FERMI ENGINEERING SPECIFICATION DOCUMENT

NO. 081-ITA

Technical Specifications for the Production of EIS_x_y_z_i Toroidal Mirrors for the FERMI@Elettra EIS-TIMER beamline

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Contents

1 General

1.1 Introduction

Sincrotrone Trieste S.C.p.A. (ST) has built and is now running Elettra, one of the first third-generation, high-brilliance synchrotron light sources in Europe, optimised for emission in the soft X-ray region. This synchrotron light machine consists of a booster and a storage ring.

A new FEL (Free Electron Laser), Linac-driven light source machine is currently undergoing commissioning. This new project, called FERMI@*Elettra* (FERMI), produced the first light at the end of 2010, and is expected to be completed by the end of 2011.

1.2 Scope

This document describes and defines the specifications, constraints and limitations for the refocusing mirrors for the FERMI EIS-TIMER beamline.

The scope of this contract is the supply of toroidal mirrors for the FERMI EIS-TIMER beamline called EIS_x_y_z_i, based on the specifications described in Chapter 2. The Contractor will be responsible for manufacturing the substrates, the optical coating (where applicable) of surfaces, packaging and delivery to ST of

- 24 (twenty-four) EIS_x_y_z_i toroidal refocusing mirrors,

ready for installation and operation, including the construction of any type of equipment needed for production.

The Contractor will be responsible for:

- creating a detailed time schedule for the supply (see paragraph 1.4), the purchase of materials and the commercial parts needed, preparing detailed drawings of the optics and their delivery to ST;
- the production of the optical substrates (bulk) to the highest professional standards, observing the constraints and limitations specified in Chapter 2 of this document;
- the coating of the optical surfaces, where required, as specified in Chapter 2 of this document;
- carrying out measurements for the metrological characterisation of substrates and coated optics, as specified in Chapter 3 of this document.

1.3 General terms

1.3.1 Formal acceptance of the toroidal mirrors is subject to inspection and positive testing (metrological measurements: dimensions, radii of curvature, slope errors, surface roughness) carried out by ST on its premises.

1.3.2 If any of the mirrors are rejected on the basis of the tests specified in Chapter 3, the Contractor will be responsible for organising and meeting transport costs to its own premises for the necessary reprocessing. In such case, ST reserves the right to ask for all the tests provided for in this document to be carried out before the reprocessed mirror is returned to ST. Once the mirror has been returned to ST, it will be accepted only after having passed the tests referred to in Chapter 3 carried out at the premises of ST.

1.3.3 No amendments to the accompanying documentation (parameters, construction drawings, etc.) will be allowed once it has been approved by ST, except where a written request has been made by the Contractor and acceptance of the same in writing by ST.

1.3.4 The Contractor must prepare all the technical documentation requested during the execution phase, in paper and digital formats, in Italian and/or in English.

1.3.5 The Contractor must appoint a Project Manager to deal with all communications with ST for the entire duration of the contract. ST will likewise appoint a Project Manager.

1.3.6 All technical documentation (calculations, construction drawings, etc.) will remain the exclusive property of ST. The Contractor will not be allowed to use it for any other purpose, unless given written authorisation by ST.

1.3.7 Any type of approval by ST will not release the Contractor from its responsibility to produce toroidal mirrors in accordance with the mechanical and optical parameters described in these specifications.

1.3.8 The warranty period for the mirrors that are the object of this document will be a minimum of 24 (twenty-four) months. The warranty period will begin from the date of formal acceptance (see 1.3.2) of the last mirror delivered to ST.

1.3.9 ST reserves the right to be present at each inspection and/or test described in this document. For this purpose, ST must be given a minimum of 2 (two) weeks' notice before the date of every planned inspection and/or test. ST staff must be given free access to the production sites and to the premises of any subcontractors during normal business hours.

1.3.10 The Contractor must deliver the completed toroidal mirrors (with coating, where applicable) only after receiving written notice from ST of acceptance of the results of the metrological measurements carried out in the factory on each mirror (see Chapter 3).

1.4 Stages in the supply contract

1.4.1 Delivery of the toroidal mirrors must take place according to the time schedule enclosed with the letter of invitation to tender. Any proposals to improve delivery times made by the Candidate will be taken into consideration by ST when evaluating the offer, as specified in the letter of invitation to tender.

1.4.2 The supply of the toroidal mirrors will be divided into the three stages specified in the time schedule.

1.4.3 The first stage will involve:

- The opto-mechanical design of the mirrors and the description of all instrumentation and equipment needed for the production of the mirrors.
- The drafting of the design technical file.
- Approval by ST of the design technical file.

1.4.4 The second stage will involve:

- Any procurement and construction of all the equipment needed for the production of the mirrors.
- The procurement of all the materials and components for the production of the mirrors (bulk and coating).
- The production of the substrates according to specifications.
- Metrological measurements on the substrates and notification and delivery of the results to ST.
- Approval by ST of the results of the metrological measurements on the substrates.

1.4.5 The third stage will involve:

- Delivery of the optics to ST according to the schedule of batches specified in Table 2 (column marked "Batch"). In particular, substrates requested without coating (batches 1 and part of batch 2) accepted by ST at the end of stage 2 will be sent to ST.
- Production of the optical coatings for the various mirrors, where applicable (batches 2 to 6).
- The metrological measurements on the completed mirrors and notification and delivery of the results to ST.
- Approval by ST of the results of the metrological measurements on the completed mirrors.
- Delivery of the completed mirrors (with coating) to ST.

1.4.6 The Contractor must complete the technical file for the design of the mirrors referred to in point 1.4.3, in collaboration with ST, no later than the timescales indicated in the time schedule, and deliver it to ST for approval. The technical

file must contain a detailed description of the opto-mechanical design of the mirrors and a description of all the instrumentation and equipment needed for the production and metrological characterisation of the mirrors. The following must be included:

- a full set of construction drawings;
- a complete list of the description and performance of the measuring instruments that the Contractor will use to check the correspondence of dimensions, radii of curvature, slope errors and surface roughness with the technical specifications.

1.4.7 The construction drawings must be created using a CAD system and must meet UNI – ISO standards. The contractor should provide a set of construction drawings in digital format, to be defined in agreement with ST.

1.4.8 The technical file must contain a description and evaluation of the procedures and measurements used (in the past) enabling certification of the accuracy of the metrological measurement systems used to determine the radii of curvature, slope errors and surface roughness.

1.4.9 The review and approval of the technical file by ST will not release the Contractor from its responsibilities in carrying out all the actions needed to build mirrors according to the specifications contained in this document. ST will issue a formal written authorisation to proceed with the second stage of the supply.

1.4.10 Following the aforesaid authorisation (1.4.9), the contractor will proceed with all the actions provided for in stage 2.

1.4.11 For each substrate, stage 3 may only begin after formal approval by ST of the relevant metrological measurements (dimensions, radii of curvature, slope errors and surface roughness).

1.4.12 The Contractor will nonetheless be responsible for reaching the operating parameters specified in this document.

1.5 Quality

1.5.1 The Contractor must produce the mirrors using a quality control system that meets international ISO 9001 or equivalent standards.

1.5.2 Within 10 (ten) business days of completion of the metrological tests for the individual substrates, the Contractor will draft a Substrate Measurement Report, which will certify the conformity of each substrate with the construction drawings and required technical specifications. The Substrate Measurement Report will list the results of all the tests performed during construction and processing, including the metrological tests on the radii of curvature, slope errors and surface roughness.

1.5.3 Following formal approval by ST for each Substrate Measurement Report (see 1.4.11), the Contractor should apply the optical coating where required using the specified materials, and then repeat the metrological measurements.

1.5.4 The results of these measurements (1.5.3) must be shown in the Mirror Measurement Report, which will be sent to ST within 10 (ten) business days from the end of the metrological tests on each mirror. This report should contain the results of the measurements for the radii of curvature, slope errors and surface roughness for approval by ST.

1.5.5 In the case of substrates requested without coating, the Mirror Measurement Report will conform to the Substrate Measurement Report and the provisions of 1.5.4 will apply.

1.5.6 The inspections and approvals provided for in the documents referred to in points 1.5.2, 1.5.3 and 1.5.4 will not release the Contractor from any responsibilities regarding the entire supply.

2 Specifications of the toroidal mirrors

2.1 General

2.1.1 Candidates must prepare an offer according to the specifications set out below.

2.1.2 The mirrors will operate in an ultra-high vacuum and will be used to focus radiation in a test chamber with wavelengths of between 100 nm and 3 nm. Given the negligible heat load, the mirrors will not be cooled.

2.2 Technical specifications

2.2.1 Each mirror will be identified using the following codes: EIS_x_y_z_i (EIS = name of the beamline; x (1,2) = FEL source used; y (1,3) = harmonic used; z (1,2,3,4) = configuration of the optic used; i (a,b) = identification for pairs of identical mirrors).

2.2.2 Each mirror must display its identification code (see 2.2.1), usually on one of the four sides in the direction of H (see Figure 1).

2.2.3 The mirrors will be used in ultra-high vacuum conditions with pressures of $\leq 10^{-10}$ mbar. The materials and treatment used during the production of the mirrors must meet this fundamental condition. Furthermore, the mirrors must be compatible with temperatures of up to 120° C.

2.2.4 Once installed in the final vacuum chamber, the mirrors must be mounted onto special manipulators to enable precision optical alignment. As a consequence, slots have been included for the supports on the bulk of the mirrors. These slots are shown in Figures 1 and 2.

2.2.5 The characteristics shared by all the mirrors are shown in Table 1. See the next point (2.2.6) for the specific parameters of each mirror.

2.2.6 The Contractor must produce the mirrors in such a way as to meet the operating parameters listed in Tables 1, 2 and 3 below. The notes to Tables 1 and 2 are part of the required specifications.

2.2.7 For coated mirrors, any binding layer needed between the coating and the substrate must be approved in advance by ST.

2.2.8 When pairs of identical mirrors are required (shown with Quantity = 2; e.g. EIS_x_1_z_i), it is essential that, for each pair, the mirrors have radii of curvature as close as possible to each other (both tangentially and sagitally), yet remaining within the requested and permitted range of values. Correspondence of the radii of curvature with each other must take priority over their correspondence to the nominal value. This means that, for every pair of identical mirrors, it is

preferable to have radii of curvature that are the same as each other, even if slightly different from the nominal value, yet within the limits shown in Table 2.

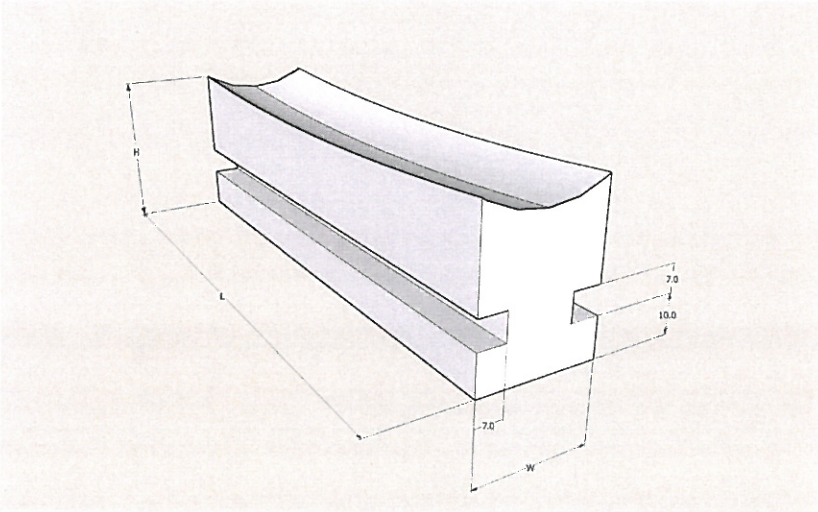

Figure 1 – Dimensions of the mirrors (in mm) and slots for mechanical support for mirrors where H = 40 mm.

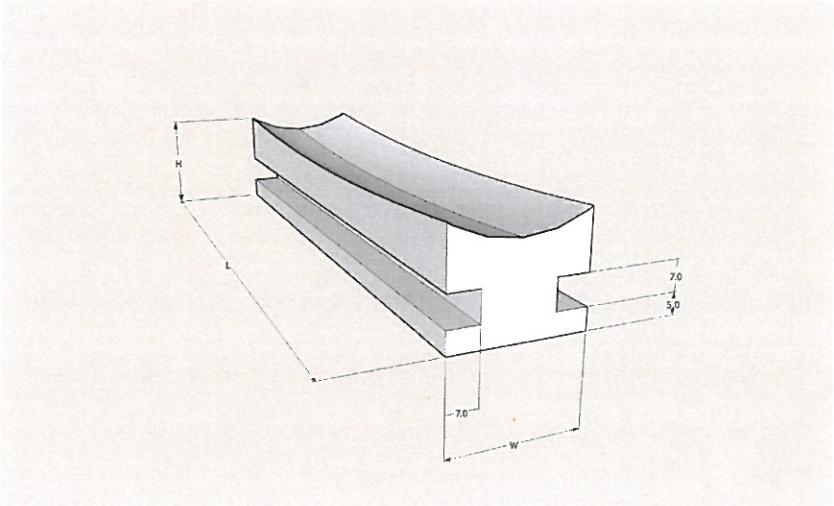

Figure 2 – Dimensions of the mirrors (in mm) and slots for mechanical support for mirrors where H = 25 mm.

Substrate material	Fused silica	
Optical surface	Toroidal	
Slope error - tangential (rms)	≤ 5	μrad
Slope error – sagittal (rms)	≤ 5	μrad
Thickness of optical coating (where used)	50	nm
PV-shape error (peak to valley) after best sphere subtraction on each 10 cm section of the mirror.	≤ 10	nm
2D surface roughness (rms), measured over a spatial period of 1-300 μm	≤ 3	Å

Table 1 – Parameters shared by all mirrors.

NB:

Slope error values (tangential and sagittal) must be lower than the limit shown in the table. Furthermore, the closer the value is to 0, the better.

Quantity	Ref.	Range (nm)	R (cm)	ΔR (%)	ρ (cm)	Δρ (%)	Angle	Coating	Batch
2	1_1_1	60-20	5851.5	±0.3	88.5	±0.5	82.9°	C	3
2	1_1_2	60-20	3379	±0.4	90	±0.6	80.6°	C	3
2	1_1_3	60-20	680	±0.7	97.6	±0.5	67.75°	Au	4
2	1_1_4	60-20	440	±0.5	103.4	±0.6	61.15°	Au	4
1	1_3_1	20-6.6	10390	±1.2	15.45	±1.9	87.8°	C	2
1	1_3_2	20-6.6	5650	±0.4	15.8	±1.9	87°	C	2
1	1_3_3	20-6.6	1100	±0.9	16.1	±1.5	83.2°	C	5
1	1_3_4	20-6.6	725	±1.4	16.2	±1.2	81.6°	TiO2	5
2	2_1_1	20-10	5900	±1.7	91	±1.2	82.9°	C	6
2	2_1_2	20-10	3420	±1.2	92.74	±1.3	80.6°	C	6
2	2_1_3	20-10	675	±0.5	101	±1.5	67.75°	- *	1
2	2_1_4	20-10	440	±0.5	107	±1.9	61.15°	- *	1
1	2_3_1	6.6-3.3	10500	±1.9	17.5	±5.1	87.8°	Ni	5
1	2_3_2	6.6-3.3	5670	±1.4	17.6	±4.5	87°	Ni	5
1	2_3_3	6.6-3.3	1115	±0.9	18	±5	83.2°	- *	2
1	2_3_4	6.6-3.3	730	±0.4	18.1	±4.5	81.6°	- *	2
				14.3		**33.7**			

Table 2 – Toroidal mirrors: optical parameters. Mirrors with quantity = 2 will be differentiated from each other by i = a,b (see 2.2.2).

**: without coating.*

NB:

Candidates may choose a maximum of two rows (or two types of mirror) from Table 2 where the corresponding mirrors may have radius of curvature tolerances (ΔR and Δρ) increased by up to (ΔR+5%ΔR) and (Δρ+5%Δρ), respectively.

For example: mirrors 2_1_3: ΔR_{ideal}= ±0.5% and $\Delta\rho_{ideal}$= ±1.5%, i.e. ΔR_{ideal}= ±3.375 cm and $\Delta\rho_{ideal}$= ±1.515 cm; it is accepted that such a mirror will have increased tolerances of up to: $\Delta R_{accepted}$= ±(3.375cm+5%3.375cm)= ±3.54375 cm and $\Delta\rho_{accepted}$ = ±(1.515cm+5%1.515cm)= ±1.59075 cm.

Quantity	Ref.	Useful area (mm)		Suggested bulk dimensions (mm)		
		L	W	L	W	H
2	1_1_1	150	30	160	40	40
2	1_1_2	150	30	160	40	40
2	1_1_3	100	30	110	40	40
2	1_1_4	70	30	80	40	40
1	1_3_1	300	20	310	30	40
1	1_3_2	200	20	210	30	40
1	1_3_3	100	20	110	30	40
1	1_3_4	100	20	110	30	40
2	2_1_1	150	30	160	40	40
2	2_1_2	150	30	160	40	40
2	2_1_3	100	30	110	40	25
2	2_1_4	70	30	80	40	25
1	2_3_1	300	20	310	30	40
1	2_3_2	200	20	210	30	40
1	2_3_3	100	20	110	30	25
1	2_3_4	100	20	110	30	25

Table 3 – Toroidal mirrors: dimensional parameters

2.3 Specifications for radii of curvature

2.3.1 The required radii of curvature (tangential and sagittal) are shown in columns R and ρ of Table 2.

2.3.2 Table 2 shows the maximum percentage variations allowed on the final value measured for tangential and sagittal radii of curvature (columns ΔR and Δρ, respectively). By way of example, a tangential radius of curvature of 5851.5 cm ±0.3% is required for the two identical mirrors EIS_1_1_1_i (i=a,b), meaning that variations of ±17.5 cm from the ideal value will be accepted (providing they do not affect the requirement set out in 2.2.8).

2.3.3 The radii of curvature values for each mirror must be checked by the Contractor after optical production/processing of the bulk substrate and after coating (where applicable). In both cases, the measurement results are to be formally accepted by ST, before moving on to the next stage (paragraph 1.4)

2.3.4 Lastly, the radii of curvature will be measured on ST premises for final acceptance of each optic (1.3.1 and 1.3.2).

2.4 Specifications for slope errors and surface roughness

2.4.1 The required slope errors (tangential and sagittal) and surface roughness, along with the tolerances for these quantities are shown in Table 1.

2.4.2 The slope error and surface roughness values for each mirror must be checked by the Contractor after optical production/processing of the bulk substrate and after coating (where applicable). In both cases, the measurement results are to be formally accepted by ST, before moving on to the next stage (paragraph 1.4)

2.4.3 Lastly, slope errors and surface roughness will be measured on ST premises for final acceptance of each optic (1.3.1 and 1.3.2).

2.5 Construction of the mirrors: general

2.5.1 All mirrors must be properly protected from damage during construction, processing, testing, transportation and storage.

3 Inspections and metrological testing at the factory and on ST premises

The measuring system and the instruments used for metrological testing at the factory must be able to confirm that the specified operating parameters have been reached for each optic. The type of measuring system and instruments used must be approved by ST.

For the metrological testing on ST premises, the following points in particular are valid and accepted: 1.3.1, 1.3.2, 2.3.4 and 2.4.3. All the provisions of the previous points are also valid and accepted.

3.1 Dimensions and appearance

3.1.1 All mirrors must be measured in the factory by the Contractor before shipment to ST. All the dimensions of each optic must conform to the technical specifications.

3.1.2 All mirrors (with or without coating) must be inspected for any flaws such as scratches, holes, non-uniformity and/or dust beneath the coating. If any flaws are found, the Contractor must inform ST of their severity and extent, providing relevant additional documentation. ST reserves the right to ask for every damaged mirror to be reprocessed.

3.1.3 All mirrors shipped to ST will again be inspected (as in 3.1.2) by ST staff for any flaws. If any flaws are found, the provisions of 1.3.2 will apply.

3.2 Radii of curvature

3.2.1 The tangential and sagittal radii of curvature must be measured in the factory by the Contractor before optical coating (where applicable) and/or before shipment to ST for final approval. The results of these measurements must conform to the technical specifications.

3.2.2 Radius of curvature measurements must be carried out using appropriate measuring instruments (Long Trace Profiler or WYKO, etc.) and approved beforehand by ST (see 1.4.3 and 1.4.6). The accuracy of these measurements must be such that they guarantee that the radius of curvature values correspond to the optical specifications set out in Table 2.

3.2.3 The working position of all 24 mirrors will be with the optical surface positioned vertically (deflection in the horizontal plane). Where possible, the radius of curvature measurements must be carried out in this position to reduce the impact of gravity to a minimum.

3.2.4 All mirrors shipped to ST will again have their radii of curvature measured by ST staff. If any deviations from the technical specifications are found, the provisions of 1.3.2 will apply.

3.3 Slope error

3.3.1 The tangential and sagittal slope errors of each mirror must be measured in the factory by the Contractor before optical coating (where applicable) and before shipment to ST for final approval. The results of these measurements must conform to the technical specifications.

3.3.2 The slope error measurements must be carried out using appropriate measuring instruments (Long Trace Profiler or WYKO, etc.) and approved beforehand by ST (see 1.4.3 and 1.4.6). The accuracy of these measurements must be within at least 0.1" rms.

3.3.3 All mirrors shipped to ST will again be measured for slope errors by ST staff. If any deviations from the technical specifications are found, the provisions of 1.3.2 will apply.

3.4 Surface roughness

3.4.1 The surface roughness of each mirror must be measured in the factory by the Contractor, before shipment to ST for final approval. The results of these measurements must conform to the technical specifications.

3.4.2 Surface roughness measurements must be carried out using appropriate measuring instruments (MicroMap, Optosurf, etc.) and approved beforehand by ST (see 1.4.3 and 1.4.6). The accuracy of these measurements must be such that they guarantee that the surface roughness values correspond to the optical specifications set out in Table 1.

3.4.3 All mirrors shipped to ST will again undergo surface roughness measurements by ST staff. If any deviations from the technical specifications are found, the provisions of 1.3.2 will apply.