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###

# Introduction

## Purpose

This Requirements Specification Document (RSD) lists the technical requirements and constraints on optics for the femtosecond compressor system for the L\_2 beamline under ADONIS FSYNC project.

## Scope

This RSD contains functional, performance and design, delivery, safety, and quality requirements for the following product *(PBS: RA1.L1.L1\_2.CMP.O*): **Set of dielectric chirped mirrors** for use in the L1 laser.

The set of dielectric chirped mirrors (DCMs) will be used as a Chirped Mirror Compressor (CMC), compensating a positive chirp of about +6000 fs2 of a broadband pulse (750 - 920 nm) and will handle pulse energies in excess of 20 mJ. The CMC will be placed in vacuum chamber whose mechanical design limits a number of chirped mirrors to 40. Therefore, the average GDD per single mirror reflection shall be < -170 fs2, while greater dispersion per reflection is desirable. Moreover, in order for the mirrors to be suitable for their application, the requirements on reflectivity, flatness, laser induced damage threshold, etc. are imposed in this document.

Additional information on target GDD curve and on method of dispersion verification test is given in the Reference documents [see Chapter 1.4].

## Terms, Definitions and Abbreviations

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

| **Abbreviation** | **Meaning** |
| --- | --- |
| AOI | Angle of the Incidence |
| CA | Clear Aperture |
| CMC | Chirped Mirror Compressor |
| DCM | Dielectric Chirped Mirror |
| D-FTR | Dispersion measurement Factory Test Report |
| ELI | Extreme Light Infrastructure  |
| GDD | Group Delay Dispersion |
| LIDT | Laser Induce Damage Threshold |
| NCR | Non-Conformance Report |
| PBS | Product breakdown structure (code of ELI Beamlines) |
| PET-G | Polyethylene Terephthalate Glycol-modified |
| RA1 | Research Activity 1 |
| R-FTR | Reflectivity Factory Test Report |
| RSD | Requirements Specification Document |
| S1 | Working surface of the mirror |
| S2 | Back surface of the mirror |
| VCD | Verification Control Document |

## Reference documents

|  |  |
| --- | --- |
| **Number of doc.** | **Title of document** |
| *RD-01* | *Description\_of\_the\_dispersion\_measurement\_procedures\_TP22\_032.docx* |
| *RD-02* | *The\_target\_GDD\_curve\_specification\_TP22\_032.xlsx* |

# Functional, Performance and Design requirements

Functional, performance and design requirements for the L1 dielectric chirped mirrors and procedures for SATs to be performed are described in this document below and in addition in the reference documents RD-01 and RD-02 (see Chapter 1.4).

REQ-034666/A

**Number of DCMs** delivered by the Supplier (excluding the required witness samples) shall be **40 pcs**.

Verification method: I - inspection

REQ-034667/A

**Operational wavelength range** of the DCMs shall be from 750 nm to 920 nm. In this wavelength range, the DCMs shall comply with all specifications given in the Table 1.

Verification method: R - review, T – test (for each coating run)

REQ-034668/A

**Operational angle of the incidence** (AOI) of the DCMs shall be 3.6 deg +- 0.5 deg. In this AOI range, the DCMs shall comply with all specifications given in the Table 1.

Verification method: R – review, T - test

REQ-034669/A

**Operational** **clear aperture** (CA) of the DCMs shall be circular with the minimum diameter of 40 mm. The center of CA shall coincide with the center of the circular mirror. In this CA region, the DCMs shall comply with all specifications given in the Table 1.

Verification method: R – review, T – test

REQ-034670/A

**Coatings on surfaces S1 and S2** of the DCMs shall cover circular area with diameter of at least 45 mm.

Verification method: I - inspection

REQ-034671/A

**Working environment** of the DCMs shall be of 10-6 mbar (vacuum). In this working environment, the DCMs shall comply with all specifications given in the Table 1.

Verification method: R – review, I – inspection

REQ-034672/A

DCMs’ substratesshall comply with all specificationsstatedin Table 2.

Verification method: R – review (report from the manufacturer)

REQ-034673/A

The Supplier shall use the single coating design - the target GDD requirement shall be satisfied by each and every mirror.

Verification method: R - review

REQ-034674/A

**The** **group delay dispersion (GDD)** per single reflection shall follow the polynomial function:

$GDD\left(λ\right)= -0.0005λ^{2}+1.188λ-C$,

where:

*C* is an offset coefficient in the range 817 *≤ C ≤* 890,

$λ$ is a wavelength in nm,

the resulting GDD value is in fs2,

with a tolerance of $\pm $120 $fs^{2}$.

*NOTE 1: A graphical representation of the target GDD per single reflection and the auxiliary data table with GDD see in the reference document* ***RD-02****.*

Verification method: T – test (according to RD-01)

REQ-034675/A

**The GDD per single reflection averaged** over the operational wavelength shall be lower than -170 fs2.

Verification method: T – test (according to RD-01)

REQ-034676/A

The absolute difference in GDD(λ) at such a wavelength between the two spots shall be less than 120 fs2.

*NOTE: Let λ be any wavelength within the operational wavelength range and A, B are any two spots within the operational clear aperture. Then, the absolute difference in GDD(λ) at such a wavelength between the two spots shall satisfy the following inequality:*

|GDD(λ,A) – GDD(λ,B)| < 120 fs2.

Verification method: T – test, A – analysis, R – review (acc. to RD-01)

REQ-034677/A

**The minimum** **LIDT** of the S1 working surface shall be >70 mJ/cm2 @ 40 fs FWHM @ 1 kHz repetition rate, verified as 10000-on-1 (S-on-1) test.

Verification method: T – test

REQ-034679/A

All the DCMs shall be coated on the back surface S2 with the same design coating (as the working surface S1) for stress compensation.

Verification method: I - inspection

REQ-034684/A

All the provided DCMs shall be assigned with unique traceable serial numbers and supplied with accompanying report giving information about coating run number for each serial number.

Verification method: I - inspection

REQ-034685/A

The working surface S1 shall be clearly marked on the side surface of the DCM.

Verification method: I - inspection

REQ-034686/A

The marking of the DCM shall be done using low-outgassing technique compatible with vacuum.

Verification method: I – inspection

REQ-034687/A

The Supplier shall provide one 1 or 2-inch diameter witness sample from each S1 coating run which can be later used for determining the LIDT. The substrate material and surface quality of the sample shall be the same as the remaining mirrors in the coating batch.

Verification method: I - inspection, R – review

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Specified value** | **Comment/Note** |
| Operational clear aperture (diameter) | 40 mm | See REQ-034669/A, 80% of the substrate diameter |
| Operational wavelength range | 750 nm - 920 nm | See REQ-034667/A |
| Operational angle of incidence | 3.6 deg +- 0.5 deg | See REQ-034668/A |
| Operational beam polarization | S-pol |  |
| Reflected wavefront distortion (after coating) | ≤ λ/5 | at λ=633 nm |
| Average reflectivity  | ≥ 99.8 % | calculated or measured over the whole operational wavelength range  |
| Minimum reflectivity | > 99.6 % | measured at any given wavelength in the operational range  |

**Table 1:** Specifications and requirements for the chirped mirrors

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Specified value** | **Comment/Note** |
| Shape | Circular | Round optics |
| Diameter | 50.8 +0/-0.1 mm |  |
| Thickness | 12.7 +/- 0.1 mm |  |
| Wedge | Max 10 arcmin  | The back surface of the mirror is wedged. |
| Substrate material | High purity fused silica |  Mirror grade UV fused silica |
| Scratch-dig (S1) | 10-5 | or better according to the standard MIL-PRF-13830B, Rev. H of Drawing C7641866 |
| Surface quality (S2) | Commercial polish |  |
| Edges | Fine ground |  |
| Chamfer | 45 deg, max leg length0.75 mm, polished |  |

**Table 2:** Specifications and requirements for the substrates of the chirped mirrors

# Environmental requirements

REQ-034688/A

The Supplier and the Contracting Authority shall agree on the cleaning method to clean the DCMs without decreasing the DCMs' properties and to avoid contamination of clean space.

*NOTE: The cleaning methods may use high gas flow (dry air) and specialized chemical cleaning liquids (i.e. methanol, isopropyl alcohol, deionized water).*

Verification method: R - review

# Delivery requirements

## General requirements

REQ-034689/A

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

Verification method: I – inspection

REQ-034690/A

All the DCMs shall be cleaned and packaged in clean environment of class 5 according to ČSN EN ISO 14644 (equivalent to ISO 14644) or cleaner.

Verification method: R - review

## Specific requirements

REQ-034691/A

Each DCM shall be placed in an appropriate (PET-G) container, double wrapped with clean plastic foils and placed in a box for transport.

Verification method: R – review, I – inspection

# Safety requirements

REQ-034692/A

The Supplier shall declare a compliance with the 2001/95/EC regulation.

Verification method: I – inspection

# Quality control

## Factory test reports

REQ-034693/A

**The Supplier shall perform a** **factory verification of GDD** (see REQ-034674/A and REQ-034675/A) on the witness samples from all S1 coating runs.

*NOTE 1: The REQ-034676/A can be tested either by methods described in the* ***RD-01*** *(see chapter 1.4) or any other method that the Supplier uses for the verification of GDD uniformity.*

*NOTE 2: The results of factory verification of GDD* *shall be provided to the Contracting Authority in the GDD factory test report (D-FTR),* *which shall include data from all witness samples.*

Verification method: R - review of report

REQ-034696/A

**The Supplier shall perform a factory verification of the absolute reflectivity** in the operational wavelength range on the witness samples from all S1 coating runs.

*NOTE: The results of the factory verification of the absolute reflectivity* *shall be provided to the Contracting Authority in the reflectivity factory test report (R-FTR), which shall include data from witness sample from each S1 coating run.*

Verification method: R - review of report

## Documentation and data control

REQ-034697/A

The Supplier shall supply the following relevant manufacturing documents:

* **Full technical documentation** and **factory test reports** (see chapter 6.1), including raw data where available;
* storage, cleaning, operation and maintenance **instructions**)

*NOTE: The scope of this documentation shall be agreed with the CA.*

Verification method: I – inspection

REQ-034698/A

The Supplier shall provide a report about the execution of outgoing check and compliance with technical requirements defined by the product RSD and completeness of the product.

Verification method: I – inspection

REQ-034699/A

The Supplier shall use following data formats:

* \*.dat (Zygo binary file format for interferograms)
* \*.JPG, \*.PDF/A, \*.HTML
* CAD 2D: \*.dwg
* CAD 3D: \*.stp; \*.ste; \*.step or other 3D CAD formats agreed with the CA
* text processors \*.doc, \*.docx, OpenDocument Format
* spreadsheet processors \*.xls, \*.xlsx, OpenDocument Format
* presentations \*.ppt, \*.pptx; OpenDocument Format

## Non-Conformance Control System

REQ-034700/A

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

## Verification Control Document (VCD)

**VCD** is a living document which shall be used throughout the entire Contract delivery and its phases (see chapter 6.5 Phasing of the delivery). The **VCD** provides traceability during delivery phases (Manufacturing, Acceptance).

The **VCD** represents a formal tool of communication between the Supplier and the Contracting Authority (formal record, reporting tool).

The **VCD** will be provided by the Contracting Authority and it can be accommodated to the Supplier’s needs.

REQ-034701/A

The Supplier shall provide a Verification Control Document (VCD) for the reviews as agreed with the Contracting Authority.

*NOTE 1: The CA can provide the Guidelines for the VCD preparation.*

*NOTE 2: The form of the VCD will be agreed between the CA and the Supplier based on the best commercial praxis used by the Supplier.*

*NOTE3: The VCD specifies* ***HOW*** *and* ***WHEN*** *each requirement is planned to be verified, when it was actually verified.*

Verification method: R – review

## Phasing of the delivery

This chapter is intended to briefly summarize basic milestones of the Contract delivery. These milestones represent gates where the quality of the delivery is to be evaluated.

Delivery shall not proceed past these gates unless their satisfactory accomplishment is approved by the Contracting Authority.

Delivery lifecycle shall contain at least the following phases (***quality gates***):

* **Manufacturing** (verified by factory test reports, see chapter 6.1);
* **Acceptance** (verified by the Contracting Authority according to the VCD).

### Manufacturing

The goal is to demonstrate that the manufactured products meet the specified technical requirements (RSD) of the Contracting Authority.

This quality gate concerns primarily:

* **Testing at Supplier’s site** (factory testing);
* **Packaging and shipping.**

Output of this phase is **Final product**.

REQ-034704/A

The results of the Manufacturing phase of verification shall be recorded by the Supplier in the factory test reports (see chapters 2 and 6.1) and overall results shall be recorded in the VCD (see chapter 6.4).

Verification method: R - review

### Acceptance

The Acceptance phase (as defined in the Contract) demonstrates that:

* Final delivered products have been successfully verified and this process has been documented in the **VCD** (see REQ-034701/A) using the Factory test reports and the results of the Contracting Authority acceptance tests.
* Final product is free of fabrication errors and is ready for the intended operational use.

Output of this phase is **Verified final delivered product**.

The results of Acceptance phase of verification shall be recorded by the Contracting Authority in final issue of the **VCD**.

Acceptance will be carried out on the final delivered complete products.

In case of successful acceptance phase the Contracting Authority shall provide to the Supplier signed acceptance protocol.

In case of unsuccessful acceptance phase the Contracting Authority shall provide to the Supplier Non-Conformance Report (NCR) and ELI non-conformance control process shall be applied (see REQ-034700/A).

REQ-034705/A

Upon delivery of the final products in appropriate and undamaged packaging the Contracting Authority shall provide to the Supplier with Handover/takeover protocol.

Verification method: I – inspection

REQ-034706/A

Acceptance shall be complete when the final delivered product complies with all specifications verified by the Supplier’s Factory tests and by passing additional acceptance tests carried out by the Contracting Authority after delivery at its own premises.

*NOTE: In the acceptance phase, the verification of the final products and required documentation will be carried out and recorded by the Contracting Authority in the final version of the VCD within 4 weeks after the issuing of the Handover/takeover protocol.*

Verification method: R – review