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MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

EVROPSKÁ UNIE
EVROPSKÝ FOND PRO REGIONÁLNÍ ROZVOJ
INVESTICE DO VAŠÍ BUDOUCNOSTI

OP Výzkum a vývoj pro inovace

PURCHASE CONTRACT

This purchase contract ("**Contract**") was concluded pursuant to section 2079 *et seq.* of the act no. 89/2012 Coll., Civil Code ("**Civil Code**"), on the day, month and year stated below by and between:

(1) **Institute of Physics of the Academy of Sciences of the Czech Republic, a public research institution,**

with its registered office at:

Na Slovance 2, Praha 8, PSČ: 182 21,

registration no.: 68378271,

represented by: prof. Jan Řídký, DrSc. – director

("**Buyer**"); and

(2) **Axis Photonique Inc.,**

with its registered office at: 1650 boul. Lionel-Boulet, Varennes, Québec, Canada J3X 1S2,

registration no.: 1146398186 (registered in Quebec, Canada)

represented by: Dr. Christian-Yves Côté, CEO

("**Seller**").

(The Buyer and the Seller are hereinafter jointly referred to as "**Parties**" and individually as "**Party**".)

WHEREAS

(A) The Buyer is a public contracting authority and the beneficiary of a grant of the Ministry of Education, Youth and Sports of the Czech Republic for a project „*ELI: Extreme Light Infrastructure*", registration number CZ.1.05/1.1.00/02.0061 ("**Project**"), within the Operational Programme Research and Development for Innovations, priority axis 1, objective 1.1 European Centers for Excellence.

(B) For the successful realization of the Project it is necessary to purchase the Object of Purchase (as defined below) in accordance with the act no. 137/2006 Coll., on public procurement, and Rules for the Selection of Suppliers within the Operational Programme Research and Development for Innovations.

(C) The Seller wishes to provide the Object of Purchase to the Buyer for consideration.

(D) The Seller's bid for the public procurement entitled "*Optical and X-ray streak cameras for experimental areas*" *(part no. 3 – X-ray streak camera system (XSCS)*, which was published in the Journal of Public Procurement under the registration number 498368 and whose purpose was to procure the Object of Purchase ("**Public Procurement**"), was selected by the Buyer as the most suitable.

IT WAS AGREED AS FOLLOWS:

1. **BASIC PROVISIONS**

1.1 Under this Contract the Seller shall hand over to the Buyer streak camera system, which shall meet requirements listed in Annex 1 (*Technical Specification*) to this Contract ("**Object of Purchase**") and shall transfer to the Buyer ownership right to the Object of Purchase, and the Buyer shall take over the Object of Purchase and shall pay the Seller the Purchase Price (as defined below), all under the terms and conditions stipulated in this Contract.

1.2 Under this Contract the Seller shall also carry out following activities ("**Related Activities**"):

a) to test the Object of Puchase at the Seller's premises to verify, whether the Object of Purchase fulfils all requirements stipulated in this Contract and prepare a protocol on such testing; the Seller shall inform the Buyer of the testing sufficiently in advance and shall allow the Buyer to be present during the testing;

b) to transport the Object of Purchase to the place of delivery;

c) to elaborate and hand over to the Buyer documents listed in Annex 1 (*Technical Specification*) to this Contract and other documents that are necessary for the proper takeover and use of the Object of Purchase in English language in electronic form;

d) to handover the declaration of conformity of the Object of Purchase with the approved standards, if there are any;

e) to elaborate a list of particular items of the Object of Purchase for the purposes of control;

f) cooperate with the Buyer during the performace of this Contract.

1.3 The Seller promises to the Buyer that if for the fulfillment of the requirements of the Buyer under this Contract or the proper operation of the Object of Purchase are necessary other deliveries and activities not mentioned in this Contract, the Seller shall procure such deliveries or shall carry out such activities at its own expense without any effect on the Purchase Price.

1.4 The Object of Purchase and all its subcomponents must be supplied new and unused.

2. **THE PLACE OF DELIVERY**

2.1 The place of delivery is the registered office of the Project in Dolní Břežany village, Central Bohemian Region.

3. **THE TIME OF DELIVERY**

3.1 The Seller shall deliver the Object of Purchase and shall carry out Related Activities within eighteen (18) months from the effectiveness of this Contract. Due to the potential delay of some activities within the Project during the performance of this Contract, the Buyer is entitled, anytime until the delivery to the place of delivery, to postpone the above mentioned terms of delivery by another six (6) months.

3.2 The Seller is entitled to handover the Object of Purchase and to carry out Related Activities during working days between 7:30 and 18:00 hours, unless otherwise agreed by the Parties. Exact working days shall be determined on the basis of mutual agreement. If the agreement is not reached, the Seller shall perform during the last day, on which it is possible to fulfill this Contract in time and the Buyer shall provide to the Seller for this purpose necessary cooperation.

3.3 Prior to the handover of the Object of Purchase and the execution of Related Activities the Seller shall invite the Buyer to control the premises for installation of the Object of Purchase in such a way that their readiness for installation of the Object of Purchase is secured (e.g. a control of the location of electricity points, etc.) and possible deficiencies preventing timely and proper installation and demonstration of the operation of the Object of Purchase are eliminated.

4. THE OWNERSHIP RIGHT

The ownership right to the Object of Purchase shall be transferred to the Buyer upon the signature of the Handover Protocol (as defined below) by both Parties.

5. PRICE AND PAYMENT TERMS

5.1 The purchase price for the Object of Purchase is 248 500,- EUR ("**Purchase Price**") without value added tax ("**VAT**").

5.2 The Purchase Price cannot be exceeded and includes all costs and expenses of the Seller related to the performance of this Contract. The Purchase Price includes, among others, all expenses related to the handover of the Object of Purchase and execution of Related Activities, costs of copyright, insurance, warranty service and any other costs and expenses connected with the performance of this Contract.

5.3 The Purchase Price for the Object of Purchase shall be paid in euro on the basis of a tax document – invoice, to the account of the Seller designated in the invoice. The Purchase Price shall be paid in the following manner:

a) 50 % of the Purchase Price shall be paid after the signature of this Contract;

b) 25 % of the Purchase Price shall be paid after the successful testing of the Object of Puchase at the Seller's premises; and

c) 25 % of the Purchase Price shall be paid after the signature of the Handover Protocol. The copy of the Handover Protocol must be attached to the invoice.

5.4 The Buyer shall realize payments on the basis of duly issued invoices within 30 days from their receipt. The invoice shall be considered to be paid for on the day when the invoiced amount is deducted from the Buyer's account on behalf of the Seller's account.

5.5 The invoice issued by the Seller as a tax document must contain all information required by the applicable laws of the Czech Republic. Invoices issued by the Seller in accordance with this Contract shall contain in particular following information:

a) name and registered office of the Buyer,

b) tax identification number of the Buyer,

c) name and registered office of the Seller,

d) tax identification number of the Seller,

e) registration number of the tax document,

f) scope of the performance (including the reference to this Contract),

g) the date of the issue of the tax document,

h) the date of the fulfilment of the Contract,

i) Purchase Price,

j) registration number of this Contract, which the Buyer shall communicate to the Seller based on Seller's request before the issuance of the invoice,

k) declaration that the performance of the Contract is for the purposes of a project "ELI: EXTREME LIGHT INFRASTRUCTURE", registr. number CZ.1.05/1.1.00/02.0061,

and must comply with the double tax avoidance agreements, if applicable.

5.6 In case that the invoice shall not contain the above mentioned information, the Buyer is entitled to return it to the Seller during it maturity period and this shall not be considered as a default. The new maturity period shall begin from the receipt of the supplemented or corrected invoice to the Buyer.

5.7 Last invoice of every calendar year must be delivered to the Buyer on December 15 of that calendar year, at the latest.

6. SELLER'S DUTIES

6.1 The Seller shall ensure that the Object of Purchase and Related Activities are in compliance with this Contract including all its annexes and applicable legal (e.g. safety), technical and quality norms.

6.2 During the performance of this Contract the Seller proceeds independently. If the Seller receives instructions from the Buyer, the Seller shall follow such instructions unless these are against the law or in contradiction to this Contract. If the Seller finds out or should have found out if professional care was exercised that the instructions are for any reason inappropriate or illegal or in contradiction to this Contract, then the Seller must notify the Buyer.

6.3 All things necessary for the performance of this Contract shall procure the Seller, unless this Contract stipulates otherwise.

6.4 The Seller is aware that the Buyer does not have at its disposal premises for the storage of packaging and, therefore, shall not store packaging of the Object of Purchase. The absence of original packaging cannot be an excuse for refusal of elimination of defects of the Object of Purchase.

7. HANDOVER OF THE OBJECT OF PURCHASE

7.1 Handover and takeover of the Object of Purchase shall be realized on the basis of a handover protocol, which shall contain following information ("**Handover Protocol**"):

a) identification of the Seller, Buyer and subcontractors, if there are any,

b) declaration of the Seller and Buyer that all Related Activities were carried out,

c) description of the Object of Purchase, and

d) date of the signature.

7.2 The Handover Protocol must contain following annexes, which shall be elaborated by the Seller:

a) the protocol on testing that was carried out at Seller's premises,

b) a list of items of the Object of Purchase,

c) a declaration of the Seller that the Object of Purchase is in accordance with this Contract, applicable laws and technical norms.

7.3 If the Seller does not hand over to the Buyer all above mentioned documents or if the Seller fails to duly carry out all Related Activities or if the Object of Purchase does not meet requirements of this Contract, the Buyer is entitled to refuse the takeover of the Object of Purchase. In such a case the Seller shall remedy the deficiencies within ten (10) working days, unless Parties agree otherwise. The Buyer is entitled (but not obliged) takeover the Object of Purchase despite the above mentioned deficiencies, in particular if such deficiencies do not prevent the Buyer in the proper operation of the Object of Purchase. In such a case the Seller and the Buyer shall list the deficiencies in the Handover Protocol, including the manner and the date of their removal (remedy). If the Parties do not reach agreement in the Handover Protocol regarding the date of the removal, the Seller shall remove the deficiencies within ten (10) working days.

7.4 In case that the Seller notifies the Buyer that the Object of Purchase is eligible for handover and takeover and during the course of the handover procedure it will be ascertained that the conditions under this Contract for the signature of the Handover Protocol are not fulfilled and based on this reason the Buyer will refuse to sign the Handover Protocol, then the Seller shall reimburse the Buyer for all costs that were incurred by the Buyer due to unsuccessful handover.

7.5 Parties exclude the application of the Section 2126 of the Civil Code.

8. WARRANTY

8.1 The Seller shall provide a warranty of quality of the Object of Purchase for the period of 12 months. If on the warranty list or other document is the warranty period of longer duration, then this longer warranty period shall have priority over the period stated in this Contract.

8.2 The warranty period shall begin on the day when the Object of Purchase (or its part) was used by the Buyer for the first time (and the Object of Purchase was removed from the sealed storage location). The Buyer shall inform the Seller of the day when warranty period started. If the Buyer

does not start using the Object of Purchase within two (2) years from the signature of the Handover Protocol, the warranty period shall start on the first day of the third year after the signature of the Handover Protocol.

8.3 The Seller shall remove defects that occur during the warranty period free of charge (i.e no charge for spare parts, workmanship, travel expenses, etc.) and in the periods of time stipulated in this Contract. Photocathodes for the XSCS are considered consumables and are not covered under warranty.

8.4 If the Buyer ascertains a defect of the Object of Purchase during the warranty period, the Buyer shall notify such defect without undue delay to the Seller. Defects may be notified on the last day of warranty period, at the latest.

8.5 The Buyer notifies defects in writing via e-mail. The Seller shall accept notifications of defects on the following e-mail address: info@axis-photon.com. The Seller shall confirm within 96 hours from the receipt of the notification.

8.6 In the notification the Buyer shall describe the defect and the manner of removal of the defect. The Buyer has the right to:

a) ask for the removal of the defect by the delivery of new Object of Purchase or its individual parts, or

b) ask for the removal of the defect by repair, or

c) ask for the reasonable reduction of the Purchase Price.

The choice among the above mentioned rights belongs to the Buyer. The Buyer is also entitled to withdraw from this Contract, if by delivering the Object of Purchase with defects this Contract is substantially breached.

8.7 The Seller shall remove the defect within 14 days from its notification, unless Parties agree otherwise.

8.8 The Seller shall remove the defect within terms stipulated in this Contract even if the notification of the defect is in his opinion unjustified. In such a case the Seller is entitled to ask for reimbursement of the costs of removal of the defect. If Parties disagree on whether the notification of the defect is justified or not, the Buyer shall ask an expert for the expert's opinion, which shall determine whether the notification of the defect was justified or not. In the case that the expert shall consider the notification as justified, then the Seller shall bear costs of the expert's opinion. If the expert considers the notification to be unjustified, then the Buyer shall reimburse the Seller for verifiably and effectively incurred costs of removal of the defect.

8.9 Parties shall execute a protocol on the removal of the defect, which shall contain the description of the defect and the confirmation that the defect was removed. The warranty period shall be extended by a period of time that elapses between the notification of the defect until its removal.

8.10 In case that the Seller does not remove the defect within stipulated time or if the Seller refuses to remove the defect, then the Buyer is entitled to remove the defect at his own costs and the Seller shall reimburse these costs within 10 days after the Buyer's request to do so.

8.11 The warranty does not cover defects caused by unprofessional manipulation or by the failure to follow Seller's instructions for the operation and maintanence of the Object of Purchase.

8.12 Parties exclude the application of Section 1925 of the Civil Code.

9. TECHNICAL SUPPORT AND ADDITIONAL SERVICES

9.1 For the ten year period starting from the day of the signature of the Handover Protocol, the Seller has to provide the following services without any cost to the Buyer:

a) any technical support (by email or by phone) required for troubleshooting the Object of Purchase.

b) any software updates that might be needed to keep the Object of Purchase functioning, as well as maintaining the cyber/network security of the control computer.

9.2 For the ten year period starting from the day of signature of the Handover Protocol, the Seller has to provide the following services to the Buyer under standard business conditions:

a) In case of any hardware failure, the Seller shall send replacement modules. If required, the Seller shall provide onsite personnel at the Buyer's facility at Dolní Břežany for troubleshooting and repairs.

b) If the problem requires repair to be done at Seller's facility, the Buyer shall send the necessary equipment to the Seller's facility and the Seller has to return the equipment after the necessary repairs.

10. REPRESENTATIONS AND WARRANTIES OF THE SELLER

10.1 The Seller represents and warrants to the Buyer that

a) has all the professional prerequisites necessary for the proper fulfilment of this Contract,

b) is fully authorized to perform this Contract, and

c) there are no obstacles on the Seller's side that would preclude him from the due performance of this Contract.

11. PENALTIES

11.1 If the Seller is in default regarding the delivery of the Object of Purchase, i.e. the Seller breaches its duty to perform this Contract in time and due manner, the Seller shall pay to the Buyer a contractual penalty in the amount of 0,1% of the Purchase Price for every (even commenced) day of default.

11.2 If the Seller is in default with the removal of the defect, the Seller shall pay to the Buyer a contractual penalty in the amount of 0,01% of the Purchase Price for every (even commenced) day of default.

11.3 The Seller shall pay contractual penalties within fifteen (15) days from the day, on which the Buyer enumerated its claims. The payment of contractual penalties shall not affect the right of the

Buyer to damages even to the extent to which such damages exceeds the contractual penalty.

11.4 Total amount of contractual penalties that the Buyer is entitled to claim shall not exceed 30 % of the Purchase Price.

11.5 The Buyer is entitled to unilaterally set off claims arising from the contractual penalties against the claim of the Seller for the payment of the Purchase Price.

11.6 Parties exclude the Section 2050 of the Civil Code.

12. RIGHT OF WITHDRAWAL

12.1 The Buyer is entitled to withdraw from this Contract without any penalties, if any of the following circumstances occur:

a) the expenses or the part of the expenses that will arise on the basis of this Contract will be found by the provider of the grant or other control body as ineligible;

b) the Seller shall be in delay with the fulfilment of this Contract and such delay lasts more than two (2) months;

c) the Object of Purchase shall not fulfil the requirements stipulated in this Contract, in particular in Annex 1 (*Technical Specification*);

d) the Buyer shall lose a grant for the realization of the Project;

e) the insolvency proceeding is initiated against the Seller; or

f) the Buyer ascertains that the Seller provided in its bid for the Public Procurement information or documents that do not correspond to the reality and that had or could have had impact on the result of the tendering procedure, which preceded the conclusion of this Contract.

13. SPECIAL PROVISIONS

By signing this Contract, the Seller becomes a person that must cooperate during the finance control within the meaning of Section 2 letter e) of the act no. 320/2001 Coll., on finance control in the public administration, and shall provide to the Directing Body of the Operational Programme Research and Development for Innovations or other control bodies acces to all parts of the bid, Contract or other documents that are related to the legal relationship formed by this Contract. This duty also covers documents that are Object to the protection in accordance with other acts (business secrets, secret information, etc.) provided that control bodies fulfil requirements stipulated by these acts (e.g. Section 11 letter c) and d), Section 12(2) letter f) of the act no. 552/1991 Coll., on state control). The Seller shall secure that all its subcontractors are also obliged to cooperate with control bodies in the above stipulated extent. The possibility of effective control must be preserved until the year 2021.

14. CONFIDENTIALITY

Parties shall not disclose information that shall become available to them in connection with this

Contract and its performance and whose disclosure could harm the other Party. Duties of the Buyer ensuing from the applicable legal regulations remain unaffected.

15. REPRESENTATIVES OF THE PARTIES

15.1 The Seller appoints following representatives for the communication with the Buyer:

In technical matters:

Name: Dr. Christian-Yves Côté

E-mail: cycote1@axis-photon.com

Tel.: +1 (450) 929-8209

In contractual matters:

Name: Dr. Christian-Yves Côté

E-mail: cycote1@axis-photon.com

Tel.: +1 (450) 929-8209

15.2 The Buyer appoints following representatives for the communication with the Seller:

Name: Deepak Kumar Batheja

E-mail: deepak.kumar@eli-beamlines.eu

Name: Katerina Falk

E-mail: katerina.falk@eli-beamlines.eu

Name: Petr Bruza

E-mail: petr.bruza@eli-beamlines.eu

16. FINAL PROVISIONS

16.1 This Contract is governed by the laws of the Czech Republic, especially by the Civil Code.

16.2 All disputes arising out of this Contract or out of legal relations connected with this Contract shall be preferable settled by a mutual negotiation. In case that the dispute is not settled within sixty (60) days, such dispute shall be decided by courts of the Czech Republic in the procedure initiated by one of the Parties.

16.3 The Seller bears the risk of changed circumstances within the meaning of Section 1765 of the Civil Code.

16.4 The Seller takes into account that the Buyer is not in relation to this Contract an entrepreneur, nor the subject matter of this Contract is connected with the business activities of the Buyer.

16.5 The Seller is not entitled to set off any of its claims or his debtor's claims against the Buyer's claims. The Seller is not entitled to transfer its claims against Buyer that arose on the basis or in connection with this Contract on third parties. The Seller is not entitled to transfer rights and duties from this Contract or its part on third parties.

16.6 All modifications and supplements of this Contract must be in writing.

16.7 If any of provisions of this Contract are invalid or ineffective, the Parties are bound to change this Contract is such a way that the invalid or ineffective provision is replaced by a new provision that is valid and effective and to the maximum possible extent correspond to the original invalid or ineffective provision.

16.8 If any Party breaches any duty under this Contract and knows or should have known about such breach, it shall notify it to the other Party and shall warn such Party of possible consequences of the breach.

16.9 This Contract is executed in four (4) counterparts and every Party shall receive two (2) counterparts.

16.10 An integral part of this Contract is Annex 1 (*Technical Specification*). In case of any discrepancy between the provisions of this Contract and the provisions of Annex 1 (*Technical Specification*) the provisions of this Contract shall prevail.

16.11 This Contract shall be valid and effective on the date of the signature of both Parties.

IN WITNESS WHEREOF attach Parties their handwritten signatures:

Buyer
Signature: _____
Name: prof. Jan Řídký, DrSc.
Position: director
Date: 19.10.2015

Seller
Signature: _____
Name: Dr. Christian-Yves Côté,
Position: CEO
Date: 23.10.2015

ANNEX 1
TECHNICAL SPECIFICATION

Annex No. 1 Technical Specification

Optical and X-ray streak cameras for experimental areas

Fyzikální ústav
Akademie věd ČR, v. v. i.

project supported by:

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE

OP Research and Development for Innovation

Content

1 Introduction

1.1 Purpose

This document lists the technical requirements, calibration and testing procedures and constraints on the delivery of visible, infra-red and X-ray streak camera systems for ELI-Beamlines.

1.2 Scope

This document contains the functional, performance, safety, operational, design, testing and calibration requirements for the streak camera systems in ELI.

1.3 Terms, Definitions and Abbreviations

For the purpose of this document, the following abbreviated terms apply:

Abbreviation	Meaning
ADU	Analog-Digital Unit
ELI	Extreme Light Infrastructure
EUV	Extreme ultraviolet
QA	Quality Assurance
RA	Research Activity
SCS	Streak camera system
XSCS	X-ray streak camera system
VSCS	Visible streak camera system
IRSCS	Infra-red streak camera system
lp	Line pairs
lp/mm	Line pairs per millimeter
MTF	Modular transfer function
FWHM	Full width at half maximum
EMP	Electro-Magnetic Pulse

The following table defines the variables used in this document:

Variable	Meaning
l	Effective length of photocathode in millimetres. Note that the l may be less than the length of the photocathode, as it is the length over which the spatial resolution of the SCS is within the limits defined in section 3.2
h	Height of the input slit in micrometers
x	Spatial resolution in lp/mm of the SCS
V_{max}	The minimum of (a) maximum voltage that can be applied to the streak tube while the image of the photocathode/slit still lies completely within the field

	of view of the digital detection device of the SCS, or (b) the maximum voltage applied by the sweep unit of the SCS. Note that the image of the photocathode is at the center of the output screen when 0 Volts is applied to the streak tube.
Sweep range	The duration in time over which the sweep unit applies a voltage ranging from $-V_{max}$ to V_{max}.
Spatial resolution unit	=1/x in millimeters or 1000/x in micrometers
Δt	Time resolution of the SCS in picoseconds. The procedure for calculation is described in section 3.4

1.4 Structure of the Document

Section 3 describes the general requirements and procedures that are applicable to all the the streak camera systems planned to be procured in this tender. Individual requirements for the separate streak camera systems are described in sections 4, 5 and 6.

2 General description

Streak cameras are high speed imaging diagnostics used for measuring fast phenomenon. Three streak camera systems are planned to be acquired by ELI Beamlines. Each of the three streak cameras are optimized to be sensitive to various wavelengths

1. Visible streak camera system (VSCS) is sensitive to visible wavelengths
2. Infra-red streak camera system (IRSCS) is sensitive to infra-red.
3. X-ray streak camera system (XSCS) is sensitive to EUV and X-ray wavelengths

The exact technical requirements of the individual camera systems are provided in the sections 4, 5 and 6.

3 Common requirements of all streak camera systems

Each streak camera system will include input optics (if specified in the sections below), choice of photocathodes, streak tubes, sweep units, digital readout systems, power supplies, control software and computer (if specified below). The seller must provide the complete system including all the components required for the system to operate independently (unless some specific component is specifically listed not to be included).

3.1 Scope of delivery

Each SCS must be delivered along with the following items

- The streak cameras system with streak tube, sweep unit(s), hardware for detection and recording, and hardware to control the sub-components of SCS.
- Any high voltage supplies that might be required for the operation of the SCS.

- The seller shall specify the trigger and delay requirements for the sweep unit, camera, etc. The buyer shall provide the necessary triggers during the operation of the SCS at the buyers facility in Dolní Brežany. The seller does not need to include and delay trigger generators as part of SCS shipment. Any delay generators required for the calibration tests before shipping the product shall be arranged for by the seller.
- Power, control, trigger and communication cables required for the operation of the SCS.
- Calibration data for the SCS as per the requirements described in this sections 3.2, 3.3 and 3.4.
- Operation manual in English for the SCS.

In addition, the XSCS shall be delivered with the following extra items:

- Installed in an air tight box with the necessary connectors and cooling.
- The seller shall also provide the design for an adaptor flange to mount the XSCS on a DN400 ISO F port.

3.2 Determination of spatial resolution (and it's distortion) in static mode

This sub section describes the setup for determining the spatial resolution of the SCS in static mode. The seller must provide the experimental results of this procedure (including raw data and final results). These results will be used for the verification of the SCS and also as the deciding criterion for its acceptance. All expenses including material and facility usage/rental for this test has to be covered by the seller, and must be performed before shipping the product.

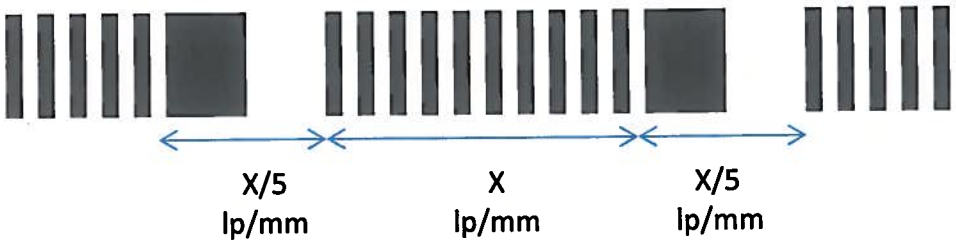

Figure 1: Example of a resolution grid

This test has to be performed using a resolution grid. An example of a resolution grid is shown in Figure 1. The length of the resolution grid must be such that it covers the entire length of the photocathode. The resolution grid shall have a repeated pattern of "10 pairs of x lp/mm grid and 1 pair of x/5 lp/mm". Where "x lp/mm" is the spatial resolution that the seller has to demonstrate, and it must be equal to or better than the specification in the requirement of the SCS.

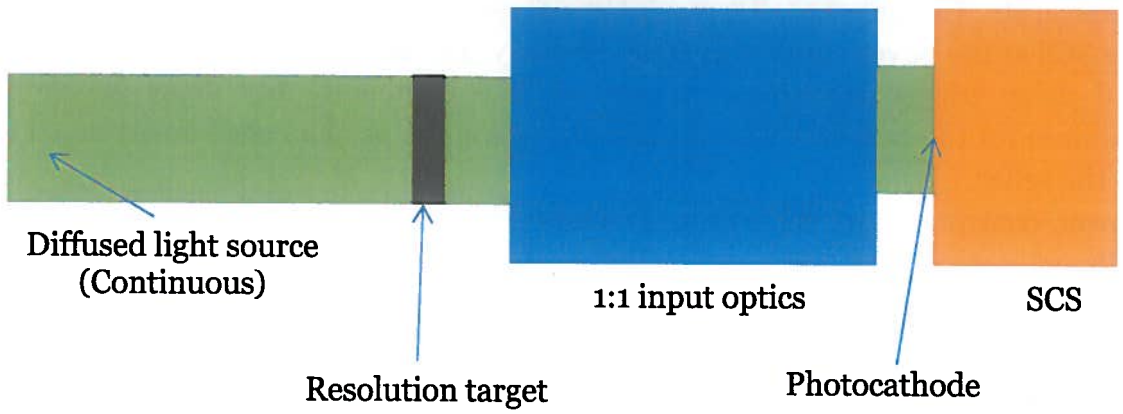

Figure 2: Schematic (block diagram) of the setup for static calibration of spatial resolution of the SCS

A schematic of the setup for static calibration is shown in Figure 2. The seller has to provide data sets and calibration results for three different static bias voltages on the streak tube:

- No bias,
- Bias of +0.66 x V_{max} volts,
- Bias of -0.66 x V_{max} volts.

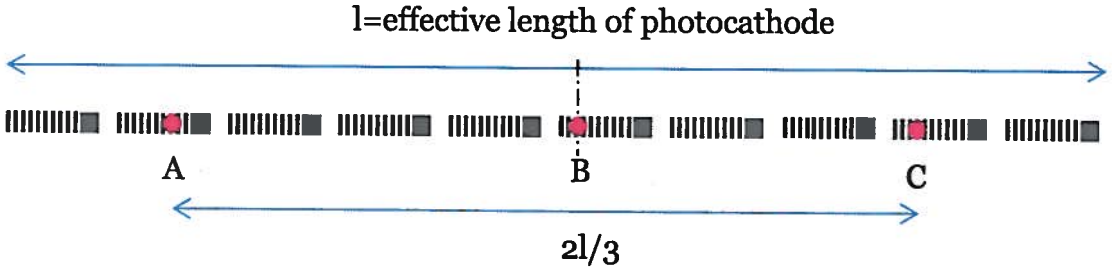

Figure 3: Example of a typical image of the resolution grid collected by the streak camera at static bias. The number of line pairs of the resolution grid shown here is only symbolic.

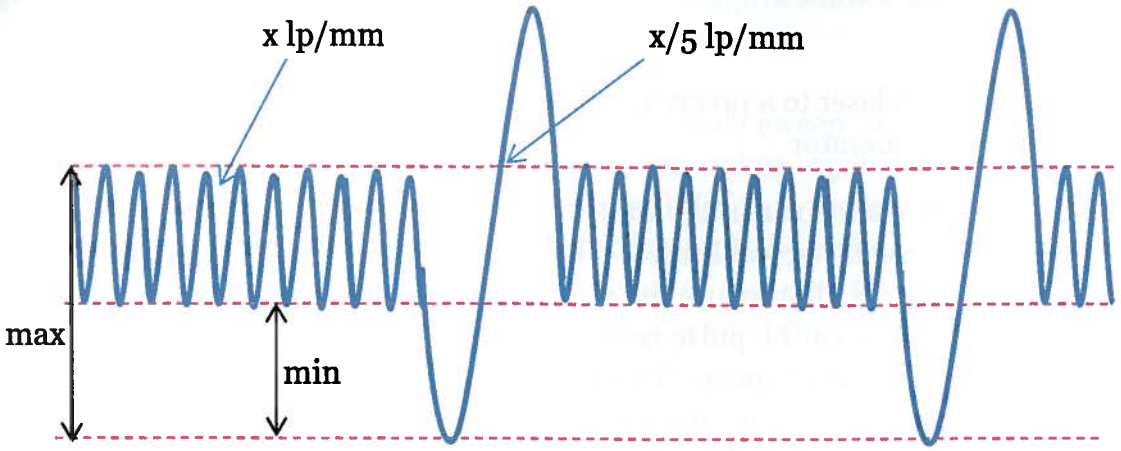

Figure 4: Section of the typical lineout measured by the SCS.

From the measured data, the seller shall calculate and document the modular transfer function at various locations on the digital output using the procedure described below:

1. The following steps shall be repeated for the three different bias voltages described above.
2. The typical image of the resolution grid for each bias voltage is shown in Figure 3. The seller has to measure and tabulate the MTF at locations A, B and C, as defined in the figure.
3. Typically expected line out of the average intensity in the vicinity of these points is shown in Figure 4. From this lineout, MTF shall be calculated as MTF=(max-min)/(max+min), where max and min are the average ADUs of the lineout of the resolution grid as shown in the Figure 4.
4. The seller shall thus calculate the MTF at the nine instances by this procedure (three biases x three spatial locations).

The MTF at the point B at no bias should be greater than 50% and for the remaining eight instances has to be greater than 45%.

3.3 Sweep range calibration

This sub section describes the procedure for determining the sweep range calibration of the SCS. The seller must provide the experimental results of this procedure (including raw data and final results). These results will be used for the verification of the SCS. All expenses including material and facility usage/rental for this procedure has to be covered by the seller, and must be performed before shipping the product.

The seller shall provide the calibration of time vs pixel number for each sweep range of the SCS. The method to generate the sweep range calibration is described below. The seller shall follow this calibration procedure unless agreed otherwise by both the parties.

The seller shall generate a train of equally spaced optical pulses by any of the following methods:

1. by coupling a Ti:Sa laser to a precisely calibrated etalon.
2. by using a comb generator

The FWHM duration of each pulse in the train has to be less than the time resolution for the particular sweep range being calibrated. The pulse train must be focussed on the photocathode and the seller shall measure the streaked image of the pulses at the centre of the photocathode. The source of the pulse train shall be adjusted to have greater than 10 pulses measured in the streaked image for every sweep range. The seller shall use a centroid finding algorithm to estimate the location of the peaks. The seller shall provide the pixel location vs relative time calibration from the location of the centroids. These calibration results shall be provided to the buyer in an ASCII table.

The seller shall also calculate the linearity slope and the percentage error in the linearity of the SCS using the following formulas:

$$\text{Linearity slope} = m = \frac{(n\sum_{i=1}^{n} x_i y_i) - (\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{(n\sum_{i=1}^{n} x_i^2) - (\sum_{i=1}^{n} x_i)^2}, \text{ in px/ps}$$

Equation 1

$$\text{Intercept} = c = \frac{(\sum_{i=1}^{n} x_i^2)(\sum_{i=1}^{n} y_i) - (\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} x_i y_i)}{(n\sum_{i=1}^{n} x_i^2) - (\sum_{i=1}^{n} x_i)^2}$$

$$\text{slope error} = \sqrt{\frac{\sum_{i=1}^{n}(y_i - mx_i - c)^2}{n-2}} \sqrt{\frac{n}{(n\sum_{i=1}^{n} x_i^2) - (\sum_{i=1}^{n} x_i)^2}}$$

$$\text{percentage slope error} = \frac{\text{slope error}}{abs(m)}\ 100$$

Where, n is the number of pulsed profiles measured in the streaked image, x_i are the relative time in ps of the pulses and y_i are the corresponding location of centroid expressed in pixels.

The SCS must have a percentage slope error of less than 10% for all sweep ranges, and a percentage slope error of less than 2% for sweep range of 10 ns and 20 ns.

3.4 Measurement of time resolution and number of temporally resolved events

This sub section describes the procedure for determining the time resolution of the SCS. The seller must provide the experimental results of this procedure (including raw data and final results). These results will be used for the verification of the SCS. All expenses

including material and facility usage/rental for this procedure has to be covered by the seller, and must be performed before shipping the product.

The seller shall calculate the time resolution for each sweep range of the SCS. The seller shall follow the following calibration procedure unless agreed otherwise by both the parties. No additional experiments are required for this measurement. The seller shall calculate the time resolution using the data collected for sweep range calibration described in section 3.3. For each pulse in the streaked image measured by the SCS, the seller shall calculate the FWHM in number of pixels. The seller shall then calculate the time resolution of the SCS in ps for each sweep range using the following formula:

$$\text{time resolution in ps} = \Delta t = \frac{1}{mn}\sum_{i=1}^{n}(FWHM\ of\ pulse\ i)$$

Equation 2

, where m is defined in Equation 1.

The seller shall also calculate the number of temporally resolved events measurable by the SCS for each sweep range using the following formula:

$$\text{number of temporally resolved events} = \frac{\text{sweep range in ps}}{\Delta t}$$

3.5 Verification methods

The seller shall allow for a representative from the buyer to participate in the experiments to calibrate the SCS as per the methods described above. If the representative from the buyer participates in the calibration tests, then all the expenses for his/her travel and lodging will be covered by the buyer.

- The seller has to provide the description (part number, etc.), datasheet and results of any calibration performed by the original manufacturer of each individual component of the SCS. This information will be used by the buyer to verify the performance required of the SCS.
- The results from the calibration processes described in sections 3.2, 3.3 and 3.4 will also be used to verify that the performance of SCS meets the required conditions and hence to decide on the criterion of its acceptance.

3.6 Other Instructions

Bidders have to describe the complete SCS system (including specific part numbers of individual components) and parameters achieved for each requirement described in the following sections.

4 Requirements for VSCS

Table 1: Technical specifications and requirements for the VSCS

Parameter	Requirement
Energy range of operation	The VSCS has to be optimized for detecting input photons in the range of 200-850 nm.
Photocathode	VSCS shall use the S-20 photocathode. The window material has to be chosen so that the transmission through the window in the wavelength range of 200-850 nm is greater than 80% The effective length of the photocathode (l) has to be greater than 4 mm. The final digital imaging system (CCD) of the VSCS has to be capable of measuring this entire effective length.
Spatial resolution in static mode	The spatial resolution (x), has to be greater than 10 lp/mm. The spatial resolution (x) and the effective length of the photocathode (l) shall be such that the number of spatial resolution units (l*x) is greater than 65. The seller has to demonstrate the MTF and the distortion in spatial resolution is within acceptable limits at static bias applied to the streak tube. The limits and the detailed procedure for determining the distortion in spatial resolution is described in Section 3.2.
Sweep ranges	The system has to offer a choice of sweep range(s) which allows it to be operated at the best time resolution. In addition the system shall offer at least the following sweep ranges: 5 ns, 10 ns, 20 ns, 50 ns (within limit of ±10%). These can be provided by a single sweep unit or by interchangeable sweep units. The supplier has to provide the time vs pixel calibration curves for the sweep ranges as described in section 3.3
Time resolution	For the fastest sweep range, the temporal resolution has to be less than 2 ps. For all sweep range settings, the SCS has to be able to record greater than 90 temporally resolved events for each sweep range (see section 3.4 for definition).
Trigger parameters	The SCS is planned to operate with a single trigger and not be synchronized to an external oscillator for integrated measurements. The triggering jitter for the SCS has to be less than 10 ps rms for single shot measurements.
Repetition rate	The entire system (including triggering, hold off and camera readout) has to operate at a repetition rate ≥ 100 Hz. Note, that if the digital camera has to be binned to achieve this repetition rate, the SCS has to still satisfy all the constraints mentioned in this table.
Detection technology	The seller has to provide the detection technology, i.e., a scientific grade camera and coupling optics to the streak tube and phosphor. The seller can use either of the two technologies to achieve this: • Tapered (or 1:1) fiber optic bundle from the phosphor at the end of the streak tube directly bonded to a cooled scientific grade camera. Such a camera shall have 16 bit measurement capability per pixel, have a quantum efficiency > 90% at the emission wavelength of the phosphor, have a readout noise level of less than 4 e^- per pixel and have a full well capacity of greater than 80000 electrons (non-binned) or • Have an intensifier to amplify the output of the streak tube which is lens or fiber coupled to a scientific grade digital camera. Such a camera has to be 16 bit, have a readout noise level of less than 3 e^- per pixel, have a dynamic range of better than 30000 (non-

	binned). Note that the intensifier can either be external to the streak tube i.e., amplifies the visible image on the phosphor at the end of the streak or be internal to the streak tube i.e., amplifies the electrons created and accelerated by the streak tube. The magnification of the SCS and the detection technology must be so designed that a spatial resolution unit at the center of the photocathode is covered by at least 4 pixels by the digital camera. The magnification of the SCS and the detection technology must be so designed that the time resolution for each sweep range shall be covered by at least 4 pixels by the digital camera, i.e., $m\Delta t \geq 4$ (see Equation 1 and Equation 2). The seller has to use standard connectors for cooling water, if required for the detection technology. The buyer shall provide the cooling water connection if required.
Input optics and slits	The seller shall provide input optics for the SCS if the input optics is required for enabling the operation of SCS at the best time resolution. The input optics is not required for those SCS models where the photons can be directly focused on the photocathode and no external slit is required to achieve the best time resolution. If input optics is provided, it shall consist of an adjustable slit (with micrometer) and lens optics of f number between 4.0 and 6.0, with a magnification of 1.
Size and vacuum requirements	No specific requirements.
Mounting holes	The front face of the streak camera (close to the input slit) shall have tapped holes for connecting an external spectrometer if needed. The seller has to consult with the buyer to finalize the location of these tapped holes for certain spectrometer models.
Software, data interface and control	The seller must provide the control software pre-installed on a computer. It is not necessary to provide the computer peripherals like monitor and keyboard. The seller must also provide the buyer with the access and rights to install the analysis and control software on multiple computers for the purpose of research. Buyer will not distribute or install the software to third parties. The control software must also give user the access to raw data (i.e., without any software based correction for jitter and calibrations). It is highly desirable that the control computer use a Linux® based operating system and the control software be interfaced to the tango control infrastructure (http://www.tango-controls.org/). The control software should be able to accept remote scripts (in ASCII, etc.) to configure/control the VSCS and store its data.

5 Requirements for IRSCS

The requirements for the IRSCS are same as the requirements of the VSCS described in section 4. Only the differences are described in the table below:

Table 2: Technical specifications and requirements for the IRSCS

Parameter	Requirement
Energy range of operation	The IRSCS has to be optimized for detecting input photons in the range of 400-1400 nm.
Photocathode	IRSCS shall use the S-1 photocathode. The window material has to be chosen so that the transmission through the window in the wavelength range of 400-1400 nm is greater than 80%. The effective length of the photocathode (l) has to be greater than 4 mm. The final digital imaging system (CCD) of the IRSCS has to be capable of measuring this entire effective length.
Repetition rate	The entire system (including triggering, hold off and camera readout) has to operate at a repetition rate ≥ 0.1 Hz.

6 Requirements for XSCS

Table 3: Technical specifications and requirements for the XSCS

Parameter	Requirement
Energy range of operation	The XSCS has to be optimized for detecting input photons in the energy range of 100-10000 eV. X-ray and EUV photons have to be detected on the photocathode by transmission and not by reflection at grazing incidence.
Photocathode	The design of the XSCS shall be such that the photocathode is exposed directly to the vacuum of a large experimental chamber for laser plasma research. Designs where the photocathode is in a different vacuum, separated by windows like Beryllium is not acceptable. The seller has to provide one new KI photodiode with the XSCS. The XSCS has to be designed so that the photocathodes are interchangeable. The seller shall provide the mechanical designs for the support of the photocathode, so that the buyer can procure additional photocathodes later. The calibration tests described in sections 3.2, 3.3 and 3.4 shall be performed using a UV photocathode and an UV source. The effective length of the photocathode (l) has to be greater than 12 mm. The final digital imaging system (CCD) of the XSCS has to be capable of measuring this entire effective length.
Spatial resolution in	The spatial resolution (x), has to be greater than 16 lp/mm. The spatial resolution (x) and the effective length of the photocathode (l) shall be

static mode	such that the number of spatial resolution units (l*x) is greater than 200. The seller has to demonstrate the MTF and the distortion in spatial resolution is within acceptable limits at static bias applied to the streak tube. The limits and the detailed procedure for determining the distortion in spatial resolution is described in Section 3.2.
Sweep ranges	The system has to offer a choice of sweep range(s) which allows it to be operated at the best time resolution. In addition the system shall offer at least the following sweep ranges 5 ns, 10 ns, 20 ns, 50 ns (within limit of ±10%). These can be provided by a single sweep unit or by interchangeable sweep units. The supplier has to provide the time vs pixel calibration curves for the sweep ranges as described in section 3.3
Time resolution	For the fastest sweep range, the temporal resolution has to be less than 1 ps. For all sweep range settings, the XSCS has to be able to record greater than 300 temporally resolved events for each sweep range (see section 3.4 for definition).
Trigger parameters	The XSCS is planned to operate with a single trigger and not be synchronized to an external oscillator for integrated measurements. The triggering jitter for the XSCS has to be less than 20 ps rms for single shot measurements.
Repetition rate	The entire system (including triggering, hold off and camera readout) has to operate at a repetition rate ≥ 0.1 Hz. Note, that if the digital camera has to be binned to achieve this repetition rate, the XSCS has to still satisfy all the constraints mentioned in this table.
Detection technology	The seller has to provide the detection technology, i.e., a scientific grade camera and coupling optics to the streak tube and phosphor. This has to be done using a tapered (or 1:1) fiber optic bundle from the phosphor at the end of the streak tube directly bonded to a cooled scientific grade camera. Such a camera shall have 16 bit measurement capability per pixel, have a quantum efficiency > 90% at the emission wavelength of the phosphor, have a readout noise level of less than 4 e^- per pixel and have a full well capacity of greater than 80000 electrons (non-binned). The magnification of the XSCS and the detection technology must be so designed that a spatial resolution unit at the center of the photocathode is covered by at least 4 pixels by the digital camera. The magnification of the XSCS and the detection technology must be so designed that the time resolution for each sweep range shall be covered by at least 4 pixels by the digital camera, i.e., $m\Delta t \geq 4$ (see Equation 1 and Equation 2). The seller has to use standard connectors for cooling water for the detection technology. The buyer shall provide the cooling water connection.
Slit	The seller shall provide a fixed slit mounted on the XSCS. The seller has to choose the height of the slit to be the maximum possible so that the XSCS meets the requirement on time resolution. The seller shall also provide the engineering drawings of the slit and its mount, so that the buyer can mount a different slit later if needed.
Size and	The XSCS is planned to operate in an air tight box inside a large vacuum

vacuum requirements	chamber. The seller shall provide such a box made of Aluminum, with the XSCS installed in it. The box (excluding the connectors) has to be smaller in size than 20 cm x 20 cm x 80 cm, unless agreed otherwise by both the parties. The front face of the box, close to the photocathode shall have four guide pins for positioning. The box shall be so designed that the top lid of the box can be opened easily for accessing and diagnosing the various sub components of the XSCS. The box shall be able to mount to standard optical breadboards at any orientation, with the breadboard being either below or above the box. The front panel of the box shall provide easy access for replacing the photocathode and have tapped holes for mounting an external X-ray spectrometer. The back panel of the box shall have the necessary electronic, optic, power and cooling connectors and feedthrough. The seller shall include the necessary cooling system within the box for reliable operation of the XSCS. The seller shall provide the design of such a box to the buyer for approval before the manufacture of the box. Prior to shipping the XSCS, the seller shall demonstrate that the system is airtight and operational within a sufficiently large vacuum chamber. The seller shall also provide the design for adaptor flange(s) to mount the XSCS (including the box) shall on a DN400 ISO F flange. The XSCS shall be shipped to the buyer in a vacuum tight enclosure covering at least the photocathode. Such an enclosure shall have a pump down port which can be used for long term storage of the XSCS.
EMP shielding	The seller shall enclose the necessary electronics (streak tube, sweep unit, etc) inside an EMP shielded enclosure. The design of such an enclosure has to be demonstrated to have worked for shielding an X-ray streak camera system from EMP generated during laser plasma experiments where an energy greater than 1 kJ is incident on target.
Mounting holes	The vacuum interface flange shall have tapped holes for connecting an external spectrometer and/or X-ray foil filters if needed. The seller has to consult with the buyer to finalize the location of these tapped holes.
Software, data interface and control	The seller must provide the control software pre-installed on a computer. It is not necessary to provide the computer peripherals like monitor and keyboard. The seller must also provide the buyer with the access and rights to install the analysis and control software on multiple computers for the purpose of research. The buyer will not distribute or install the software to third parties. The control software must also give user the access to raw data (i.e., without any software based correction for jitter and calibrations). It is highly desirable that the control computer use a Linux® based operating system and the control software be interfaced to the tango control infrastructure (http://www.tango-controls.org/). The control software should be able to accept remote scripts (in ASCII, etc.) to configure/control the VSCS and store its data.

5. BID PRICE

The following bid price is for an ***X-ray streak camera system (XSCS)*** corresponding to:

Part no. 3 of the public tender entitled: OPTICAL AND X-RAY STREAK CAMERAS FOR EXPERIMENTAL AREAS

Total bid price in EUR excluding VAT:	**248 500**
Total bid price in EUR including VAT:	**300 685**

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6. AXIS-PXE INSERTABLE X-RAY STREAK CAMERA SYSTEM

The system we propose is an x-ray streak camera that can be easily installed in two configuration: with the camera head mounted on the chamber wall or freely inserted in the vacuum chamber.

Figure 1: Schematics of AXIS system in **"Mounted" configuration.**

The camera head mounted on a tube which fits in the diameter of a DN400 flange. This adaptor can be built with different lengths to bring the photocathode at the desired distance from the source.

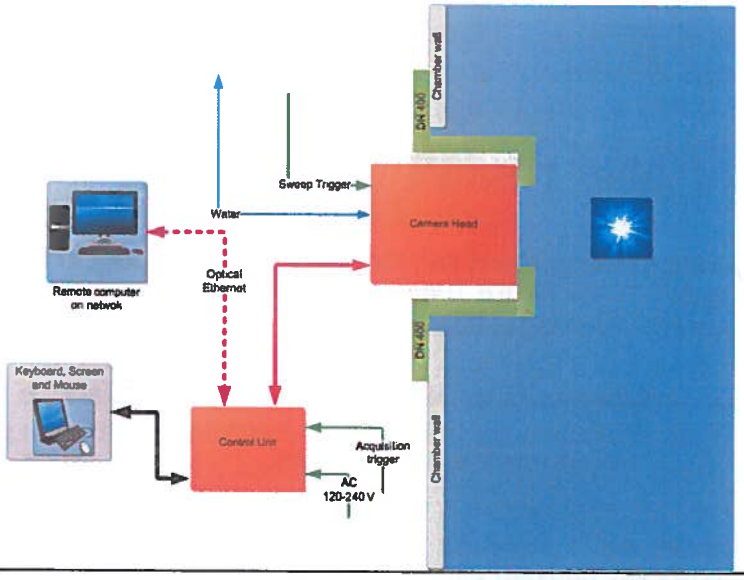
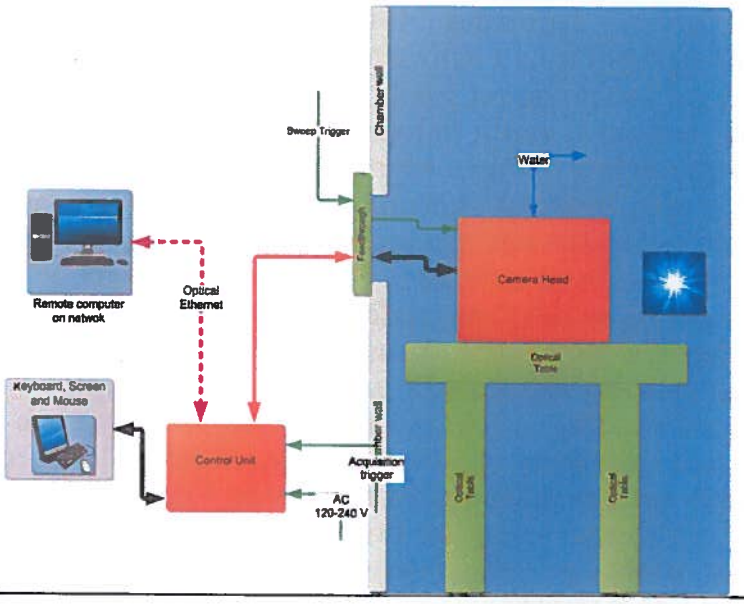


Figure 2: Schematics of AXIS system in **"Inserted" configuration.**

The camera head is located entirely inside the vacuum chamber and standing on an optical table.

This configuration allows free positioning inside the chamber.



The system that we propose here includes the camera head, the control unit, the <u>non-vacuum cabling</u> between both (orange-colored in the previous figures) and some accessories listed in the next sections.

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6.1 CAMERA HEAD

The camera head is an hermetic airbox which includes the streak tube, a high performance CCD camera and a sweep unit.

NOTE

All figures presented in section 6 are artistic/schematics renderings for information only. The 3D model of the final system will be submitted to the ELI team for approval before fabrication.

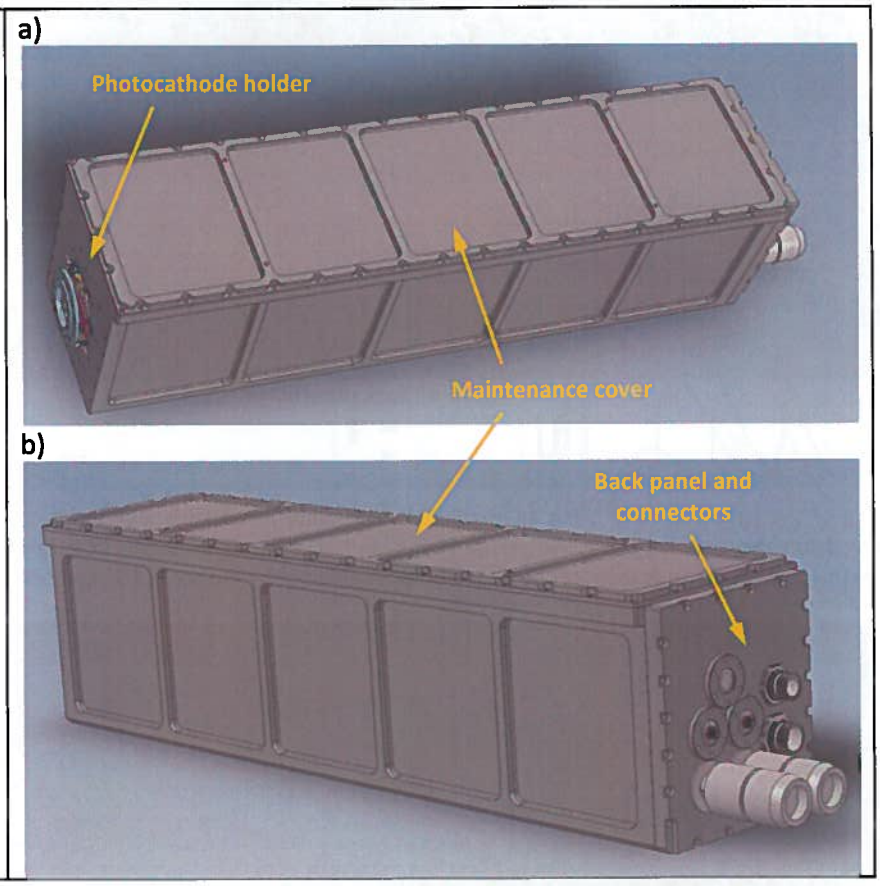

Figure 3: Camera head.

a) entrance side

b) back side

Dimensions of this airbox are

20cm x 20cm x 80cm (excluding connectors).

Final design might be smaller.

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The following figure shows the back panel interface. All connectors are hermetic. Optical communication and Electrical signals are fed to the airbox via 38999 series connectors. Triggers uses SMA standard and water connectors are SWAGELOK DESO quick disconnect fittings (PN . SS-QTM4A-B1-600)

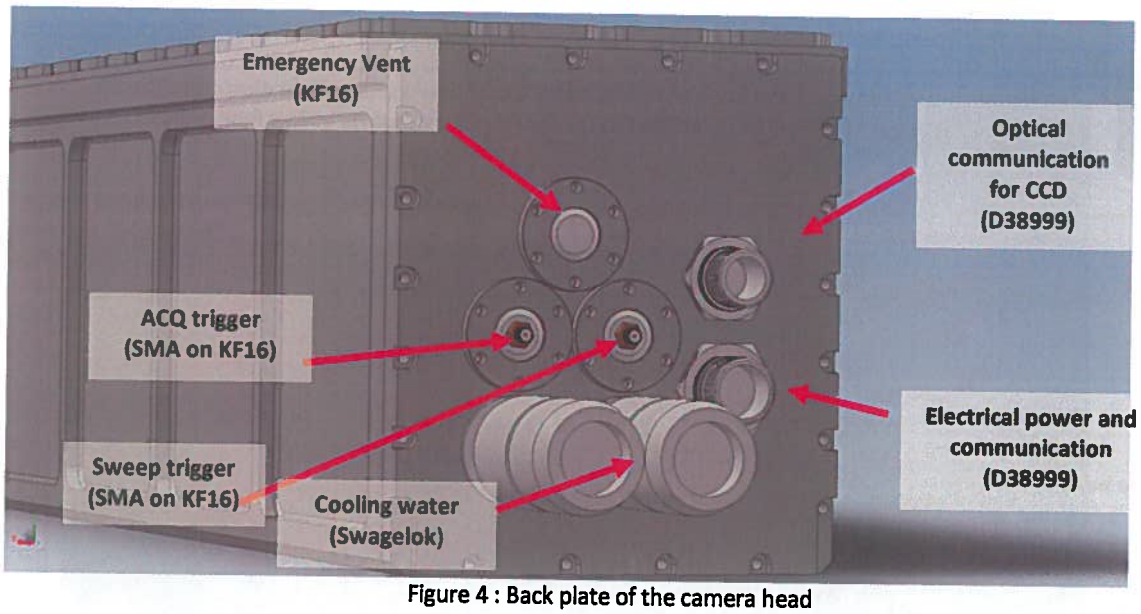

Figure 4 : Back plate of the camera head

Cooling of the airbox is done using an aluminium cold plate in which is inserted a copper-pipe serpentine. Water is coming from the first hermetic Swagelock fitting and goes straight to the CCD camera. It then goes through the serpentine and cools the bottom of the airbox before going out by the second Swagelock fitting.

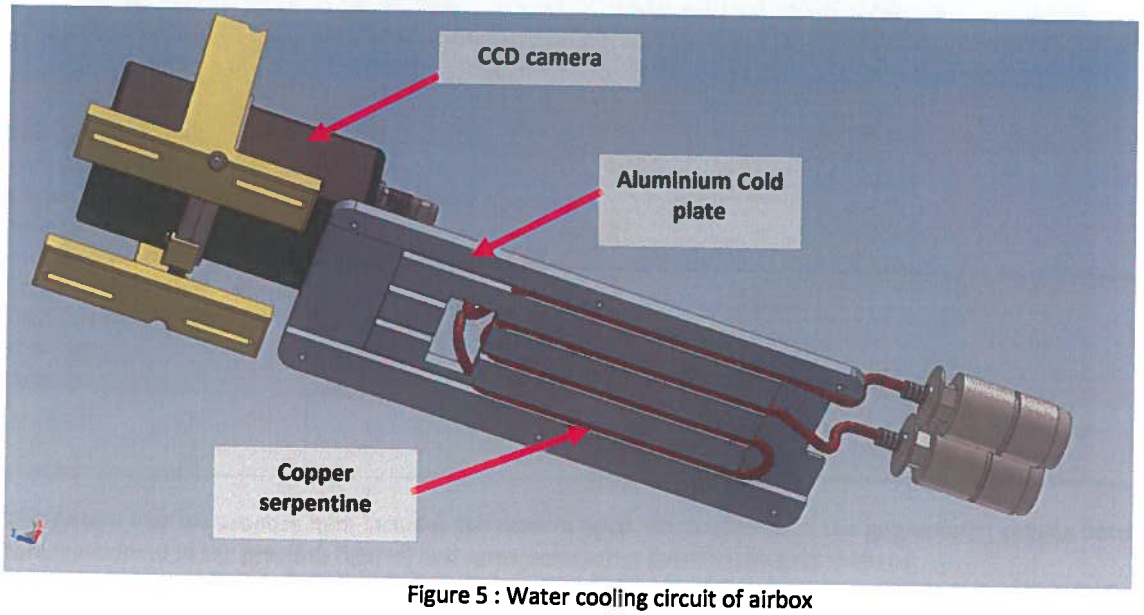

Figure 5 : Water cooling circuit of airbox

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6.1.1 STREAK TUBE:

The streak tube is a P864X bilamellar tube built in France by Photonis according to our specifications. Its front end is open such that the user can easily interchange the photocathode to match the experimental conditions. It is capable of sub-ps resolution while maintaining a 25 lp/mm (with 50% contrast) spatial resolution in sweep mode. The photocathode can easily be changed by the user so the cathode material fits the needs of the experiments.

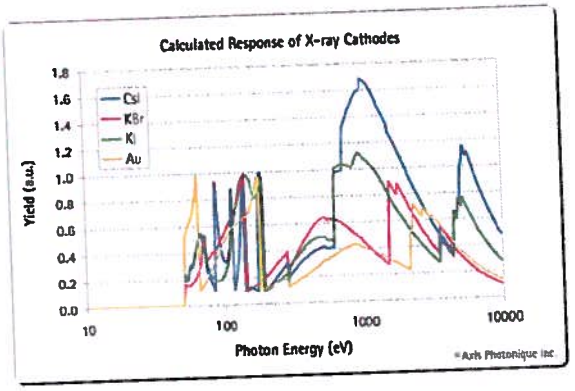
The input slit of the streak tube is 18mm long and the width is fixed at a value of 75 µm. Therefore, this tube can resolve about 450 spatial points.

Bilamellar streak tube built by PHOTONIS.

6.1.2 PHOTOCATHODES:

The photocathode is exchangeable by the user. It has to be considered has consumable and must be procured regularly. Axis Photonique can supply them but they can also be procured from other suppliers (we will give you the mechanical drawings of the support).

There are different choices for matching different experiments as shown on the next figure.



6.1.3 CCD CAMERA:

The readout system is a Spectral Instruments Series 1000 with a **back-thinned** E2V CCD42-40, Grade 1, 13.5 micron 2048 x 2048 pixel. The front faceplate is made of BPLSE-6 material. The camera is TE cooled to -35°C with a liquid cooled with a backplate made from Naval Brass. **A suitable liquid chiller must be supplied by the user.** With standard CCD chips (front-illuminated), the photosensitive area is located under different layers of material (Poly-Si electrodes, borophosphosilicate glass, gate oxide, etc...). Visible light is mostly absorbed in these layers so that the quantum efficiency is limited to about 40%. To increase the quantum efficiency, the silicon substrate is thinned and the chip is flipped around to expose its back to incoming light. Therefore, with the back-thinned chips, the visible light only goes through a thin layer of Si before being absorbed in the photosensitive area allowing quantum efficiencies up to 95%.

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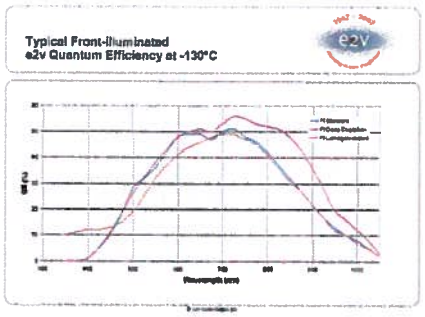
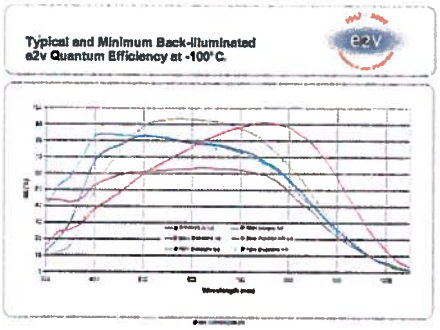
The benefit of using a back-thinned CCD is a quantum efficiency increased by a factor 2.3. This highest sensitivity can be of great help when working with faint signals.



Around 550 nm which corresponds to the peak emission of the phosphor screen, the quantum efficiency of the front-illuminated CCD is about 40%.

The proposed Front-Illuminated chip is the standard type corresponding to the blue curve.
Note that because of the thermal load of the fibre-optic taper, the CCD in our system is operated at around -30°C. The quantum efficiency is at least the same or slightly better.



At 550 nm, the quantum efficiency of the back-thinned CCD is almost 95%.

The proposed Back-Thinned CCD is the midband type corresponding to the green curve.
Note that because of the thermal load of the fibre-optic taper, the CCD in our system is operated at around -30°C. The quantum efficiency is at least the same or slightly better.

6.1.4 SWEEP UNITS

The proposed system comes with 2 sweep units that a located in the camera head. There is also an automated sweep unit selector that allows switching between both units electronically.

Ultrafast sweep unit: This ultrafast sweep unit is suitable for subpicosecond time resolution. It provides two sweep ranges: 250ps (or as fast as possible) and 500ps. Time resolution is around 700 fs and 1.5 ps, for 250ps and 500ps, respectively.

Standard sweep unit: The standard sweep unit triggers on an electrical pulse and provides nanosecond and microsecond time ranges (5ns to 1 µs). Time resolution of the camera will be given by Range/550.

The sweep unit will have 5 sweep ranges*: 5ns, 10ns, 20ns, 50ns.

Therefore, resolution will be: <10ps, <20 ps, <40ps, <100ps

*Sweep ranges will be adjusted to values close form these. The exact time calibration and time resolution for each setting will be given in the test report.

For triggering, they requires 5-10V in 50Ω. Trigger jitter is < 10ps providing that the trigger pulse as a slope ≥ 3V/ns.

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6.2 CONTROL UNIT

The Control Unit is a separate enclosure which can be placed 3 meters away from the camera head. It includes all control electronics for the camera head. It includes a fully featured computer on which the control software is running.

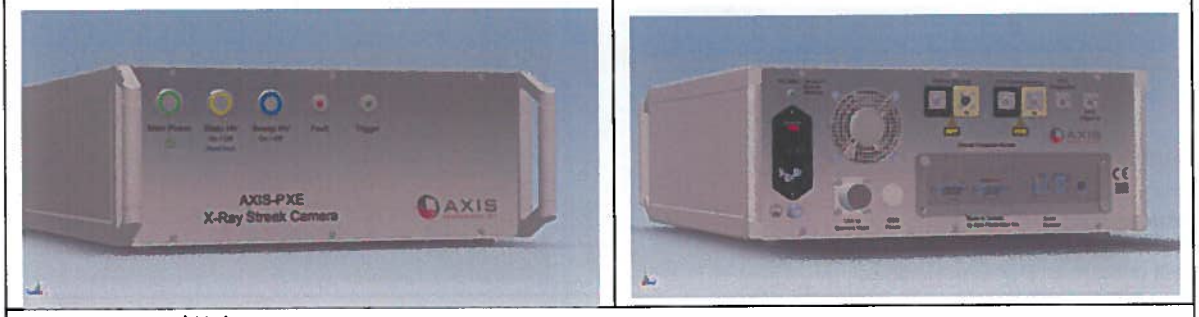


Figure 6: Control Unit.

The internal computer controls the HV supplies, the sweep circuits, monitors voltage stability, performs different self tests and safety checks. It also runs the image acquisition software.

It has the following specifications:

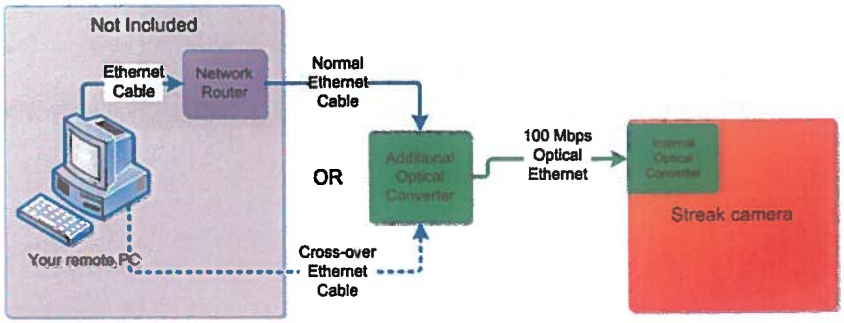
- Single board computer with all standard ports
- RAM suitable for running all required software
- Running Windows 7 (or Win XP upon request)

The user can operate the system:

- Locally: by connecting I/O peripherals (not included); a monitor, a keyboard and a mouse.
- Remotely: via "Remote Desktop" over an Ethernet connection (optical or copper).

6.2.1 Optical Ethernet Communication

To communicate with the streak camera via an optical network (100BASE-FX) an optical converter is installed inside the control unit and the fiber optics connectors are on the back panel.



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6.3 SOFTWARE INTERFACE

Control software running on Windows 7 is pre-installed on the system. This software is be used to:

- Control the streak camera: set time base, exposure time, set trigger, set image size, etc
- Perform image processing and many measurements.
- save image in different formats

6.4 INCLUDED ACCESSORIES

6.4.1 Photocathodes

The system will come with 2 photocathodes:

- A palladium photocathode with a test pattern for testing the camera in the UV range
- A potassium Iodide (KI) photocathode for use with x-rays

6.4.2 Cables between Control Unit and Camera Head

The system will come all the electrical and optical cables necessary to run the camera in **"Mounted configuration"** (as described in Figure 1: Schematics of AXIS system in **"Mounted" configuration.**)

These cables will not be suitable for vacuum. We will provide guidance to the ELI scientists to help them built the necessary cables to install the camera in "Inserted" configuration (see Figure 2: Schematics of AXIS system in **"Inserted" configuration**.on page 41).

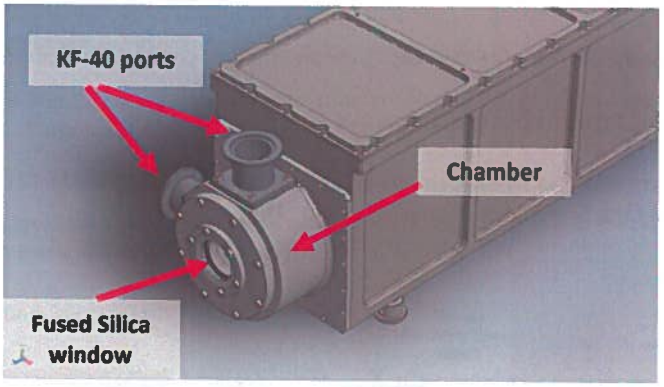
6.4.3 Test and storage chamber

The system will come with a chamber sealing the front end of the streak tube

It will have 2 KF-40 ports usually used for installing a pump and a vacuum gauge.

A fused silica window is located in the front for testing the system with UV light.

This chamber is also used for long term storage.



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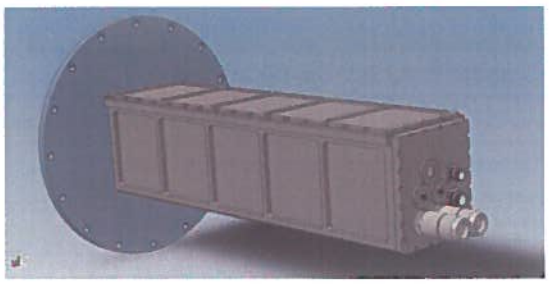
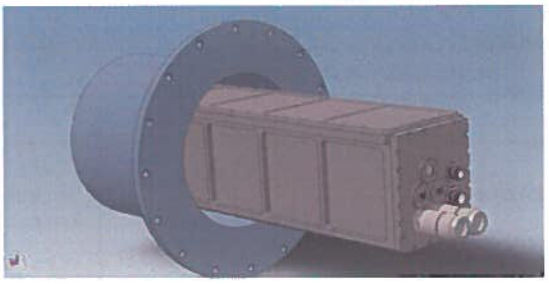
6.5 DESIGNS AND MODELS PROVIDED

6.5.1 Adaptor flanges to mount the XSCS on chamber

We will provide design and models for mounting the camera head to a DN400 ISO F port of your chamber.

	
Camera head mounted on a DN400 flange with the cathode plane flush with the wall of the chamber	Camera head mounted on a DN400 flange with the cathode plane inside the chamber.

6.5.2 Photocathodes

We will provide the model and drawings for the cathode holder so the user can manufacture his own cathodes.

6.5.3 Installation in "inserted " configuration

The cabling provided is meant for use with the camera in "mounted" configuration. The cabling will not be vacuum-compatible.

Therefore installation of the streak camera in **"inserted" configuration** (as described in Figure 2: Schematics of AXIS system in **"Inserted" configuration.**), will require the user to build:

- a feedthrough flange to pass the experiment chamber wall
- a vacuum-compatible set of optical/electrical cables to mate with the camera head

We will supply drawing, specifications and guidance for the user to have them build.

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6.6 OTHER CONSIDERATIONS

The following subjects will be treated as described in the contract and technical specifications detailed in section 9 "Binding Draft Contract and Technical Specifications" starting at page 58 of this document.

- Tests and calibration methods
- Time of delivery
- Shipping terms
- Installation
- Terms of payment
- Technical support
- Warranty

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7. COMPLIANCE MATRIX

In this section, we list the requirements found in "Annex No. 5 Technical Specification" and we compare with of the proposed system. For the sake of clarity, we have sometimes summarized the specifications.

Annex No. 5 Technical Specification		This proposal: AXIS-PXE System	
Section	**Specification**	**Met**	**Comment**
3.1	Each SCS must be delivered along with the following items • The streak cameras system with streak tube, sweep unit(s), hardware for detection and recording, and hardware to control the sub-components of SCS. • Any high voltage supplies that might be required for the operation of the SCS. • The seller shall specify the trigger and delay requirements for the sweep unit, camera, etc. • Operation manual in English for the SCS.	Yes	
3.1	Each SCS must be delivered along with the following items • Power, control, trigger and communication cables required for the operation of the SCS.	Yes	As explained in section "6.4.2 Cables between Control Unit and Camera Head" page 47, the set of cables that will be supplied are not for use in vacuum. They are meant for use in the "Mounted" configuration.
3.1	In addition, the XSCS shall be delivered with the following extra items: • Installed in an air tight box with the necessary connectors and cooling. • The seller shall also provide the design for an adaptor flange to mount the XSCS on a DN400 ISO F port.	Yes	
3.2	Spatial resolution in static mode: The seller must • Perform the test procedure to determine the spatial resolution • provide the experimental results of the test procedure (including raw data and final results). • The MTF at the point B at no bias should be greater than 50% and for the remaining eight instances has to be greater than 45%.	Yes	
3.3	Sweep range calibration: The seller must: • Perform the test procedure to determine the sweep range calibration • provide the experimental results of the test procedure (including raw data and final results). • The SCS must have a percentage slope error of less than 10% for all sweep ranges, and a percentage slope error of less than 2% for sweep range of 10 ns and 20 ns.	Yes	The AXIS-PXE streak camera will be tested and calibrated using a Ti:Sa femtosecond laser system and an optical test bench that creates two collinear pulses at 266nm separated by a calibrated delay.

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3.4	Measurement of time resolution and number of temporally resolved events: The seller must: • calculate the time resolution for each sweep range of the SCS • calculate the number of resloved events • provide the experimental results of the test procedure (including raw data and final results).		Yes	
3.5	Verification methods: The seller shall allow for a representative from the buyer to participate in the experiments to calibrate the SCS. : • The seller has to provide the description (part number, etc.), datasheet and results of any calibration performed by the original manufacturer of each individual component of the SCS. • The results from the calibration processes described in sections 3.2, 3.3 and 3.4 will also be used to verify that the performance of SCS meets the required conditions and hence to decide on the criterion of its acceptance.		Yes	We will supply the calibration/test report of: • the Streak tube (PHOTONIS) • The CCD camera (Spectral Instruments)
3.6	Other instructions: Bidders have to describe the complete SCS system (including specific part numbers of individual components) and parameters achieved for each requirement described in the following sections.		Yes	
6 (table 3)	Energy range of operation	The XSCS has to be optimized for detecting input photons in the energy range of 100-10000 eV. X-ray and EUV photons have to be detected on the photocathode by transmission and not by reflection at grazing incidence.	Yes	
6 (table 3)	Photocathode	The design of the XSCS shall be such that the photocathode is exposed directly to the vacuum of a large experimental chamber for laser plasma research. The seller has to provide one new KI photodiode with the XSCS. The XSCS has to be designed so that the photocathodes are interchangeable. The seller shall provide the mechanical designs for the support of the photocathode, so that the buyer can procure additional photocathodes later. The calibration tests described in sections 3.2, 3.3 and 3.4 shall be performed using a UV photocathode and an UV source. The effective length of the photocathode (l) has to be greater than 12 mm. The final digital imaging system (CCD) of the XSCS has to be capable of measuring this entire effective length.	Yes	Photocathode is exposed to the vacuum of the chamber (see Figure 3: Camera head. Page 42) They are interchangeable. A KI cathode will be supplied. Drawings of cathode support will be supplied. UV photocathode with test patterns will be supplied. Photocathode lenth is 18mm CCD is chosen accordingly to record this length.
6 (table 3)	Spatial resolution in static mode	The spatial resolution (x), has to be greater than 16 lp/mm. The spatial resolution (x) and the effective length of the photocathode (l) shall be such that the number of spatial resolution units (l*x) is greater than 200.	Yes	Spatial resolution is 25 lp/mm Number of spatial resolution units is: 18 m x 25 lp/mm = 450

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6 (table 3)	Sweep ranges	The system has to offer a choice of sweep range(s) which allows it to be operated at the best time resolution. In addition the system shall offer at least the following sweep ranges 5 ns, 10 ns, 20 ns, 50 ns (within limit of ±10%). These can be provided by a single sweep unit or by interchangeable sweep units.	Yes	Description of the sweep ranges is given in section "6.1.4 SWEEP UNITS" on page 45. For best time resolution, the ultrafast sweep unit proposes a range of 250-500 ps. The standard sweep unit provides 5 sweep ranges: 5ns, 10ns, 20ns, 50ns.
6 (table 3)	Time resolution	For the fastest sweep range, the temporal resolution has to be less than 1 ps. For all sweep range settings, the XSCS has to be able to record greater than 300 temporally resolved events for each sweep range.	Yes	With the ultrafast sweep unit, time resolution is better than 0.9 ps at the fastest sweep speed and the number of temporally resolved events is >300. For longer sweep ranges this numbers climbs to 680. See section 8.6 Describe the sweep unit(s): on page 55 for details
6 (table 3)	Trigger parameters	The XSCS is planned to operate with a single trigger and not be synchronized to an external oscillator for integrated measurements. The triggering jitter for the XSCS has to be less than 20 ps rms for single shot measurements.	Yes	Typically, jitter is 10-15 ps RMS.
6 (table 3)	Repetition rate	The entire system (including triggering, hold off and camera readout) has to operate at a repetition rate ≥ 0.1 Hz. Note, that if the digital camera has to be binned to achieve this repetition rate, the XSCS has to still satisfy all the constraints mentioned in this table.	Yes	The streak camera can be operated at 100 Hz in accumulation mode. The CCD can work at 0.5 Hz, without binning.
6 (table 3)	Detection technology	The seller has to provide the detection technology, i.e., a scientific grade camera and coupling optics to the streak tube and phosphor. This has to be done using a tapered (or 1:1) fiber optic bundle from the phosphor at the end of the streak tube directly bonded to a cooled scientific grade camera. Such a camera shall have 16 bit measurement capability per pixel, have a quantum efficiency > 90% at the emission wavelength of the phosphor, have a readout noise level of less than 4 e- per pixel and have a full well capacity of greater than 80000 electrons (non-binned). The magnification of the XSCS and the detection technology must be so designed that a spatial resolution unit at the center of the photocathode is covered by at least 4 pixels by the digital camera. The magnification of the XSCS and the detection technology must be so designed that the time resolution for each sweep range shall be covered by at least 4 pixels by the digital camera...	Yes	For details, see section 8.7 "Describe the readout system" on page 56
6 (table 3)	Detection technology	The seller has to use standard connectors for cooling water for the detection technology. The buyer shall provide the cooling water connection.	Yes	Cooling water connections are located on the airbox and are from Swagelock (see "Figure 4: Back plate of the camera head" on page 43)

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6 (table 3)	Slit	The seller shall provide a fixed slit mounted on the XSCS. The seller has to choose the height of the slit to be the maximum possible so that the XSCS meets the requirement on time resolution. The seller shall also provide the engineering drawings of the slit and its mount, so that the buyer can mount a different slit later if needed.	Yes	On P864X streak tube, the entrance slit is defined by the electron optics and is fixed at around 75 µm to obtain the best performance.
6 (table 3)	Size and vacuum requirements	The XSCS is planned to operate in an air tight box inside a large vacuum chamber. The seller shall provide such a box made of Aluminum, with the XSCS installed in it. The box (excluding the connectors) has to be smaller in size than 20 cm x 20 cm x 80 cm, unless agreed otherwise by both the parties.	Yes	Preliminary design of the airbox (section 6.1 "Camera Head", page 42) fits in the 20x20x80 requirement. Final design will probably be smaller.
6 (table 3)	Size and vacuum requirements	The box should: 1. Have 4 guide pins for positioning. 2. Have a top lid designed for easy access to inside components. 3. be able to mount to standard optical breadboards at any orientation, with the breadboard being either below or above the box. 4. Have an open front for easily replacing photocathode 5. Have tapped holes for mounting an external X-ray spectrometer. 6. The back panel of the box shall have the necessary electronic, optic, power and cooling connectors and feedthrough. 7. The seller shall include the necessary cooling system within the box for reliable operation of the XSCS. 8. The seller shall provide the design of such a box to the buyer for approval before the manufacture of the box. Prior to shipping the XSCS, the seller shall demonstrate that the system is airtight and operational within a sufficiently large vacuum chamber. 9. The seller shall also provide the design for adaptor flange(s) to mount the XSCS (including the box) shall on a DN400 ISO F flange. 10. The XSCS shall be shipped to the buyer in a vacuum tight enclosure covering at least the photocathode. Such an enclosure shall have a pump down port which can be used for long term storage of the XSCS.	Yes	1. Although they are not shown in the preliminary design, 4 guiding pins will be added after consulting with the ELI scientists for their position. 2. Top lid: see section 6.1 "Camera Head", page 42. 3. The airbox will have Thorlabs feet and threaded holes for fixation to a optical table. Exact positions are to be defined. 4. Front of the streak tube is open 5. Tapped holes for the spectrometer will be present. Exact positions are to be defined. 6. Back panel: see Figure 4 : Back plate of the camera head on page 43 7. Cooling: see Figure 5 : Water cooling circuit of airbox on page 43. 8. Approval: There will be a Critical Design Review to which ELI scientists will be invited to participate for approval of the design. 9. 3D model of the DN400 ISO F adaptor flange will be provided. See preliminary design in section 6.5.1 "Adaptor flanges to mount the XSCS on chamber" on page 48. 10. Test and storage chamber: See section 6.4.3 "Test and storage chamber" page 47.

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6 (table 3)	EMP shielding	The seller shall enclose the necessary electronics (streak tube, sweep unit, etc) inside an EMP shielded enclosure. The design of such an enclosure has to be demonstrated to have worked for shielding an X-ray streak camera system from EMP generated during laser plasma experiments where an energy greater than 1 kJ is incident on target.	Yes	Control Unit and camera head are EMP shielded. Inside the airbox, The streak tube is shielded with µmetal and the most succeptible or noisy modules are separately boxed. This design has been successfully tested and is currently in use at AWE, on the 5 kJ Orion laser.
6 (table 3)	Mounting holes	The vacuum interface flange shall have tapped holes for connecting an external spectrometer and/or X-ray foil filters if needed. The seller has to consult with the buyer to finalize the location of these tapped holes.	Yes	Tapped holes for the spectrometer will be present. Exact positions are to be defined.
6 (table 3)	Software, data interface and control	The seller must provide 1. the control software pre-installed on a computer. 2. the buyer with the access and rights to install the analysis and control software on multiple computers for the purpose of research. 3. software that gives user the access to raw data (i.e., without any software based correction for jitter and calibrations). 4. Linux® based operating system (not mandatory) 5. Control software be interfaced to the tango control infrastructure (http://www.tango-controls.org/).(not mandatory) 6. The control software should be able to accept remote scripts (in ASCII, etc.) to configure/control the VSCS and store its data.	Yes	1. The computer is inside the control unit and preloaded with all required software 2. Full acces is granted 3. software gives access to raw data 4. OS is Win 7 5. Software architecture is dedigned such that a Tango interface can be added in the future. 6. Control software will accept remote scripts. The exact protocol is to be defined.

8. ANSWER TO QUESTIONS OF ANNEX NO. 7

8.1 STREAK TUBE TO BE USED

List the model and make of the streak tube to be used.

The streak tube is a PHOTONIS P864X. It is built in Brive (France) according to our specifications. It is the same streak tube that is in use at AWE-Orion in their 5 x-rays streak cameras. See section 6.1.1 "STREAK TUBE:" page 44.

8.2 LENGTH OF THE PHOTOCATHODE

List the effective length of the photocathode which satisfies the definitions given in the Annex 5

The effective length of the cathode is 18 mm.

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8.3 SPATIAL RESOLUTION

List the spatial resolution in lp/mm of the SCS, as per the definition given in Annex 5

The spatial resolution is 25 lp/mm.

8.4 NUMBER OF SPATIAL RESOLUTION UNITS

List the number of spatial resolution units for the SCS

The number of spatial resolution is >450.

8.5 TEMPORAL RESOLUTION

List the best temporal resolution of the system.

We guarantee 900 fs of time resolution (measured at FWHM) but we have often seen 700 fs.

8.6 DESCRIBE THE SWEEP UNIT(S):

Describe the sweep unit(s): mention sweep range and number of temporal resolved events detectable.

There are 2 separate sweep units located in the airbox. Switching between them is made by a module that is controlled by the system. No physical intervention is required.

Sweep Unit	Sweep range (ns)	Time resolution (ps)	Number of Time-Resolved event detectable
Ultrafast	0.25	< 0.9	>300
	0.50	1.3	400
Standard	5	10	500
	10	15	680
	20	30	680
	50	70	680

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8.7 DESCRIBE THE READOUT SYSTEM

Describe the readout system: Kind of camera used, intensifier if any, method of coupling to the streak tube, etc.

The readout system is a Spectral Instruments Series 1000 with a **back-thinned** E2V CCD42-40, Grade 1, 13.5 micron 2048 x 2048 pixel. The front faceplate is made of BPLSE-6 material. The camera is TE cooled to -35°C with a liquid cooled with a backplate made from Naval Brass.

Extract of the manufacture's datasheet:

Specifications *(Subject to Change Without Notice)*

Camera Performance	
Digitization Precision	16 Bits
Number of Readout Ports	1
Readout Speeds	1MHz, 680kHz
Typical Readout Noise @ 1MHz	9.2e⁻
Maximum Readout Noise @ 1MHz	≤ 12.0e⁻
Typical Readout Noise @ 680kHz	7.7e⁻
Maximum Readout Noise @ 680kHz	≤ 10.0e⁻
Operating Temperature	-20°C ± 5°
Typical Dark Current @ -20°C	0.1e⁻/pixel/second
Maximum Dark Current @ -20°C	≤ 0.5e⁻/pixel/second
Cooling Method	TEC with chilled water/glycol
Typical Single Pixel Full Well	100,000e⁻
Minimum 1x1 binned Full Well	≥ 85,000e⁻
Linearity from 0% to 80% of Full Well	2% +150 e⁻
Typical Serial CTE at 5000e⁻ level	0.99998
Minimum Serial CTE at 500e⁻ level	≥ 0.99995
Typical Parallel CTE at 5000e⁻ level	0.99999
Minimum Parallel CTE at 500e⁻ level	≥ 0.99995
Operating Temperature Range	+15°C to +35°C
Operating Humidity Range	< 60% Relative Humidity
Software	Labview based SI Image
Drivers	Windows and Linux available

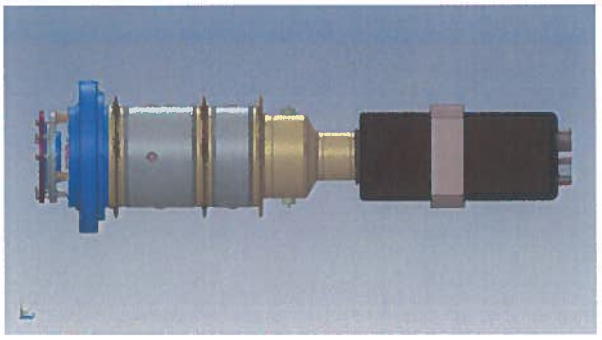
Communication	
Trigger Signal In	ST Fiber Optic or 50 Ohm Terminated SMA*
Shutter Sync Out	TTL SMA*
Data	Fiber Optic Cable to SI PCI board

* Note: SMA connector can be configured as Trigger in or Sync out

Fiber Optic Input	
Input Fiber Characteristics	6-micron Enhanced EMA
Input Fiber Shape	40-mm square corners rounded
Fiber Front Extension	0.1-mm
Typical Resolution	40 lpm

Coupling between the streak tube and the CCD is done by direct contact between two fiber optics tapers. The screen of the streak tube is a 1:1 fiber optics taper on which phosphor is deposited. The CCD chip is also bonded to a 1:1 fiber-optics taper with ~4µm fibers.

This allows preserving the spatial resolution of the tube while minimizing distortion and loss on the image.



The CCD camera is chosen so it can measure the impact of a single photo-electron. It prevents from having to use an image intensifier which will introduce distortion, saturation and loss in spatial resolution. This is why this design does not use any image intensifier.

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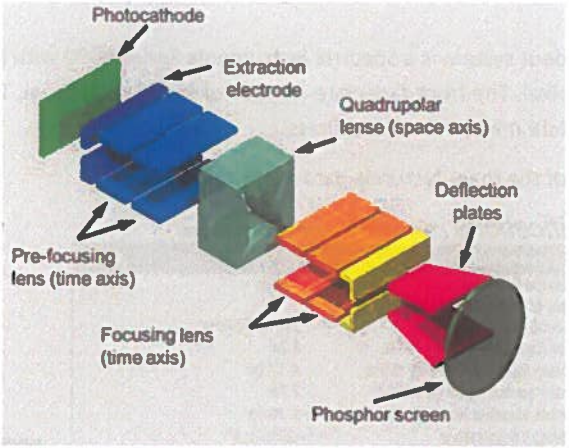
8.8 DESCRIBE THE MAGNIFICATION

Describe the magnification of the streak tube and of the readout system at the end of the streak tube.

Since the P864X streak tube has a bilamellar architecture, time axis and space axis are independent. Thus, there are two magnification factors for the is tube:

Magnification on spatial axis = 1.65

Magnification on time axis = 0.75



As described in the previous section, the CCD is directly coupled to the screen of the streak tube with a 1:1 ratio. Therefore, a 40µm (25 lp/mm) pattern at the photocathode plane will become 66 µm on the CCD and will spread on 4.9 pixels on the spatial axis

Similarly, the slit aperture of ~75 µm (on the time axis) will produce a line width of 56µm which will spread on about 4 pixels.

8.9 DESCRIBE THE DATA AND COMMUNICATION LINK

Describe the data and communication link to the SCS (optical or serial or Ethernet, etc.)

Communication link to the streak camera is done over Ethernet. There are 2 standard RJ45 ports on the back of the control unit and also an optical port (100BASE-FX).

The user can either drive the streak camera

- locally by plugging a monitor, a keyboard and a mouse
- remotely by connecting the control unit on the laboratory network (via Ethernet RJ45 or optical)

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9. BINDING DRAFT CONTRACT AND TECHNICAL SPECIFICATIONS

The following pages contain the Draft Contract (file "Purchase-contract-Streak-Cameras-final") and the technical specifications (file "Streak-cameras-requirement-specifications_final.docx").

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