1 Purpose

This document describes the required technical properties and functional specifications for selection and procurement of a sub-system of the 55.E6 VSRS (Visual Spectroscopy Reference System) diagnostic for ITER. Actual procurement and integration are the responsibility of ITER. The sub-system is foreseen to be integrated as key element into an overall measurement system, therefore these specifications are essential to ensure the overall systems performances and facilitate the integration of the sub-system.

The sub-system described here is the ‘Survey spectrometer’.

This document is written as a self-standing document which implies all essential information is included within this document unless it concerns international standards, published information or commercial information.

2 Scope

This requirement specification document describes all technical performances, verification requirements for the manufacturing and delivery of the ‘Survey spectrometer’ for the ITER VSRS diagnostic system.

The scope of this document includes:

- Functional and technical specifications
- Environmental constraints
- Interfacing specifications
- Factory acceptance Tests
- Site Acceptance Test
- On-site support

2.1 References

2.1.1 Documents applicable to TNO

TNO AD	Document	Reference	Issue
AD-01	System Design Description (DDD)	ITER_D_UJ2J2Z	2.0
AD-02	55.E6 - Description of back-end architecture, alignment and calibration	ITER_D_URM3B9	2.2
AD-03	Sub-System Requirement Document sSRD-55.E6: Visible Spectroscopy Reference System (VSRS)	ITER_D_WYXE79	1.0

2.1.2 Reference Documents

TNO RD	Document	Reference	Issue
RD-01	55.E6 - Design Description of the filter-based polychromator	ITER_D_4THGPC	1.2
RD-02			
RD-03			

2.1.3 Normative documents

TNO ND	Document	Reference	Issue
ND-01			
ND-02			
ND-03			

3 Acronyms and definitions

3.1 Acronyms

The Acronyms and abbreviations used within this document are listed below.

BOL	Begin of Life
CCD	Charge Coupled Device
CDR	Conceptual Design Review
COTS	Commercial Off The Shelf
CXRS	Charge eXchange Recombination Spectroscopy
DDD	Design Description Document
DIP	Dispersion Interferometer and Polarimeter
DNR	Dynamic Range Ratio
DSM	Diagnostic Shield Module
DFW	Diagnostic First Wall
e^-	Electron
EP/EPP	Equatorial Port / Equatorial Port Plug
FAT	Factory Acceptance Test
FB	Fiber Bundle
FWHM	Full Width Half Maximum
FDR	Final Design Review
SUS	High Resolution Spectrometer
IO	ITER Organization
ISS	Interspace Support Structure
LOS	Line Of Sight
NA	Numerical Aperture
PBS	Plant Breakdown Structure
PDR	Preliminary Design Review
RR	Retro Reflector
SAT	Site Acceptance Test
SNR	Signal to Noise Ratio
SUS	Survey Spectrometer
TNO	TNO institute of applied physics
Vm	Verification Method
VSRS	Visual Spectroscopy Reference System

3.2 Requirements definition

Each requirement in this document is defined and presented as follows:

RS-SUS-xxxx	v	Requirement title	Requirement text

xxxx represents the requirement ID-number
v represents the intended verification method(s), see section 3.3

3.3 Verification methods

The intended verification methods (Vm) of each requirement are coded as follows:

I Inspection

R Review of Design
A Analysis
T Test

I	Inspection: Requirement can be demonstrated by a visual inspection of H/W and/or the relevant documentation
R	Review of Design: by presenting the design, implementation of the requirement can and must be demonstrated
A	Analysis: by presenting a documented analytical result the implementation of the requirement can be demonstrated
T	Test: Results of a (set of) test(s) will demonstrate verification of the requirement

4 Introduction

The ITER 55.E6 VSRS diagnostic is an optical diagnostic system with its front-end components located in diagnostic equatorial port plug 8, from where it measures plasma properties along a line to the 55.FA Dispersion Interferometer and Polarimeter (DIP) retroreflector in equatorial port 3. Its main function is to measure the line integrated core Plasma Bremsstrahlung for the derivation of the averaged Zeff. Important secondary roles are measurement of the core charge exchange (CX) and motional Stark effect (MSE) measurements on the diagnostic neutral beam (DNB) and scrape-of-layer (SOL) line emission. The full design and functional description are given in the System Design Description (DDD) [AD-01]. Description of back-end architecture, alignment and calibration" is provided in [AD-02]

In Figure 1 a schematic overview of the VSRS system is given, showing the beam path in-vessel on the left, the in-vessel section in the DSM, the ISS, the fibre bundle and the optical instruments in the diagnostic room.

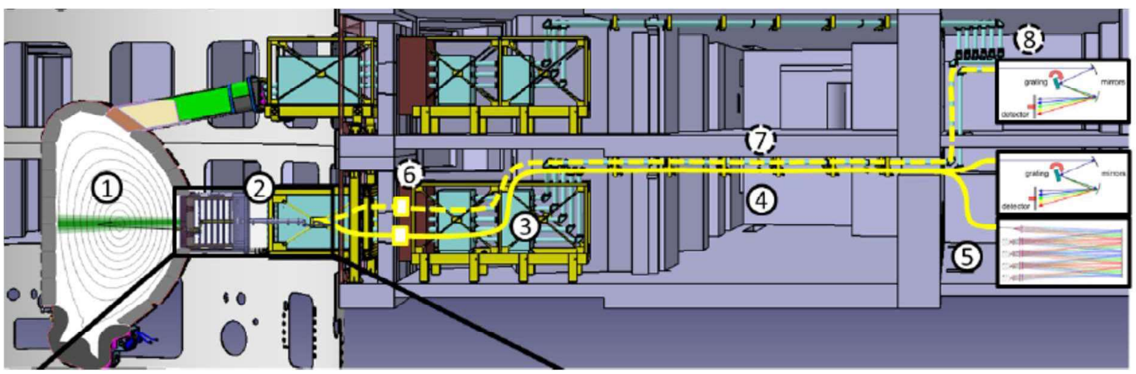

Figure 1 VSRS system level overview showing 1: the tokamak, 2: Interspace, 3: port cell, 4: gallery, 5: diagnostic room, 6: bio-shield wall, 7: cable trays and 8: back-end systems

The VSRS diagnostic system consists of five main parts, each with its own environment and guidelines for material use and integration:

1. In-vessel section containing mirror optics, plasma cleaning, shutter mechanism. Here the local environment comprises high magnetic fields, vacuum, bake-out and strong gamma and neutron irradiation.
2. The Interspace houses the equipment and optics that is required to be just outside the vacuum vessel. For the VSRS this includes relay optics and a first alignment mechanism. Here ambient pressures and temperatures apply, however magnetic field and radiation remain high here. In combination with safety regulations material usage restrictions apply.
3. In the port cell region just after the bio-shield wall the collection optics are placed in combination with a second alignment mechanism, to guide the light into a fiber bundle. Here ambient pressures and temperatures apply, however magnetic field and radiation remain high here. In combination with safety regulations material usage restrictions apply.
4. The optical fiber bundle and electronics cables are routed through the gallery over the cable trays towards the diagnostic room. These cables are considered part of the building and are supplied through ITER.

5. All controlling electronics and instruments are foreseen to be placed in the diagnostic room. This comprises spectrometers, calibration optics, alignment optics and interconnecting optics. At this location laboratory environment applies, and regular maintenance and inspection can be allowed.

The Survey Spectrometer will be located in the **diagnostic room** and integrated into the overall diagnostic system. As such it is operated in a laboratory environment and regular maintenance and inspection can be allowed.

The VSRS measurement duties are divided over four sub-systems, each with their own distinct roles;

- A Filter Based Polychromator (FBP),
- a High-Resolution Spectrometer (HRS),
- a Survey Spectrometer (SUS) and a
- Charge Exchange Spectrometer (CX/MSE)

The VSRS receives its light from the plasma through a set of optical fibers. These fibers are routed to a free-space calibration and alignment system, after which they are distributed to the different instruments. The light received from the plasma has two main components (schematically depicted in Figure 5):

1. The Bremsstrahlung, which has a continuous 1/λ shape
2. Discrete emission lines

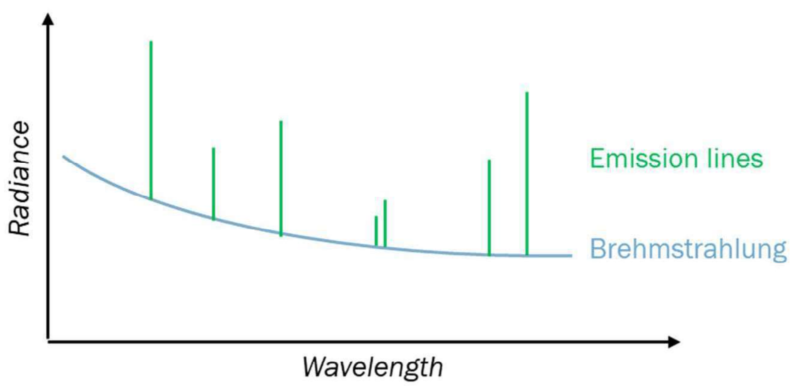

Figure 2: Schematic representation of the shape of the spectrum

The Polychromator is the main instrument to measure the magnitude and shape of the Bremsstrahlung spectrum. It does so using a fixed set of narrow band filters in the wavelength range between 400 and 700 nm. In order to verify whether or not the measurement bands are line emission free a verification is required.

This verification is the main task of the Survey Spectrometer. A second (back-up) task of the Survey Spectrometer is to verify that the continuum spectral shape is compliant with the 1/λ expected for Bremsstrahlung. This allows for redundancy (in case e.g. there is unexpected line emission in the band pass of one of the filters) in the fast filter-based measurement.
In addition the survey spectrometer is used to monitor emission of a white light source over two different optical paths during the transmission monitoring calibration.

Key instrument parameters to enable these tasks are a high spectral resolution, access to the full spectral band and large dynamic range.

4.1 *Other relevant background information*

4.1.1 Number of sources and fiber inputs

The survey spectrometer will need to measure at least 3 different “sources” simultaneously; the center and the periphery of the line-of-sight through the plasma and a reference light source. Whether or not this functionality is performed by a single instrument or by multiple instruments is left to the supplier. Since the expected photon fluxes can be very low. It is foreseen that the survey spectrometer is fed with up to 6 individual optical fibers (113µm core, 125 µm outer diameter, NA 0.22) from each source.

4.1.2 Expected photon flux

The minimum and maximum expected Bremsstrahlung photon flux *from a single fiber* at the spectrometer input is presented in Table 1. Note that the shape of the spectral distribution of the Bremsstrahlung is the same in both cases, the only difference is a factor 36.6 between the minimum and maximum.

The photon flux values depend on the plasma settings of the experiment. Changes will not occur simultaneously or unexpectedly. Therefore, it is allowed to “tune” the spectrometer a priori to one of these two cases or any case in between that has the same spectral distribution. Tuning should be possible remotely, e.g. by changing detector settlings like integration time, gain etc.

Table 1 Minimum and maximum Bremsstrahlung photon flux from a single fiber at the Survey spectrometer input

Wavelength [nm]	Minimum Bremsstrahlung photon flux from a single input fiber [photons/s/nm]	Maximum Bremsstrahlung photon flux from a single input fiber [photons/s/nm]
400	1.7E+06	6.3E+07
450	2.2E+06	8.2E+07
500	2.3E+06	8.4E+07
550	2.2E+06	7.9E+07
600	1.9E+06	6.8E+07
650	1.6E+06	5.8E+07
700	1.2E+06	4.2E+07

For accurate determination of the Bremsstrahlung shape, it is important that its spectrum is measured with sufficient SNR.

On top of the Bremsstrahlung there will be spectral peaks with width varying from 0.1 to several nm’s. The wavelength and magnitude of which will vary with the different operational modes of the reactor. The largest of these peaks is expected to be a factor of 43 higher than the Bremsstrahlung around it. Ideally the dynamic range of the detector should be sufficient to allow unsaturated measurement of this peak, but this will put an unrealistic high requirement on the dynamic range of the detector, since the (continuous) Bremsstrahlung also needs to be measured with sufficient SNR. The subsequent peaks are all an order of magnitude lower, therefore these peaks are used as the basis for the dynamic range requirement and some local saturation from the highest peak is allowed.

The total photon flux is assumed to be uniformly distributed over the fiber core cross-section area.
When a slit is used in front of the fiber that is smaller than the fiber core diameter, the flux will be reduced accordingly. Assuming that the slit with height *h* is placed right in front of the fiber tip, this reduction factor is given by:

$$R(h) == 1 - 2 * \frac{D^2 \cos^{-1}\left(\frac{h}{D}\right) - h\sqrt{D^2 - h^2}}{\pi D^2}$$

The results are plotted in Figure 3 and listed in Table 2 for a number of commonly used slit heights.

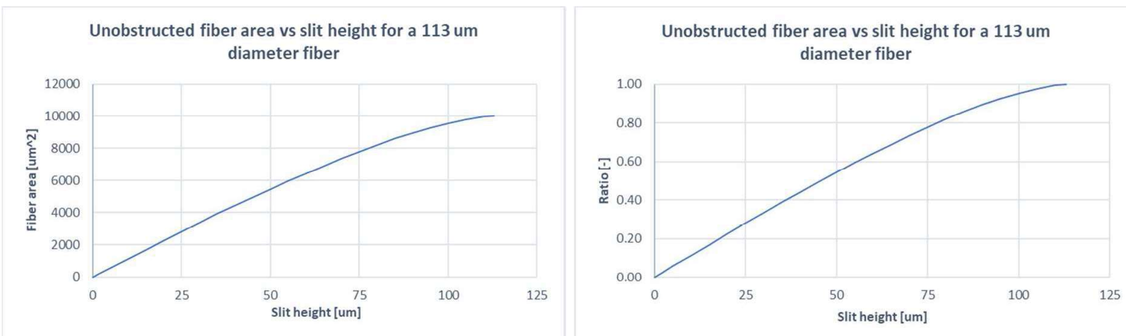

Figure 3 Unobstructed fiber area (left) and ratio (right) versus slit height

Table 2 Unobstructed surface ratio of a 113 µm core fiber as a function of the most common slit heights

Slit height [µm]	**Unobstructed surface ratio of a 113 µm diameter fiber**
10	0.113
25	0.279
50	0.544
100	0.954

4.1.3 Signal to noise and dynamic range definitions

4.1.3.1 Noise

Noise is a general term for all unwanted signal in a spectrum. It can appear as a high-frequency, fuzzy series of lines that follows the contours of the desired spectral shape, a blurring of spectral peaks, or a low-frequency modulation of the spectrum. It is a combination of a number of different, often unrelated sources:

1. Photon noise – caused by statistical variation in the number of photons hitting the detector in a given time (shot noise) that increases with incident light intensity. Frequently, the term “shot noise” is used in place of photon noise.

2. Dark, or thermal, noise – caused by electrons that are thermally promoted in the detector rather than by incident light (increases with temperature, reduced by TEC)
3. Readout noise – noise resulting from reading a pixel's accumulated charge; this noise is introduced into the detector as a result of the read process itself and originates primarily from the detector's pre-amplifier
4. Electronic noise – errors made in the A/D converter and electronic circuitry that is misinterpreted by the spectrometer as a light signal

5. Aberration – blurring/fringing caused by different focusing powers of the optical components at different wavelengths
6. Stray light – light being scattered/reflected/refracted onto the wrong parts of the detector; this is an example of systematic noise
7. Imperfections/defects in hardware – dead pixels or scratches in lenses may add/remove features in the final spectrum.

Contribution 1 (the photon or shot noise) is influenced by the number of incoming photons at the spectrometer slit (which is outside the control of the spectrometer supplier), the spectrometer transmission and the QE of the detector (which are both within the control of the supplier). If the transmission of the spectrometer or the detector QE are low the photon noise will decrease, but its relative magnitude w.r.t. the total signal is increased. Therefore, it is vital that the spectrometer transmission and detector QE are taken into account in the total noise calculations.

Contributions 2-4 are detector properties, which will be referred to as *baseline noise;* i.e. the summation of *readout noise, dark noise (at a certain integration time), and electronic noise*.

4.1.3.2 Signal to noise ratio (SNR)

SNR is defined as the signal intensity divided by the noise intensity at a particular signal level – it therefore may change measurement to measurement. Since the noise typically increases as a function of signal due to photon noise, the SNR function is actually a plot of individual SNR values versus the signal at which they were obtained.

The SNR can be improved by using different types of signal averaging.

- For time-based averaging, the SNR will increase by the square root of the number of spectral scans used.
- For spatially based averaging (boxcar), the SNR will increase by the square root of the number of pixels averaged together.
- Finally, the SNR can be increased by averaging multiple fiber inputs.

In the Survey Spectrometer requirement spec we will explicitly state with the SNR requirement that spatial and temporal averaging of pixels are not allowed, unless the spatial averaging is done in the spatial direction, over the image of 113 um fiber on the detector. Averaging over multiple fiber inputs (up to 6) is allowed.

In order to make a fair comparison between spectrometer candidates, the supplier will be asked to put forward a calculation of the SNR versus wavelength as follows:

1. Given a certain input flux from the Table 1:

$$\Phi_{fiber}(\lambda) \qquad [ph\, s-1\, nm-1]$$

2. Scale the input flux with the unobstructed ratio, which is a function of the slit height h (see Table 2)

$$\Phi_{scaled}(\lambda) = \Phi_{fiber}(\lambda) * R_{unobstruct}(h) \qquad [ph\, s-1\, nm-1]$$

3. Given the spectrometer transmission T(λ) and the spectrometer dispersion D(λ), calculate the photon flux per detector pixel: FP(λ)

$$\Phi_{pixel}(\lambda) = \Phi_{fscaled}(\lambda) * T(\lambda) * D(\lambda) \qquad [ph\, s-1]$$

4. Given the detector quantum efficiency QE(λ)in electrons/photon, calculate the total electron flux per pixel:

$$\Phi_{pixel\_electrons}(\lambda) = \Phi_{pixel}(\lambda) * QE(\lambda) \qquad [electrons\, s-1]$$

5. Given a certain dark current per pixel I_dark and a chosen integration time t (see requirement), calculate the total signal in electrons per pixel:

$$S_{pixel\_electrons}(\lambda) = (\Phi_{pixel\_electrons}(\lambda) * I_{dark}) * t \qquad [electrons\,]$$

6. Given a certain baseline noise σ_b, calculate the total noise σ_total as:

$$\sigma_{total} = \sqrt{{\sigma_b}^2 + S_{pixel\_electrons}(\lambda)^2} \qquad [electrons\,]$$

7. The (unit-less) signal-to-noise ratio of single pixel at a certain wavelength is then defined as

$$SNR_{pixel}(\lambda) = \frac{S_{pixel\_electrons}(\lambda)}{\sigma_{total}} = \frac{S_{pixel\_electrons}(\lambda)}{\sqrt{{\sigma_b}^2 + S_{pixel\_electrons}(\lambda)^2}} \qquad [-]$$

8. Given an amount of N binned pixels and M fibers, the total signal-to-noise is defined as:

$$SNR_{total}(\lambda) = SNR_{pixel}(\lambda) * \sqrt{N * M} \qquad [-]$$

The above calculation shall be performed for:
- All input Bremsstrahlung fluxes mentioned in Table 1 (i.e. minimum and maximum)
- The integration time required to meet a frame-rate of 100 fps.
- The integration time required to meet a frame-rate of 10 fps.

In case the supplier cannot meet the SNR requirement given the boundary conditions (input spectrum, frame rate), compliant alternatives need to be mentioned like for example
- Using longer integration times
- Using larger slit heights
- Use of custom detectors or detector cooling
- Other

4.1.3.3 Dynamic range

Most spectrometer specifications list the dynamic range as the ratio between an almost saturated signal divided by the sum of the baseline noise and the dark current noise at the shortest possible integration time. For the anticipated use of the Survey Spectrometer this definition is not useful.

Instead, we will ask for a dynamic range that is sufficient to allow unsaturated measurements of the spectral peaks up to a certain relative height above the Bremsstrahlung, *with the detector settings that allow the Bremsstrahlung to be measured with sufficient SNR*.

4.1.3.4 Slit height, dispersion and pixel size

As mentioned above a lower slit height will reduce the number of photons that will access the spectrometer. For a spectral line with a FWHM that is significantly smaller than the spectral resolution, the net effect is that a smaller slit will result in less illuminated pixels in spectral direction (and hence a higher spectral resolution). The signal per pixel will not decrease. For a continuous spectrum however, a smaller slit will reduce the width of the slit image and the signal per pixel, as the contribution from “neighboring” wavelengths is cut-off.

Hence:

- For a good SNR of the (quasi-continuous) Bremsstrahlung it is advantageous if the slit is wide
- For a good spectral resolution in order to distinguish the spectral peaks it is advantageous if the slit is narrow.

However, the goal of the Survey Spectrometer is not to identify individual peaks with a high resolution, but rather identify wavelength regions that are not affected by the presence of peaks. Therefore, we will limit the spectral resolution requirement to 1 nm (goal), 2 nm (threshold).

For the best SNR performance, it is more advantageous to use a single large pixel than multiple (binned) smaller ones as the contribution from readout noise and electronic noise is decreased. But obviously the dispersion should be such that there is always a fully illuminated pixel in the center of the slit image. Hence the maximum pixel size is in the order of 1/2 of the FWHM of the slit image. Put in other words: we will require a spectral oversampling factor of at least 2.

4.1.3.5 Stray light and ghosts

Ghosts and reflections from (high) spectral peaks to other wavelengths will cause false-positive peak identifications and hence should be prevented.

The other way around: integrated stray light from all wavelengths outside a spectral sample to that spectral sample will provide an unknown offset to the signal and hence degrade the fitting accuracy of the Bremsstrahlung.

Therefore, two distinct requirements will be used: one for ghosts/reflections and one for straylight.

4.1.4 Power supply

The survey spectrometer will be placed on an optical table. For safety reasons it is not allowed to run a 230V power line directly to the optical table. The only way to power the spectrometer is therefore:

1. Via Ethernet (this is preferred)
2. Via a low voltage (≤24 DC) cable that is run from a cubicle (shielded 19-inch rack) nearby

In both case the cable length should be ≥10m.

In case the supplier opts for option 2, it is for example possible to place a 230V AC adapter in the cubicle and then run a 10 m low power line to the spectrometer.

5 Delivery and milestones

Procurement of hardware will be arranged under the responsibility of ITER but is anticipated to comprise of hardware, documentation and software.

5.1 Hardware delivery

The following hardware shall be delivered:

- 1 or more (if required to fulfill the requirements) survey spectrometer(s)
- 1 set of replacement slits, one size larger than the offered slit(s)
- A container (for transport & long-term storage)
- Data and power cables
- Spare parts (details shall be provided by supplier as part of the spare part policy)

5.2 Software delivery

The following software shall be delivered:

- The system shall be delivered with all the installation software required to re-install the read out and control of the spectrometer. Remarks:
    - This includes all the programs that can be installed on an external control PC.
    - The installation process shall be documented in a manual that is part of the data pack to be delivered.
- Software for spectral calibration on gas line source (if required to meet the specifications)
- Control API or SDK that allows for spectrometer control to be integrated in other software (Unix).

5.3 Workflow and document deliverables

The manufacturing activities described shall at least consist of:

- Manufacturing of the hardware as specified in the requirements below
- Verification of the hardware according to the verification control document

The workflow and (sub) deliverables of each project phase are described in Table 3. As the targeted device is sold as COTS device, separate project milestones are not foreseen.

Table 3 Milestones and document delivery

Step	Document deliverables
Design & manufacturing	Design data package, containing at least: - Description in detail of test setup(s) - Verification control document - Interface control document (containing interface drawings) - FAT plan - User Manual - Control API description - A list of materials
Factory Acceptance Test	Delivery data package, containing at least:

Step	Document deliverables
	- As-built compliance matrix against this procurement specification - Certificates of conformance - Non-conformance reports (NCR's, if applicable) - Acceptance test reports - Photographs of hardware
Shipment	Shipping documents
Site Acceptance test	Following successful incoming inspection at Chromodynamics (location: Eindhoven, The Netherlands) Photographs Acceptance test report
On-site integration support	Up-to date User Manual No document foreseen

6 Detailed specifications

In the sections below the technical requirements of the system are detailed. However, the supplier is invited to propose in first instance their most compliant, existing spectrometer type and indicate any non-compliances this system would have.

6.1 Functional and technical specifications

ID	Vm	Requirement title	Requirement text
RS-SUS-001	T	Spectral range	The spectral range of the spectrometer shall cover uninterruptedly: 400nm to 700nm (threshold) 350nm to 820nm (goal)
RS-SUS-002	T	Spectral resolution	The FWHM spectral resolution shall be ≤ 2 nm (threshold) ≤ 1 nm (goal)
RS-SUS-003	T	Frame rate	The frame rate of individual spectrum measurements shall be ≥ 10 fps (threshold) ≥ 100 fps (goal)
RS-SUS-004	T	Number of channels	The spectrometer shall have at least 3 separate measurement channels in order to measure 3 different sources simultaneously. *Note: a measurement channel is defined as the measurement of the spectrum of a single source, via one or more fibers.*
RS-SUS-005	R,I	Number of fiber inputs per channel	The spectrometer shall have at least 6 fiber inputs per measurement channel. (This can be through a fan-out-fiber-bundle)
RS-SUS-006	T	Spectral oversampling	The dispersion should be such that the spectral oversampling is at least 2, i.e. the total pixel size in spectral direction of one or more binned pixels is less than 0.5*FWHM of the slit image.
RS-SUS-007	T	Signal-to-noise	The SNR per (binned) pixel shall be $SNR \geq \frac{1}{0.007 * \sqrt{D}}$ Where D is the dispersion in nm/pixel, *Note:* - *Spatial averaging over the image of 113 um fiber on the detector in the direction parallel to the slit is allowed* - *Spatial averaging in the across slit (i.e. spectral direction is allowed as long as the spectral oversampling requirement is met* - *Temporal oversampling is only allowed as long as the frame-rate requirement is met*

ID	Vm	Requirement title	Requirement text
			- *Averaging over multiple fiber inputs is allowed up to a maximum of 6 fibers.*
RS-SUS-008	A	SNR calculation	The SNR shall be calculated according to the procedure in section 4.1.3.2. As a minimum the outcome of the calculations need to be shared, but insight in the calculation inputs is considered a pre.
RS-SUS-009	T	Dynamic range	Given the detector settings required to meet the SNR requirement on the measurement of the Bremsstrahlung, the dynamic range of the spectrometer shall be sufficient to allow an unsaturated measurement of individual spectral peaks that are a factor of 3 (threshold) or 10 (goal) higher than the Bremsstrahlung.
RS-SUS-010	T	Stray light	Given a continuous (i.e. white light) input between 400 and 700 nm, the total stray light contribution from all wavelengths to a single wavelength sample shall not exceed 0.5%.
RS-SUS-011	T	Ghosts	Ghosts, reflections etc from a single wavelength input at wavelength λ to any other wavelength sample outside the range λ±3nm shall be smaller than 0.01% (goal), 0.05% (threshold) of the input signal
RS-SUS-012	R	Volume	The instrument volume shall be less than: 250mm x 250mm x 100mm
RS-SUS-013	R	Mass	≤5kg
RS-SUS-014	R	Power consumption	≤10W
RS-SUS-015	T	Stabilization time	The time required between start-up of the instrument and performing stable measurements shall be less than 10minutes

6.2 Environmental constraints

ID	Vm	Requirement title	Requirement text
RS-SUS-030	R	Operating environment	The spectrometer will be operated in a laboratory environment under ambient conditions and shall work within its specifications for the environmental conditions detailed below
RS-SUS-031	R	Operational temperature range	Any temperature in the range of 15-25°C
RS-SUS-032	R	Temperature stability	Temperature stability of: • ±0.1DegC hourly variation • ±1DegC variation over the year
RS-SUS-033	R	Pressure	Between 970mbar and 1040mbar
RS-SUS-034	R	Relative Humidity	RH 50%-70%

6.3 Interfacing specifications

ID	Vm	Requirement title	Requirement text
RS-SUS-040	R	Optical input	The optical fibers used to supply the measurement light have the following properties: • Material Fused Silica • NA 0.22 • 113µm core and 125 µm cladding diameter
RS-SUS-041	R	Fiber connector	SMA 905 with one or more fibers in a linear array
RS-SUS-042	R	Bolting or clamping provision	The instrument shall have provisions for mechanical mounting on an optical table by bolting of clamping
RS-SUS-044	T	Communication connection	Goal: RS-232, RS-485, RS-422, RJ-45 or Ethernet Threshold: USB 2.0 (not preferred)
RS-SUS-045	T	Communication protocol	Goal: GigE Vision
RS-SUS-046	T	Device software	Device software support should include native Linux kernel driver/module, user space API libraries and/or native protocol specification (serial USB etc.) along with the device operation manual (state cycles etc.). If no native Linux support is available, the vendor should allow and provide support for developing ITER Linux Driver
RS-SUS-047	T	Power supply	Goal: Power over Ethernet Threshold: power supply ≤24V with a lead of at least 10m.
RS-SUS-048	R	External synchronization	The instrument shall have an option to apply external synchronization / triggering
RS-SUS-049	R	Connector location	Optical and electrical connectors shall be located on the sides of the instrument (100mm x250mm sides) so that effective height for integration is 100mm
RS-SUS-050	R	Camera control parameters	It shall be possible to remotely control (read and set) at least the following instrument parameters • integration time, • frame rate • gain Control over more instrument parameters is preferred.

6.4 Transport, packaging and storage

ID	Vm	Requirement title	Requirement text
RS-SUS-060	R	Storage container	The spectrometer shall be packed in a box or shipping container that provides adequate protection during handling, shipment and storage. Each packaging and shipping container shall be marked on the outside showing all relevant information (e.g. company, contents, destination). Also, the warnings "DELICATE OPTICAL COMPONENTS REQUIRING SPECIAL HANDLING" and "TOP" or "OPEN THIS SIDE" shall be clearly marked on the shipping container or box. The supplier is invited to propose container/packaging applicable.

6.5 Factory acceptance Tests

ID	Vm	Requirement title	Requirement text
RS-SUS-070	R	Factory acceptance tests	Factory acceptance tests shall provide evidence of the compliance with respect to the requirements that are verified by test. This comprises as a minimum all requirements marked with verification method (Vm) T This includes but not limited to: • Spectral range • Spectral resolution • Signal-to-noise • Dynamic range
RS-SUS-071	R	Test reports delivery	Test reports shall be delivered prior to shipment of the spectrometer

6.6 Site Acceptance Test

ID	Vm	Requirement title	Requirement text
RS-SUS-080	R	Site acceptance tests	Site acceptance tests provide evidence of the instrument integrity and functionality after transport. This comprises as a minimum: • Photograph of packaged and unpacked device • Power on/off • Recording of example spectrum The supplier is invited to propose alternative or additional tests

RS-SUS-081	R	Site Acceptance Test reports delivery	Site acceptance test will be reported by e-mail, stating compliance to the site acceptance tests.

6.7 On-site support

ID	VM	Requirement title	Requirement text
RS-SUS-090	R	On-site support	On-site support targets the functional demonstration of the instrument. This comprises as a minimum demonstration of: • Instrument connections • Power on/off cycle • Operation and use of instrument in software package • Recording of example spectrum • Calibration procedure • Slit replacement (if applicable) The supplier is invited to propose alternative or additional tests. Site acceptance testing can be combined with on-site instruction
RS-SUS-091	R	On-site support test reports delivery	On-site support will be reported by e-mail, stating compliance to the demonstration tests