Annex I: Definitions

Primary Source	Laser system that will drive the SHHG PW. It will be the Peta Watt (PW) laser system
SHHG PW	Surface High-order Harmonic Generation Secondary Source
End station	Multipurpose end station for performing pump-probe experiments in gas, liquid, solid targets. The design of the end station is not part of this Request for Proposal.
Auxiliary pulses	Pulses that will be used in combination with the attosecond XUV pulses for performing pump-probe experiments. They could consist in: 1) Replica of the generated attosecond XUV pulses 2) Reasonable fraction of the intense driving pulses delivered by the corresponding primary source 3) Low-order harmonics (2^{nd},3^{rd},4^{th},5^{th}) of the radiation of the primary source generated either on solid surfaces , crystals or gases.
SHHG PW generation region	Region where the primary source will interact with the solid target to generate attosecond XUV pulses and, auxiliary pulses. This region is part of the SHHG PW.
SHHG PW interaction region	Region where the attosecond XUV pulses and the auxiliary pulses will be focused and spatially and temporally overlapped for performing pump-probe and interferometry experiments. This region is part of the SHHG PW.
End station interaction region	Region where the attosecond XUV pulses and the auxiliary pulses will be focused and spatially and temporally overlapped for performing pump-probe and other experiments. This region is not part of the SHHG PW. It will be part of the end station(s), which will be used in combination with the SHHG PW.

ANNEX II: Characteristics of the Primary Source PW

The SHHG PW will be driven by the primary source PW. The fundamental characteristics of the primary source for the two operation modes PW and PW PM are described hereafter in Table 1. These parameters shall be used for the design of the SHHG PW. *Additional details on the Primary Source will be discussed with the winner.*

Primary source	**Rep. Rate**	**Pulse Energy /Peak Power**	**Pulse Duration**	**Diameter after compressor (FWHM)/Clear apperture for laser beam**	**Energy stability**	**Output beam quality (Strehl ratio)**	**Temporal contrast at -5 ps / -20 ps / -1 ns(ASE)**
PW*	10 Hz	34 J / 2 PW	17 fs	24 cm / 30 cm	1.5 %	0.9	$\leq 10^7$ / $\leq 10^9$ / $\leq 10^{11}$
PW PM#	10 Hz	<20 J / 1.2 PW	17 fs	24 cm / 30 cm	1.5 %	0.9	$\leq 10^{11} \leq 10^{12}$ / $\leq 10^{14}$

Table 1

*PW corresponds to laser parameters without implementation of a double plasma mirror set up for pulse temporal cleaning.

#PW PM enlists beam parameters assuming a double plasma mirror set up adding a temporal contrast of ~10^4 and transmission of 60% of the pulse energy for experiments. The double plasma mirror set up which leads to this operation mode is not part of the SHHG PW and would be designed and provided by ELI-ALPS and would be located outside the laboratory space provided for the SHHG PW.

ANNEX III: Characteristics of the SHHG Secondary Source

Table 1: Specification of the necessary vacuum levels and temporal synchronization

The proponent should define the vacuum conditions of the different units composing the SHHG PW and the attosecond synchronization of the planned interferometric pump-probe setup.

Vacuum conditions (divided in different units) (mbar) (maximum values)	
Attosecond synchronization between pump and probe pulses (as) (maximum value)	

Table 1

Table 2: Continuous operation specifications

The proponent should define maximum continuous operation time (which would be different for different on target laser damage size) and replacement time (which might be dependent on vacuum constraints and/or radiation issues) of the solid target for the two operation modes of the Primary Source.

	PW	**PW PM**
Minimum and maximum continuous operation time without changing the target		
Typical break time between two continuous operations due to target replacement (range)		

Table 2

Table 3: Specifications of the generated attosecond pulses

The proponent should define the characteristics of the attosecond pulses for the two operation modes of the corresponding Primary Source. They should also clearly indicate the experimental technique/diagnostic used for their characterization.

	PW	**PW PM**
	Trains of attosecond pulses	Trains of attosecond pulses
Spectral range (eV) *(minimum two energy intervals)*		
Output energy on the SHHG PW interaction region(s) (nJ) *(minimum value or range over two energy intervals)*		
Output energy on the endstation interaction region(s) (nJ) *(minimum value or range over twoenergy intervals)*		
Focal spot size (microns)		

(maximum value or range over two energy intervals)		
Pulse divergence (mrad) *(range over two energy intervals)*		
Polarization state and direction of the polarization axes		

Table 3

Table 4: Specifications of the auxiliary pulses

The proponent should define the performances of the auxiliary pulses for the two operation modes of the PW primary source, indicating the experimental technique/diagnostic used for their characterization. In case of different types of auxiliary pulses, for each type the proponent should provide a separate table including the corresponding specifications.

	PW	**PW PM**
Photon energy (eV) *defined for all type of auxiliary pulses*		
Output energy on the SHHG PW interaction region(s) (nJ) *defined for all type of auxiliary pulses (minimum value or range)*		
Output energy on the endstation interaction region(s) (nJ) *defined for all type of auxiliary pulses (minimum value or range)*		
Pulse divergence (mrad) *defined for all type of auxiliary pulses (range)*		
Polarization state and direction of the polarization axes *defined for all type of auxiliary pulses*		

Table 4

ANNEX IV: Pulses temporal specifications

The proponent should estimate and define the targeted temporal duration of the attosecond pulses and the auxiliary pulses (train and isolated attosecond pulses) for the two operation modes of the primary source. They should also clearly indicate the experimental technique/diagnostic used for their characterization. In case of different types of auxiliary pulses, for each type the proponent should provide a separate table including the corresponding temporal specifications. *The pulse durations will not be part of the deliverables of the R&D project*.

	PW		**PW PM**	
	Trains of attosecond pulses	Isolated attosecond pulses	Trains of attosecond pulses	Isolated attosecond pulses
SHHG PW Pulse duration (as) *(range)*				
Auxiliary Pulse duration (when these are as pulses) *(range)*				

Table 5

ANNEX V: Information available to the Bidders

The following information relevant to SHHG PW would be provided upon written request by interested parties at different phases of this Request of Proposal.

1. A more detailed description of the SHHG PW, as an extract from the Conceptual Design Report of ELI-ALPS.
2. Relevant building details for operational specifications for SHHG PW, including ambient conditions (cleanliness, temperature, humidity, base vibration level etc).
3. Available building space for SHHG PW, and the plan of the corresponding part of the building.

ANNEX VI: Detailed description of SHHG PW

The eleven fundamental activities that SHHG PW shall accomplish are described in more detail below:

1) Generation of vacuum conditions

A system of vacuum units should be designed in order to ensure generation, transport and application of attosecond pulses in the XUV spectral region. The vacuum system should include suitable hardware, input and output windows and the associated security features and remote control.
The vacuum conditions should be defined for the different units composing the SHHG PW according to Table 1 Annex III

A separate vacuum chamber in the front end of the SHHG PW at proper place is to be included in the SHHG PW design by the developer. This chamber space would be used for PW beam manipulation/measurements and diagnostics near the SHHG PW generation region and also as a space for additional plasma mirror(s) (if further optimization of temporal contrast would be needed in order to increase the efficiency of the harmonic generation process). ELI-ALPS would already provide a double plasma mirror set up in PW PM operation mode during the SHHG PW implementation. The requirement for additional temporal cleaning device would be decided at a later stage in the lifetime of the SHHG PW by ELI-ALPS and would be provided by ELI-ALPS.

2) Efficient and controlled generation of trains of attosecond pulses

Trains of attosecond pulses in the XUV spectral range should be efficiently generated in the controlled interaction of an optically flat solid target with the driving pulses. This implies that the SHHG PW must incorporate several additional components:
(a) Focusing conditions should be chosen in order to maximize the photon flux, while preserving sub-femtosecond pulse duration and acceptable beam divergence of the attosecond pulses. Tight/Optimal focusing conditions should be considered along with active adaptive optics wave front correction of the pulses delivered by the primary source for increasing the XUV photon flux and spectral range.
(b) Target motion should be actively stabilized to constrain it in focal plane of the driving pulses to optimize SHHG beam energy and to minimize pointing fluctuations.
(c) Provision for plasma gradient control and metrology in the SHHG PW generation region should be included for optimizing emission efficiency.

(d) Provision to spatially and temporally probe and characterize the plasma dynamics with an additional time delayed 2nd harmonic probe should be included in the SHHG PW generation region.
(e) Solid target size target motion and focal spot parameters are to be optimized in the design in order to increase maximum continuous operation time. The above components (a to e) including the wave front diagnostics and the corresponding adaptive optics for focal spot corrections will be designed by the developer and are part of the design and implementation of the SHHG PW.

3) Plasma diagnostics access ports
The proposer should design the generation chamber providing access to different plasma parameters using diagnostics tools that will be provided by ELI-ALPS. Further details will be discussed with ELI-ALPS personnel during the design of the generation chamber.
An additional number of ports and flanges should be included in the design of the generation chamber for plasma diagnostics. The final position and number of ports will be discussed with ELI-ALPS personnel after the delivery of the preliminary design of the generation chamber.

4) Investigation for Isolated attosecond pulses
Since SHHG PW is a development SHHG PW with unique primary laser parameters experimental investigation of different possible techniques focused on the generation of isolated attosecond pulses should be undertaken. Different techniques (such as polarization gating and attosecond lighthouse effect) should be considered and implemented for R&D on the generation of isolated attosecond pulses in this development SHHG PW.

5) Spectral separation of the generated attosecond pulses from the radiation of the Primary Source
Suitable optics and/or devices should be used in order to separate the attosecond pulses from the co-propagating driving pulses. Suitable devices and instruments should be considered for the temporal recompression and for the control (attenuation) and fine-tuning of the pulse energy of the attosecond pulses. Suitable strategies for the absorption of the rejected radiation of the Primary Source should be implemented.

6) Conditioning and focusing of the generated attosecond pulses
The XUV radiation generated on the solid targets should be conditioned using appropriate steering optics and directed from the generation region to the SHHG PW interaction region with the option of switching it to the end station interaction region(s) (as defined in Annex I). The optical design should be done to maintain high XUV photon fluxes and spectral bandwidth in the interaction region(s). It should include optical elements for focusing the attosecond XUV pulses in the SHHG PW interaction region and in the end station interaction region(s). It should also include the necessary diagnostics (for example, an ion microscope) to characterize the focal spot of the XUV pulses (Table 3 of Annex III).

7) Generation of auxiliary pulses
The proponent should define all types of auxiliary pulses (additional pulses as defined in table 4 Annex III) available and the techniques they will implement for their generation. For each type of auxiliary pulses the proponent should provide a table defining their characteristics (Table 4 of Annex III).

8) Characterization of the attosecond pulses and of the auxiliary beams
The principal characteristics of the attosecond XUV pulses should be specified according to Table 3 of Annex III in correspondence of the SHHG PW interaction region(s) and of the End-station interaction region(s), separately.

The definition of the characteristics of the attosecond XUV pulses should be based upon the characteristics of the PW primary source according to Table 1 of Annex II. The proponent should consider two independent measurement techniques for the characterization of the parameters defined in Table 3 of Annex III. The proponent should define the instruments that will be implemented for the characterization of the attosecond XUV pulses/pulse trains. Whenever possible, on-line single-shot characterization of the attosecond XUV pulse characteristics (energy, spectrum, temporal profile) is strongly recommended.
The SHHG PW should be able to operate for the generation of trains and/or isolated attosecond pulse with minor changes and readjustments.
The principal characteristics of the auxiliary beams should be specified according to Table 4 Annex III in correspondence of the SHHG PW interaction region(s) and/or the end station interaction region(s). The definition of the characteristics of the auxiliary pulses should be based upon the characteristics of the corresponding primary source according to Table 1 of Annex II. The proponent should define the instruments they will use for the demonstration of the performances described in Table 4 of Annex III. Whenever possible, on-line single-shot characterization of the auxiliary pulses characteristics (energy, spectrum, temporal profile) is strongly recommended.

The attosecond pulses should be temporally characterized by means of XUV-IR cross-correlation techniques (for example, attostreaking) and/or XUV-XUV autocorrelation techniques. The proponent should provide an estimation of the temporal duration of the attosecond pulses according to table 1 in Annex IV (though not a deliverable). The SHHG PW design and implementation should be complete and ready on delivery for performing measurements towards these time domain characteristics (part of the SHHG PW).

9) Beam-splitting and beam-recombination, including suitable delay lines, for the accomplishment of pump-probe experiments with attosecond time synchronization between pump and probe pulses.

Suitable options for beam-splitting and beam-recombination should be defined for the accomplishment of pump-probe experiments with attosecond time synchronization.
A clear scheme for the splitting and recombination of the attosecond XUV pulses and auxiliary pulses should be defined. The level of attosecond synchronization between the attosecond and the auxiliary pulses should be specified according to Table 1 of Annex III. Clear experimental techniques should be defined for the demonstration of attosecond synchronization between the attosecond and auxiliary pulses. A clear scheme for temporal and spatial matching of the attosecond and the auxiliary pulses in the SHHG PW interaction region(s) and in the end station interaction region(s) is to be implemented. Diagnostics for the same are to be included as part of the SHHG PW design.

10) Beam steering and focusing towards end station(s).

An optical scheme for the transport and focusing of the attosecond and auxiliary pulses to the end station interaction region(s) should be defined and implemented. The transport should occur with minor XUV flux losses and preserving, as much as possible, the XUV spectral bandwidth. The developers should define an (or more) access flange(s) where an (or more) end station(s) could be installed and operated in combination with the SHHG PW.
The design and implementation of the end station(s) is not part of this Request for Proposal. In the design and installation of the SHHG PW, it is required to reserve additional space to ensure the allocation of end station(s) (see Annex V). An indication of space and minimal vacuum conditions requested for the end station(s) will be provided to the winner. Close interaction with the developers of the Primary Source and with the developers of the end station(s) is required, in order to optimize

the SHHG PW performances. The SHHG PW should be designed and constructed to be working with the Primary Source in the two operation modes.

Further details on each of these points are available in the Conceptual Design Report of SHHG PW, ELI-ALPS.