum gauge controller generates states of pre-alarm and alarm if the pressure rises, and these signals are sent to the PLC controlling gate valve closure.

### 3.1.4 Pumping system and vacuum monitoring

The following items are part of the supply and the responsibility of the Contractor:

- vacuum pumping systems for all sections into which the beamline is logically divided (portions enclosed between sectioning gate valves), including the fittings necessary for their installation. It is the Contractor's responsibility to assess the correct distribution and sizing of all pumping units to reach and maintain the required vacuum levels in the specific section;
- vacuum gauges (low and high/ultra high vacuum transducers) from atmospheric pressure down to that required for all vacuum sections of the beamline, where necessary, including their controllers and interconnection cables (indicative maximum length 45 m);
- power supplies and control units for vacuum pumps with relative connection cables (indicative maximum length 45 m);
- all other devices envisaged by the Contractor for the creation, monitoring and maintenance of the vacuum levels on the beamline.

In the areas of possible medium/high irradiation, that is, the PFM chamber inside the radioprotection hutch, to avoid possible damage to the electronics by ionizing radiation, it is necessary to use passive components with remote control electronics of the pressure gauges (such as Pfeiffer IKR 070 and TPR

018). In areas with less or zero irradiation, it is possible to use active pressure transducers (with electronics on board), such as the Pfeiffer IKR 270, PKR 361, TPR 280 or equivalent. The position of the gauges must ensure that synchrotron light cannot impinge on their in-vacuum parts, and that there is no direct line of sight from the gauge to any optical element. The allowed controllers are type Pfeiffer TPG 500, TPG 366 or equivalent (TANGO devices must be provided for controllers not listed in sub-annex 3E).

The allowed ion pumps are of triode type such as Agilent "StarCell" or equivalent, with "Fischer" type high voltage connectors. High voltage cables must have electrical safety interlock pins. This must be inserted in the controller in order to ensure that an accidental detachment of the connector on the pump side immediately interrupts the supply of the high voltage. The required controllers are Agilent 4UHV type or equivalent, with negative HV outputs, and equipped with a serial (obligatory) and Ethernet (additional) communication port. TANGO devices must be provided for controllers not listed in sub-annex 3E.

Alternatively, non evaporable getter (NEG) pumps combined with ion pumps can also be used, provided that the ion pump is of the "triode" type compatible with the controls indicated above. NEG-type pumps formed by disks of sintered (and not simply pressed) powders can be used in addition to ion pumps in ultra-high vacuum conditions (also in order to reduce the size of the ion pumps) if the required pressure is guaranteed, without inducing a premature saturation of the NEG pump itself. The activation units of the NEG pumps and the relative power cables between pumps and controllers must also be provided. Possible solutions are the SAES Getters CapaciTorr series Z and D or equivalent.

### 3.1.5 Pneumatic components

Included in the supply are all pneumatic components such as solenoid valves, pressure regulators, and filters where they are necessary to connect the compressed air supply of the particular device to the general distribution system of Elettra. Particular care must be taken in the design of the mechanical supports of the gate valves used for the sectioning of the vacuum system of the beamline. In particular, the supports must be sufficiently rigid to withstand the condition in which there is vacuum on one side and atmospheric pressure on the other.

### 3.1.6 Bake-out system

The Contractor must provide all the equipment and manuals necessary to perform a correct bake-out. The presence of several bake-out sections must be foreseen, coinciding with the vacuum sections into which the beamline is divided.

The bake-out must be performed with suitable heaters (integrated heating elements on the ion pumps, flexible grounded metal-braided heating tapes, e.g. Hemi Heating MB series, etc.) and insulating blankets, K-type thermocouples and relevant controllers. In correspondence with each bake-out section, collection panels for thermocouples and heating elements must be provided. The first bake-out must be performed in the factory without the optics. After installation of the system, including the optics, at Elettra, a bake-out will be performed to ensure conformity with the vacuum specifications, as part of the site acceptance tests.

### 3.1.7 Actuators

All motors must be included in the delivery (typically 2-phase stepper motors, max 5 A/phase, 24 V), together with the wiring up to the junction box (see sub-annex 3D) and the extension cables (indicative length 45 m) for handling/controlling all provided devices, such as masks, mirrors, gratings, slits, filters, chambers etc. All motorized axes must be equipped with precision limit switches, and with an absolute position encoder on the moving part (translational or rotary). If necessary, a brake must be provided to maintain the position of the axis with the motor de-energized. In-vacuum motors are not acceptable.

### 3.1.8 Connections

Each type of signal coming from or directed towards the various devices (in air or vacuum) must be conveyed to a suitable junction box which will be placed near the device itself along the beamline. Extension cables with an approximate length of 45 m will start from here to reach the control cabinets. Exceptions are:

- vacuum pumps;
- vacuum gauges;
- power cables.

The junction boxes and the extension cables with connectors on both ends are part of the supply.

### 3.1.9 Pre-alignment

The contractor is required to provide on each vacuum chamber a system for alignment, which is compatible with the standard Elettra procedure described in sub-annex 3C, Installation and Alignment of Beamlines at Elettra. In brief, the method is based on a Laser Tracker, Spatial Analyzer application, and Corner Cube Reflectors (CCRs). Each chamber is to be equipped with 4 positions at which a CCR can be mounted, of which at least 3 can be viewed by the laser tracker placed at a single point. Note that in particular:

The Contractor, equipped with its own alignment instrumentation, or in collaboration with the Elettra alignment group, will:

- mark the ground plates and levelling feet of the supports;
- position and secure all components in situ;
- perform the final pre-alignment of all components.

The Contractor must also provide all data used for component alignment organized in text files (\*.txt) and tabulated in the following format: component\_name point\_name XYZ with coordinates expressed in mm. Specifically, the file must contain:

- the CCR coordinates referenced to the local fiducialization system;
- the coordinates of plates and levelling feet referenced to the beam source point;
- the final coordinates of all component CCRs referenced to the beam source point.

If the manufacturer uses SA for component alignment, all the above data in a proprietary SA \*.xit64 format file must be provided.

## 3.2 Pre-focusing mirror (*PFM*)

The *PFM* will be mounted in a dedicated chamber. Based on calculations of the Radiation Protection Group of Elettra it will have to be enclosed in a radioprotection hutch that may be shared with the first part of a neighbouring beamline, named XAS-mW. During operation there will be no physical access to the *PFM*, so all movements must be motorized and all included parts (especially electronics) must be resistant to elevated levels of X-ray irradiation or properly screened.

The *PFM* chamber will be connected to the DN100CF-F flange with M8 tapped holes of the last gate valve of the CUBES front end, situated at nominal height 1300 mm above the floor and 14100 mm from the source. Since the photon beam divergence will be limited by a dedicated mask in the front end to 2.4 mrad horizontal × 3.5 mrad vertical, the beam dimensions at this point are about 35 mm horizontal × 50 mm vertical, and thus the pre-focusing mirror chamber could be connected to the last front-end valve by using a bellows of inner diameter of e.g. 63 mm welded on a DN100CF-F flange with through holes, or a combination of CF100–CF63 zero-length adapter and CF63-flanged bellows. The exit flange of the *PFM* chamber is a DN63CF-F flange.

The first element in the chamber should be a vertically adjustable water-cooled cleanup mask that filters out any stray light possibly coming from the front end, and can act as polarization aperture, too. The mask should have two degrees of freedom, either upper baffle height and lower baffle height, or vertical position and vertical opening (baffle distance). The maximum absorbed power is about 85 W.

Axis	Range	Accuracy, repeatability, stability	Resolution
Upper baffle height	80 mm	0.1 mm	0.01 mm
Lower baffle height	80 mm	0.1 mm	0.01 mm

Table 2: Cleanup mask/polarization aperture parameters in case of two independent baffles

or

Axis	Range	Accuracy, repeatability, stability	Resolution
Center height	80 mm	0.1 mm	0.01 mm
Vertical opening	80 mm	0.1 mm	0.01 mm

Table 3: Cleanup mask/polarization aperture parameters in case of center height and vertical aperture

The *PFM* is manufactured from a silicon block with a Au-coated toroidal reflective surface of dimensions 1000 mm horizontally × 60 mm vertically, and will be mounted on a manipulator with its center at 1300 mm nominal height above the floor and at 15100 mm distance from the source. The nominal grazing incidence angle is 2 degrees off-surface. Any interlayer between the Si block and Au coating should be avoided if possible, and if deemed to be necessary, must be discussed with CERIC. The radii should be 432670 mm (±0.5%) × 527mm (±0.25%), surface roughness below 0.5 nm rms, slope error below 8 μrad (tangential) and 20 μrad (sagittal), see sub-annex 3J for details. The mirror must be cooled to safely withstand the incident photon flux without any deformation or drift. The mechanical mounting of the mirror must be sufficient to ensure that the stability of the position of the photon beam in the experimental chamber station of the end-station (distance 33200 mm from the source) is better than 0.1 mm.

The required range of movements, accuracy, repeatability, stability, and encoder resolution are listed in table 4.

Axis		Range	Accuracy, repeatability, stability	Resolution
z	pitch	±0.5°	1 μrad	0.1 μrad
		10 mm	0.1 mm	0.01 mm
y	roll	±0.5°	10 μrad	1.0 μrad
x	yaw	±0.5°	15 μrad	1.5 μrad
		10 mm	0.5 mm	0.05 mm

Table 4: Requirements of movements of the *PFM*.

The *PFM* chamber will be connected to the transfer line 1 without any valve, so they form a single vacuum section.

The cleanup mask baffles and the mirror holder will be equipped with a type K thermocouple, as described in section 3.1.3.

### 3.3 Transfer line 1 (TL1)

From the *PFM* the beam will pass to a vacuum tube denoted *TL1*. The maximum beam size in this section will be the same as before entering the *PFM* chamber so the inner diameter may also be 63 mm or greater. The line can be pumped by a small ion pump. The nominal height of the line above the floor is 1300 mm and the length around 7–8 m. The *TL1* will end with a CF63 edge-welded bellows and a CF63 electropneumatic gate valve 1. Although out of the radioprotection hutch, the intensity of the beam is still high so we require an all-metal valve.

### 3.4 Plane grating monochromator (PGM)

The *PGM* consists of three optical elements; one plane mirror (PM) and two interchangeable plane gratings (PG1 with 1200 lines/mm and PG2 with 400 lines/mm). It will be connected to *gate valve 1* (see Fig. 2) with an edge-welded bellows to limit *PGM* vibrations when operating the electropneumatic valve.

For beam monitoring, there will be a manually actuated phosphor screen which can be inserted in the beam path upstream of the PM, and a viewport with an external camera for viewing. The phosphor is tilted by 45° with respect to the beam path and the camera views the screen at normal to the screen. The PM reflects the beam downwards where it impinges on one of the two selected PGs. Three of the movements in the PGM are to be motorized: PM pitch, PG selection, PG pitch; for the other movements (translations, roll, yaw of PGs) it is sufficient to adjust them manually during installation and alignment which might require appropriate in-vacuum tools, such as screwdrivers etc. The mechanisms must allow continuous selection of the photon energy within the ranges of at least 50–2000 eV (PG1) and 20–300 eV (PG2) with the resolution, accuracy and repeatability equal to or better than listed in tables 5 and 6. The optical elements must be water-cooled in order to avoid heat deformations and mechanical drifts but the heat load is much lower than in the case of the PFM.

Suitably large flanges are to be mounted to allow easy access to the optical elements for alignment in air, with the mechanism already mounted in the vacuum chamber. Where possible, a viewport should allow the visual inspection of the surfaces of the optical elements.

The alignment of the elements should ensure that the spot in the analysis chamber does not move laterally by more 0.1 mm in the whole tuning range, including switching from one PG to another. Energy change from the lowest to the highest energy or back for one grating should not last more than 120 s. Tuning (i.e. setting the PM and PG pitch angles) should be possible simultaneously. It should also be possible to set either of the two PGs to zero-order diffraction angle (=reflection) at any possible setting of the PM, to let white beam pass through the PGM.

Axis		Range	Accuracy, repeatability, stability	Resolution	Actuator
z	pitch	14°	2 μrad	0.2 μrad	motorized (energy scan)
y	roll	1°	8 μrad	0.8 μrad	manually adjusted when mounting the mirror
x	yaw	5 mm	0.1 mm	0.01 mm	manually adjusted when mounting the mirror

Table 5: Requirements of movements of the PM.

Axis		Range	Accuracy, repeatability, stability	Resolution	Actuator
z	pitch	15°	2 μrad	0.2 μrad	motorized (energy scan)
		≥40 mm	<1 mm	0.1 mm	motorized (grating selection)
y	roll	1°	8 μrad	0.8 μrad	manually adjusted when mounting the grating
		2 mm	0.5 mm	0.05 mm	manually adjusted when mounting the grating
x	yaw	1°	0.005°	0.0005°	manually adjusted when mounting the grating
		5 mm	0.1 mm	0.01 mm	manually adjusted when mounting the grating

Table 6: Requirements of movements of the PGs.

The mechanical design must prevent the PM from coming into contact with either of the PGs even in the case of encoder failures, control software failure, or if software parameters are accidentally set to incorrect values. If not mechanically possible, their vicinity must be detected by a safety switch that blocks further movements before any collision occurs.

The beam will exit the chamber at 1270 mm nominal height from the floor (30 mm lower with respect to its entrance). The chamber is connected with another edge-welded bellows to the following electropneumatic *gate valve 2*.

The PM holder and the PGs holders will be equipped with a type K thermocouples, as described in section 3.1.3.

The Contractor is invited to provide a specific control software — TANGO device (and its documented source code) whose functionality, reliability, efficiency, usability, maintainability, and portability will be evaluated. The TANGO device must include at least:

- among the **attributes**: status, value of the photon energy and *cff* or the subtended angle corresponding to the current pitch angles of PM and chosen PG1/PG2, positions of the actuators, their instantaneous speeds and offsets, activation of end-switches and PM–PG collision switch (if present);
- among the **methods**: PG1/PG2 selection, desired *cff* or the subtended angle, change of photon energy, speeds, accelerations of the actuators, backlash, unblocking the PM–PG collision (if present) and the end-switch activation, and calibration functions for the different axes and energy value.

### 3.5 Transfer line 2 (TL2)

After gate valve 2 the beam will continue through a vacuum tube labelled *TL2* towards the exit slit chamber, from which it will not be separated by any valve, thus forming a unique vacuum section. The TL2 can be pumped by a small ion pump. The nominal height of the line above the floor is 1270 mm and the length is around 5 m.

### 3.6 Exit slit (ES)

In front of the slit, the diffracted light is blocked by a mask with circular aperture, 5 mm in diameter and on a fixed mounting. The total power passing through this aperture and arriving to the *ES* varies from 4 mW at 1500 eV to fractions of a mW at energies below 50 eV. The mask surface should be covered with phosphor.

The *ES* has blades parallel to the floor. It is motorized, with variable aperture in the range 10–1000  $\mu\text{m}$ . The slits are required to be parallel to within 5  $\mu\text{m}$  over a lateral distance of 1 mm, or 50  $\mu\text{m}$  over the width of 10 mm. Control of the slits must be motorized with an encoder, and include protection against damage due to accidental over-closing. The slits are to be painted with a suitable fluorescent material on the light entrance side to allow visualization of the beam. The chamber includes a suitable viewport and a camera for observing the synchrotron light on the slits and on the circular aperture.

The power density on the slit is variable from a maximum value of 2.2 W/cm<sup>2</sup> at 1500 eV, to 1.6 W/cm<sup>2</sup> at 100 eV to small fractions of W/cm<sup>2</sup> at the low energy range of each of the two PGs.

Axis	Range	Accuracy, repeatability, stability	Resolution
aperture	10–1000 $\mu\text{m}$	1 $\mu\text{m}$	0.1 $\mu\text{m}$

Table 7: *Exit slit setting*

### 3.7 Filters (F)

A series of thin filters should be installed, preferably in front of the RFM. The filter wheel should have at least 8 positions (4 positions with filters as specified in table 8 for the energy range 20–100 eV, 1 position for the free beam, 3 spare positions).

Material	Energy region [eV]	Thickness [ $\mu\text{m}$ ]	Calculated average transmission	Thermal load [ $\mu\text{W}$ ]
Si	70–100	0.25	0.6	300
Al	36–72	0.25	0.6	140
Mg	25–50	0.25	0.6	70
Sn	20–23	0.25	0.13	5

Table 8: Filter for suppression of higher order light

The selector should be motorized and the speed should permit the change in less than 60 s. A viewport to observe each filter when inserted in the beam is required. Optionally, one chamber can host both the *ES* and the filters, thus reducing the number of ion pumps and pressure gauges.

### 3.8 Refocusing mirror (*RFM*)

After the *gate valve 3* there is the chamber of the toroidal *RFM* with dimensions  $120 \times 20 \times 20 \text{ mm}^3$ , mounted with the reflecting surface in the vertical plane. It will deflect the beam by  $3^\circ$  to the left (incidence angle  $1.5^\circ$  off surface). The mounting requires three rotations and two translations, all manually actuated from outside the chamber. The range and precision required for each movement are in Table 9:

Axis		Range	Accuracy, repeatability, stability	Resolution
z	pitch	$\pm 0.5^\circ$	15 $\mu\text{rad}$	1.5 $\mu\text{rad}$
		3 mm	0.1 mm	0.01 mm
y	roll	$\pm 0.5^\circ$	$0.025^\circ$	$0.0025^\circ$
	yaw	$\pm 0.5^\circ$	$0.025^\circ$	$0.0025^\circ$
x		4 mm	0.5 mm	0.05 mm

Table 9: Requirements of movements of the *RFM*

The *RFM* does not need to be cooled. The mirror will be mounted so that it is electrically isolated from the chamber. An electrical feedthrough will be provided on the chamber, CF16 with BNC connector, with a suitable wire attached to the conducting surface of the mirror, or to the holder (if it is in electrical contact with the surface), to measure the emitted photocurrent. In addition, provision will be made to insert and remove a gold wire mesh in order to monitor the beam intensity by photocurrent, and on a separate linear translator, a photodiode (for example, AXUV100G from Photo Diode), for the purpose of measuring the light intensity (suitable electrical feedthroughs must be supplied), and a retractable screen viewed by a camera. A CF40 viewport will be included to observe the mesh and the photodiode when inserted. Another CF40 flange will be included, not necessarily in the same plane as the viewport, for the purpose of installing a gold evaporator (not part of the supply) to refresh the surface of the mesh. This flange should view the mesh from an angle of about 30 degrees on the upstream side.

#### **4 Special and spare parts**

At least one spare part must be provided for components fulfilling any of the following conditions:

- the component is critical;
- the component is nonstandard;
- the component has a life cycle of less than 4 years.

At least two spare parts must be provided for any non-standard gaskets or sealing systems of the vacuum chambers.

All non-standard tools and systems necessary for the assembly of the components inside the chambers and flanges, for mounting chambers on the supports, and for fixing the assembly to the floor must also be included in the supply.