STRATEGIC PLAN
2013 - 2016

Centro de Láseres Pulsados

CLPU CENTRO DE LÁSERES PULSADOS

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Junta de Castilla y León

VNiVERSiDAD D SALAMANCA
CAMPUS DE EXCELENCIA INTERNACIONAL

"Strategic Plan 2013 – 2016"
Ultra-short Ultra-intense Pulsed Laser Centre (CLPU)
Salamanca, June 2013

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1 Introduction

1.1 Executive summary

The origins of the *Centro de Láseres Pulsados* (CLPU by its Spanish initials) go back to December 2007, when the three Consortium members signed the Collaboration Agreement that would join their efforts to create of the most important laser infrastructure in Spain and one of the world's top ten. However, the formal constitution of the Consortium, published in the national and regional official bulletins, took place in September 2008. Since them, the Centre has been taking shape and growing.

The first steps were oriented towards the configuration and design of the infrastructure. Due to its singularity, the identification of such extreme laser as a potential Spanish users facility was approved by the CAIS (Advisory Committee for Unique Infrastructures) on March 2009 and included as a singular scientific and technological infrastructure (ICTS) of the national roadmap. In that year, after the transfer of laser and accessory equipment to the CLPU by the University of Salamanca, the Centre initiated the activities related to the design and construction of the petawatt laser system. At that time was just identified as a compact PW system, meaning by that a Ti:Sapphire CPA system with pulse durations close to 30 fs. The fine detail of the VEGA laser system and its three arms was decided after.

Although the first foundation stone for the headquarters wasn't placed until February 2011, the Centre has been constantly on the move, being awarded several grants for the development or participation in international and national programmes, such as the European Regional Development Funds (Construction of the headquarters and two phases of the petawatt laser system), the national R&D Internationalization Programme (ACI-Promociona), the Plan E (Radioprotection Plan) or the integrated initiative of European Laser Research Infrastructures II (Laserlab Europe).

Besides, to gain expertise which will be applied to the installation and configuration of the VEGA and to be able to offer service to users while the main equipment becomes operative, the additional equipment has been placed on a temporal location in adjacent premises. In this way the Microscopy Service, including the scanning electron microscope and the atomic force microscope, and the Mechatronics Service have opened their doors to users in January 2013. The HRR laser and the CEP laser have also been installed and tests are being developed.

The headquarters, the M5 building, is close to completion and it is expected to be operative in mid 2013. From that moment, the works for the reception of the VEGA will commence. The architecture of the VEGA system after two tenders and many years of work is completely defined and its construction at a very advanced stage. The architecture of this laser is world unique in the sense of having a VEGA-1, VEGA-2 and VEGA-3 simultaneously firing in a synchronized way. This opens a set of unprecedented possibilities for this laser at global level. According to schedule, the first users of this system will be received in 2015.

A recent report of the Scientific and Technical Advisory Committee (CACT) of the centre, formed by international recognised experts, has confirmed that *CLPU " is an excellent facility in concept with a high potential for important scientific and technological impact. In particular the impact of the high repetition rate petawatt (PW) class ultra-fast laser on electron and proton acceleration and compact high brightness X-ray sources is likely to be profound and far reaching. The highest priority must be given to ensuring that the PW project is a success".*

The CLPU expects to be an international reference centre for ultra-short, ultra-intense pulsed lasers, offering its resources to the scientific and technological community for the development of cutting-edge experiments and breakthrough projects and promoting the transfer of knowledge to the entrepreneurial sector, and therefore, to society.

However, and despite its moderate operating costs, two important issues for the CLPU are the funding of its activities and the difficulties in attracting talent. To make up for these handicaps, the Centre will search for national and international funding sources, both public and private.

Femtosecond lasers and particularly intense femtosecond lasers do represent now a scientific and technical revolution. The list of potential applications, especially at the CLPU thanks to its versatile laser system, is enormous and covers cross-cutting disciplines. The challenge of the Centre is to be capable of transmitting this knowledge and expertise to communities that have never considered lasers as a relevant, or even a key tool, for their research.

This user community, in turn, will push forward and spread this technology, which represents for Spain an exceptional opportunity to be on the crest of the wave of the coming laser market expansion.

The CLPU is aware of the amplitude of the objectives that has envisaged for this Strategic Plan, so it has drawn up an action plan to achieve them. Nevertheless, the Direction likes keeping, to a certain point, the feet on the ground and doesn't lose sight of the main target of the Centre in this four-year period: the installation of the petawatt laser system with the compromised very high specifications and to construct the first target area with the most wide implication possible of the users community and its opening to users. On the other hand, CPA is a fast changing technology and it is necessary to follow the advances of the technology, and also participate in them, in order to be proactive with the long term evolution of the project.

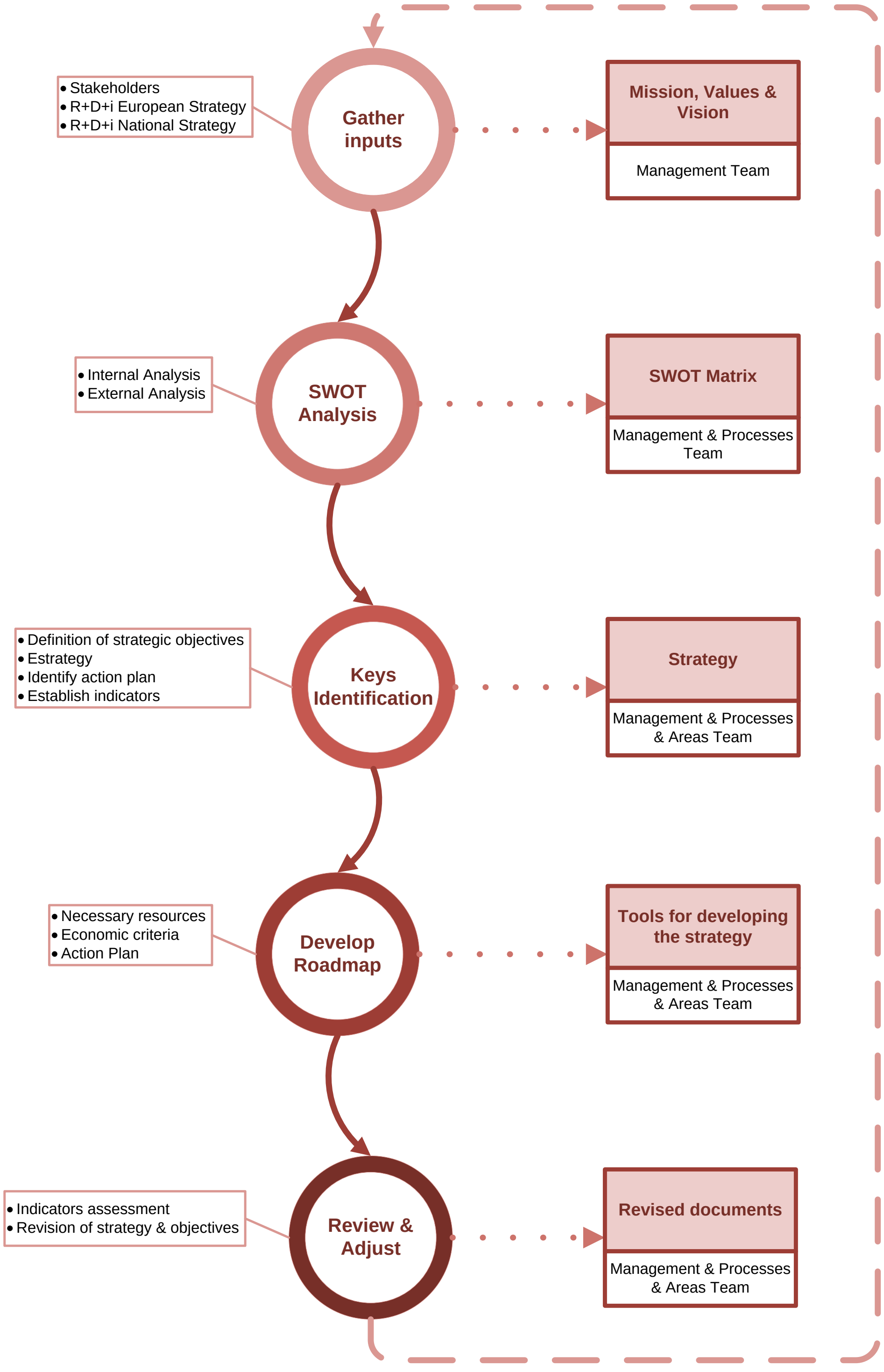
The fulfilment of the plan will be periodically followed up according to the schedule outlined. At that moment, the indicators established to assess the level of achievement will be analysed, which will allow to review and keep the Strategic Plan updated and realistic and in constant line with the national and European R+D+i strategies.

Finally, we cannot forget that the origins of CLPU and also the close future explained in this Strategic Plan were and will be involved in an international crisis context. This issue must be taken into account for the assessment of the ICTS achievements and the progress fulfilled up to now.

Therefore, all the CLPU executive boards and staff will try to make the maximum effort in order to reach the strategic objectives and turn this Centre into a world class ultra-intense laser reference.

1.2 Methodology

The following diagram represents the methodology used for the description of the different work phases for the , the tasks developed in them, the resources applied and the final result, taking into account the necessary feedback for a constant improvement and updating.



2 General Information & Progress of the project

2.1 General Information

2.1.1 Origins

Before starting with this document it is relevant to make a general comment on the *Centro de Láseres Pulsados Ultracortos Ultraintensos* (CLPU, Ultra-short Ultra-intense Pulsed Lasers Centre) Consortium, a three-part association.

CLPU is a new research facility that has been created as a Consortium of the Spanish Ministry of Education and Science (competencies assumed at present by the Ministry of Economy and Competitiveness, MINECO), the Regional Government of Castilla y León and the University of Salamanca, as part of the implementation of the Spanish Scientific Infrastructures Roadmap. The Consortium headquarters are located in Salamanca, Spain. The Consortium was created on December 14th, 2007. Its Spanish CIF number (Código de Identificación Fiscal) is S3700007B

The objectives of the Consortium, as stated at the starting document, are:

- To build and operate a petawatt Laser in Salamanca
- To develop ultra-short-pulse technology in Spain
- To make significant advances in intense, compact laser technology
- To promote the use of such technology in several fields: Physics, Engineering, Chemistry, Biology, Medicine, Energy, etc
- To open the facility to the domestic and international scientific community

CLPU is the evolution of the Laser Service at the University of Salamanca that is acting as a user facility since March 2003. As a user service, it has been giving access and support to many national and international groups over the years. Obviously, the scope of users broadens as more powerful lasers are available.

Salamanca, at the University first and at the CLPU now, is the reference place for this technology in Spain.

Physics building of the University of Salamanca,
that can be considered as the starting point of CLPU

The design of the centre main beams is based on several phases:

a. Phase zero (half-terawatt), is the old laser of the University of Salamanca, operative since March 2003 (being at that time the record peak power in Spain). This laser, ten years later, remains operative at the Physics building of the University and is mostly dedicated to high level teaching.
b. Phase one (20 terawatt), is the second laser of the University of Salamanca, operative since September 2007. This laser was given by the University to the CLPU Consortium, and now has been reinstalled at CLPU.
c. Phase two (200 terawatt). This laser is just now starting to be operative in conjunction with Phase one in a provisional mode, waiting for the installation of the next phase.
d. Phase tree (petawatt). This laser is under construction, it is expected to start operation by the end of 2014.

Besides this, the centre is committed by the approval of its Technical Design Report (TDR), to have a coherent X ray source, by high order harmonics, in order to generate synergies with synchrotrons and XFELs. For that purpose CLPU has some other CPA lasers.

Moreover, the centre is committed to provide whenever possible, a continuity of the users of the initial University Laser Service from which it evolved. In this sense, CLPU is considered internally in the University as a Service, and a number of University users are using our basic equipment.

2.1.2 Trade Mark

CLPU is the only Spanish ICTS specifically devoted to lasers. So a proper name to it would have been National Lasers Centre or something like that. However, that name was not considered due to the existence of several laser centres in Spain associated to universities or private companies. The aim of the centre is to generate synergies, not problems.

For that reason, the name was chosen to remark the specificity of the centre and so, the name *"ultra-short ultra-intense laser"* appeared. Of course, all that with the indication of the consortium character. Thus, the Spanish official name of the centre is *Consorcio para el diseño, construcción, equipamiento y explotación del Centro de Láseres Pulsados Ultracortos Ultraintensos*[1] and this name is definitely too long.

In 2009 a contest was made for proposals of possible logos of CLPU. The name of the Centre and the winner logo were registered in the Office for Harmonization in the Internal Market (OHIM) as Community Trade Mark in May 10th, 2010 with the Registration No. 008676471.

CLPU trade mark

However, the everyday use has made advisable to shorten the name to *Centro de Láseres Pulsados*, maintaining the logo registered.

The importance of the trade mark is to identify the origin of services, guarantee consistent quality through the commitment to users and be a form of communication and divulgation of the Centre and its scientific and technological achievements.

In this sense, we always use the name and the logo in a consistent way, according to the CLPU Style Guide elaborated and distributed in April 2012.

Our trade mark is easily recognizable in scientific maps, websites, research and technological networks, as a mean of enhancing the CLPU image all over the world.

[1] Consortium for the design, construction, equipping and operation of the Ultra-short Ultra-intense Pulsed Lasers Centre

2.1.3 Internal Organization

The proposed structure for this infrastructure is a CONSORTIUM. This is just one of the legal possible forms according to the Spanish regulation, but seems the most adequate.

The key points of this structure, as defined at CLPU statutes[2], are:

- The **Rector Council** that governs the facility. It has a balanced representation of all the founding agencies.
- The **Executive Commission,** responsible of the main decisions related to the facility. Its members are selected from the Rector Council.
- The **Director** of the facility, selected by the Rector Council. The Director is the scientist in charge of the facility. The Director is assisted by the **Managing Director** that is in charge of the Administrative and Economical aspects of the facility. Director and Managing Director form the **Direction** of the facility, and participate, without vote, in the meetings of the Rector Council and of its Executive Commission.
- The **Scientific and Technical Advisory Committee**, selected by the Rector Council, and formed by well recognized scientists not belonging to the facility. It is the highly qualified committee that assists the Rector Council in the technical decisions. The CACT issued its first report of the CLPU in February 2011.
- The **Access Committee,** responsible for the evaluation of the users proposals and for the distribution of the beam time of the petawatt laser system among users. Its creation is pending.

The personnel of CLPU is distributed in three different Areas: Management, Technological, and Scientific. Each area is coordinated by a Head of Area. More Areas can be incorporated if necessary.

Besides that there is the figure of the **Senior Key Scientist**, a new position that was suggested by the Advisory Committee and approved by the Rector Council. CLPU is now in the process of seeking a candidate that meets the requirements indicated by the Advisory Committee.

The Direction of the Centre (Director and Managing Director), the Senior Key Scientist, and the Heads of Area, will form the **executive platform** for the internal governance of the centre.

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[2] Annex II to the Collaboration Agreement included in the Resolution of September 30th, 2008, published in the Boletín Oficial del Estado (BOE No. 251 of 17th October 2008)

2.2 Progress of the Project

2005	▪ Initial stage
2006	▪ Preliminary reports of the convenience of a PW laser
2007	▪ Provisional approval of the CLPU ▪ Creation of the Consortium
2008	▪ Starting of the design phase ▪ Application sent to CAIS ▪ Formal constitution of the Consortium
2009	▪ Approval of the project of CLPU by the CAIS ▪ Preparation of the tenders and final design ▪ First contacts with CSN
2010	▪ Tender for the building ▪ Tender for the 200 TW class (VEGA-2) ▪ Contract for the building with Ferrovial Agromán, S.A. ▪ Tender for PW (VEGA-3)
2011	▪ Contract for 200 TW class with SA Amplitude Technologies ▪ 1st foundation stone of headquarters (M5 building) ▪ First meeting of CACT ▪ Tender for High Repetition Rate laser (HRR) ▪ Tender for the Scanning Electron Microscope (SEM) ▪ Installation of concrete slab ▪ Contract for PW with Amplitude and final design of VEGA with three phases ▪ 20 TW class (VEGA-1) sent to Amplitude for integration with VEGA-2 ▪ Contract for HRR with Lasing, S.A. ▪ Contract for SEM with Carl Zeiss MicroImaging S.L. ▪ Tender for CEP laser system ▪ Reception of 1st partial delivery of VEGA-3 ▪ Acceptance Tests of HRR ▪ Acceptance of SEM ▪ Tender for vertical continuous-five-axis milling machine ▪ Contract for CEP with FEMTOLASER Produktions GmbH ▪ Tender for cleanroom ISO-8 for 200 TW (VEGA-2)
2012	▪ Move to the provisional site at M3 building ▪ Contract for vertical continuous-five-axis milling machine with D.M.G. Ibérica S.L.U. ▪ Factory Acceptance Tests of VEGA-1 + VEGA-2 ▪ Installation of enclosure for HRR ▪ Reception of 2nd partial delivery of VEGA-3 ▪ Acceptance Tests of vertical continuous-five-axis milling machine ▪ Completion of cleanroom ISO-8 for 200 TW (VEGA-2) ▪ Installation of VEGA-1 + VEGA-2 in M3 Building ▪ Acceptance Tests of CEP ▪ Installation of trepanning system and LIBS spectroscopy for HRR (Lab 2) ▪ Installation of enclosure in mechanical workshop

2013	▪ Opening to users of Microscopy and Mechatronics Services ▪ Installation of enclosure of trepanning system ▪ Installation of enclosure of X-ray source (Lab 2) ▪ Acceptance Tests of VEGA-1 + VEGA-2 ▪ Application to CSN for 3rd Category Radioactive Facility (X-ray source) ▪ Installation of the compressor chamber of VEGA-1 + VEGA-2 ▪ Interim meeting of CACT ▪ M5 building will be operative ▪ Opening to users of HRR laser system ▪ Opening to users of CEP laser system ▪ VEGA-1+VEGA-2 operative for tests at M3 ▪ Reception of pending deliveries of VEGA-3 ▪ Fine design of the M5 bunker ▪ Survey on scientific priorities of potential users ▪ Second meeting of CACT ▪ Fine design of the first target area
2014	▪ Application to CSN for 1st Category Radioactive Facility ▪ Installation of VEGA-3 ▪ Installation of 1st target area ▪ VEGA-3 operative for tests ▪ Integration of VEGA-1, VEGA-2 and VEGA-3 as a single system.
2015	▪ Opening to users of VEGA laser system ▪ Design of 2nd target area (external bunker)

Table with general view of progress of the project:
In black milestones already accomplished.
In grey, pending milestones

The Scientific and Technical Advisory Committee (CACT), after the interim visit carried out on June 3rd 2013 by two of its members, Jon Marangos from Imperial College and Ramón Corbalán from the Autonomous University of Barcelona, made the following observations related to the progress of the project:

- *"We continue to be impressed by the Project and the potential as a world-class facility*
- *It is very positive that the building has been completed (more or less) on time and appears to be of a high standard*
- *Issues with the acceptance tests of the 200TW laser (Vega 2) are being handled very well and there is a solid understanding of the issues concerning the PW commissioning when it is delivered late this year*
- *We were very impressed with the technical competence of the team in Laser Optics and the growing expertise in High Power Laser Interactions (albeit at a more preliminary stage)*
- *It is excellent that the budget provision continues on a strong basis*
- *The Project has now reached a critical stage and measures must be implemented to ensure success"*

2.2.1 Buildings

Upon constitution, the legal address of the Centre –needed to start formal operation- was the University of Salamanca address (Patio de Escuelas 1). Initially the design phase was done using premises at the Physics building of the University of Salamanca. Currently the CLPU dedicated building, M5, is close to be finished and we have some rented space at the adjacent building, M3, both at the Scientific Park of Villamayor (Salamanca).

2.2.1.1 M5 Building

The M5, the headquarters of our facility, is under construction. The building was designed to host the petawatt laser, and includes the laser bay itself and the target area, the maintenance areas, the auxiliary experimental areas, all technical elements (temperature control, uninterrupted power supply, vacuum, …), as well as the office space.

Headquarters of CLPU, the M5 building

Although the Rector Council agreed to open the tender dossier in July 2009, due to some construction requirements and permits, the contract for the elaboration of the project and the construction of the building wasn't awarded to Ferrovial Agromán, S.A. until November 29th, 2010.

The total initial budget for the project is 3.217.599,00 € (VAT not included) and is financed by the European Regional Development Fund (ERDF), that contributes 2.252.319,30 €.

The project has a timeframe of 24 months. The works began on January 21st, 2011. However, the M5 building suffered some delays due to the reinforcement and anti-vibration preparation of the ground below the laser bay, first, and then later due to some adjustments in the temperature and humidity control of the room once the supplier of the laser was known. In order to carry out these modifications, the Rector Council on July 16th, 2012 authorized the amendment of the project, establishing a new budget (3.882.506,17 €). The deadline has been extended until June 23th, 2013.

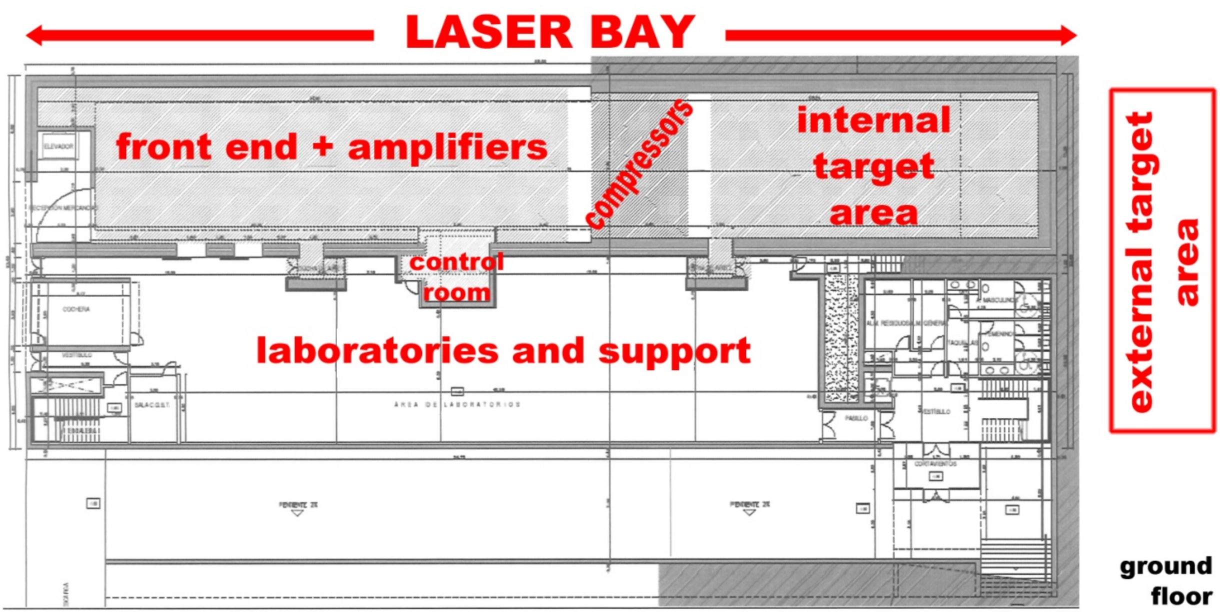
As far as May 2013 the works can be considered completed (99,87%), pending some minor details, such as the testing of installations. Acceptance tests have taken place on May 23rd and 24th and June 17th, 2013. The reception of the building, which took place on June 21st, will be followed by the activities related to the work completion certification. Meetings have been held with the Town Council of Villamayor in order to prepare the documentation to get the compulsory municipal license required to start up the activity and the first occupancy licence.

It is expected to move the offices to the M5 building after summer 2013.

The present situation of the facility and the steps to follow in the next few months about the building will be, by levels:

Ground floor.- According to the project, the M5 building ground level has a petawatt bay of 60 m long by 10 m wide and another area for labs.

The foreseen distribution of the ground floor is depicted in the next figure:



Distribution of the ground floor of the M5 building

a. The **laser bay** is a special space specifically dedicated to the petawatt laser and the internal target area. It is the key part of the M5 building. Its structure lies on a sand bed and is fully separated from the rest of the building to avoid vibrations. The laser bay has the temperature and humidity stability conditions needed for the right operation of the laser. It has two doors, one at each side, being the one at the rear at ground level while the door in front is 2.5 metres above the ground level, just to enter big pieces of equipment. The laser bay is divided into: a part for the VEGA front-end and amplifiers (about 250 m^2), a part for the compressors (about 150 m^2); and an internal target area (about 200 m^2). Moreover, the target area needs radioprotection due to the acceleration potentialities of the VEGA system.

The laser bay as in May 2013. The enclosed area at the end will be the target area At the right is the control room.

Next steps in relation to the preparation of the laser bay are:

- The design and full enclosure of the internal target area to make it safe from a radiological point of view. Conversations have been kept with different companies to assess the options for the enclosure proposed at the CLPU. This is a key task, since it has to fulfil somehow contradictory conditions. The best compromise has to be defined on the basis of the expected users at the same time that some degree of flexibility is important to allow adaptation to future requirements. For that reason all this internal work is planned with modular concrete bricks (of several tones each).

- The design and enclosure of the laser area, including the arrangement of the compressor chambers, in order to fulfil the requirements for clean areas of the supplier.

- The beam transport of the two main lines (VEGA-2 and VEGA-3) after compression. This is another key action because the propagation of the intense compressed pulses from the compressors to the target chambers in the target area has to be done at vacuum. This includes the design of the chicanes to pass through the shielding walls of the target area, and has to deal with two major problems: radiation shielding and debris entering back to the compressor chamber.

- Preparation the vacuum lines for the compressors, transport lines and target chambers. Define the conditions of differential vacuum –if needed- between compressor and target chambers.

b. In the M5 ground floor, just at the centre, there is the **control room**. Although this is a very small space it is the neuralgic centre of the system. The control room is opened to the laser bay and is the only part where technicians and scientists are allowed –under certain restrictions- during the operation of the petawatt.

Next steps in relation to the control room are:

- The final definition of the control room, including the intra-bay part and the external part out of the concrete shielding
- The final definition of the control system, including the global control of laser front end, amplifies, compressors, target chamber, vacuum systems, temperature and humidity conditions, safety, interlocks, …
- The equipment of the control room. This includes basic furniture a final blind to be placed between control room and laser area.

c. **The labs area** is 400 m^2 and will host the following rooms: laser maintenance room, primary vacuum room/s, vacuum workshop, radioprotection room, additional support area for experimental set-ups, target assembling room, electronics workshop, IT workshop (computers repairing) and warehouse. This area is predesigned in the sense that air-conditioning, light sector, switches, and all that are distributed in a predesigned way. The idea is to allow a quick division of that space, and a division that can be reversed or modified easily according to the users needs.

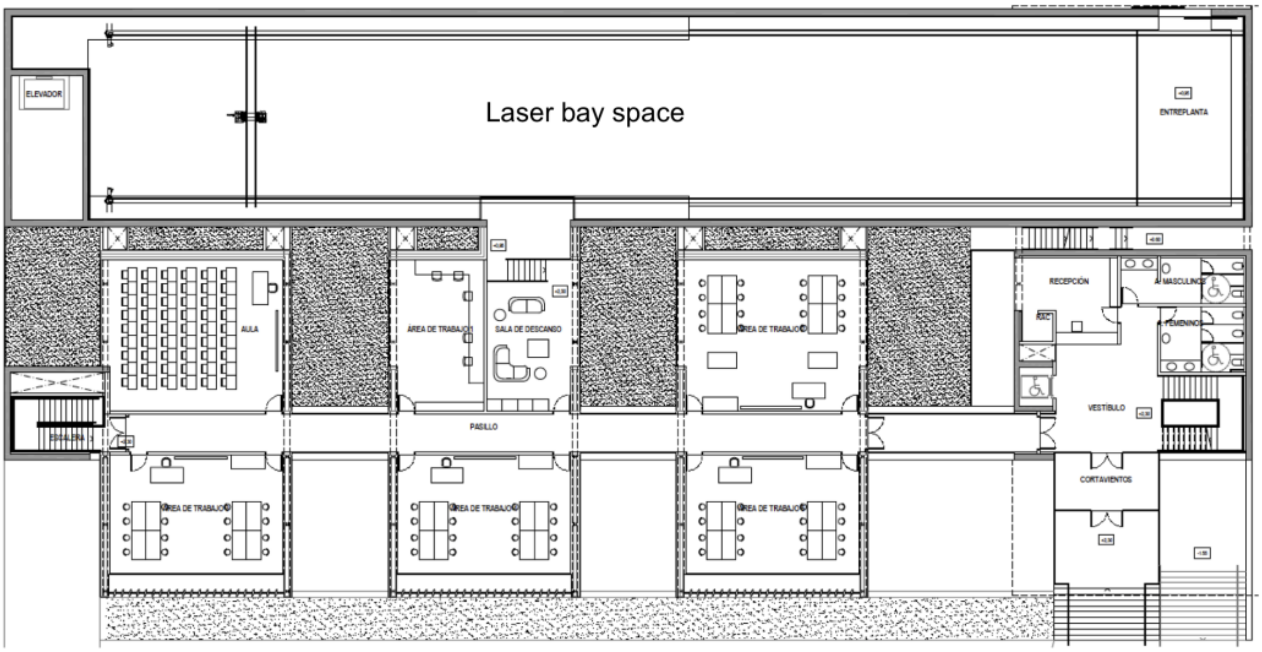
Laboratory area of the ground floor of M5, as in May 2013. It is empty but with a predesign to panel it in a flexible way

Next steps in relation to the labs area are:

- The design, distribution and enclosure of the mentioned laboratories and spaces based on the presently determined needs, leaving as much free space as reasonably possible, and with special emphasis on the flexibility.

– A decision shall also have to be taken about the advisability of moving the laboratories 2 and 3 from the M3 building to the M5. It seems highly desirable that the microscopy part (SEM and AFM) is integrated at M5. The Mechatronics laboratory is considered incompatible with the VEGA laser, particularly due to the intense vibration level of that machine.

First floor.- The M5 building first level includes the main entrance and the office space for the scientific and the technological areas, for the users, and some space for meeting rooms. The total extension of these rooms is 450 m^2. The office space is divided in three blocks that can be seen in the next figure, each block is divided in two parts.



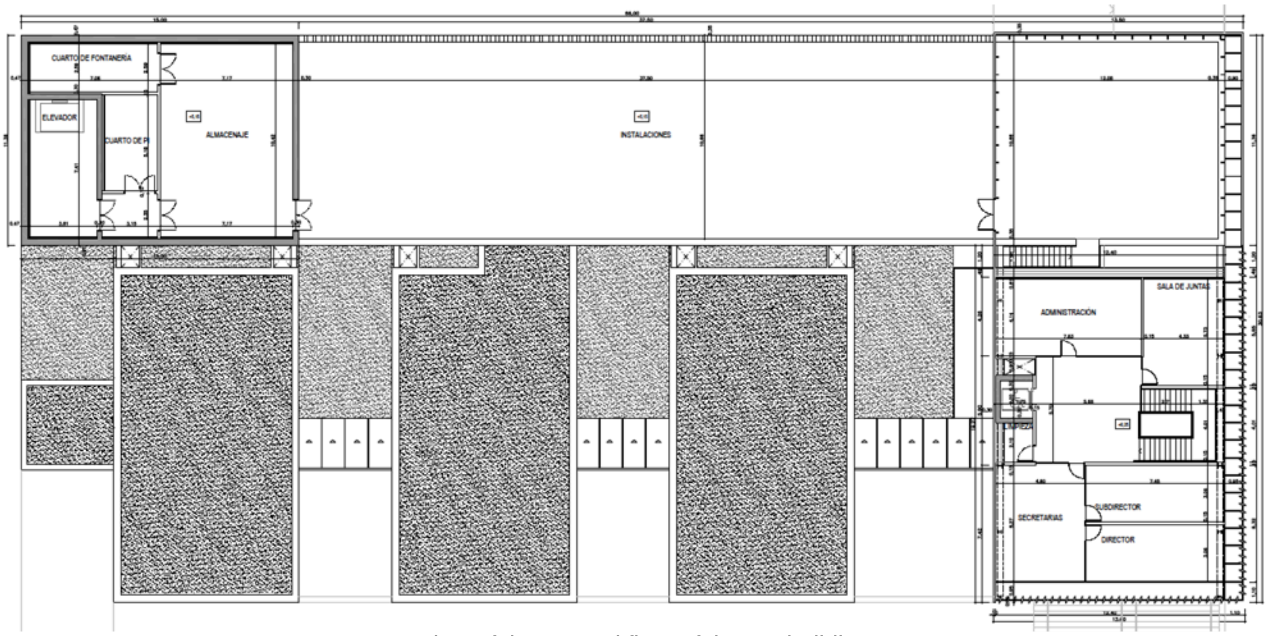
Distribution of the office space in the M5 building.

One of the meeting zones of M5 as in May 2013. In the front is the window to the laser bay and its protective curtain.

Next steps in relation to the first floor are:

- The acquisition of the furniture, IT equipments and multimedia resources.
- The transfer of the staff and equipments from the M3 building to the M5.

Second floor.- The M5 building second level is very reduced. It includes the administrative area and the direction offices. Their extension is 160 m^2.



View of the second floor of the M5 building.
It corresponds to the administrative area (lower right) and to the roof of the laser bay.

View of the Direction offices on the second level of the M5 building

Next steps in relation to the administrative area on the second floor are:

- The acquisition of the furniture, IT equipments and multimedia resources.
- The transfer of the staff and equipments from the M3 building to the M5.

At the same level, but on top of the laser bay there is a wide and open technical space.

General view of the technical space on top of the laser bay

The next step in relation to the top of the laser bay is to study the possibilities of covering this area in order to preserve the laser bay against water injuries.

As a conclusion of this part, it is relevant to point out that the M5 building with a total of 2.600 square meters is a building designed to host the petawatt and its team, optimizing the available space.

2.2.1.2 M3 Building

To start operation and prepare some equipment and experiments the Rector Council approved the provisional installation of the CLPU at the M3 building, a building owned by the University of Salamanca. The M3 is a completely new building and their lower level has been prepared for laser laboratories.

The total extension of the area occupied by the CLPU is 1.129,19 m^2 at the M3 building, distributed in two floors:

Ground floor.- There is an open concept space of 246,49 m^2 rented for offices. This space is being used for the personnel of CLPU while the M5 is not available.

Basement.- There are 882,7 m^2 rented at the basement of the M3 building, where are located the four labs[3]:

1. Lab 1 (256,04 m^2) is used for general facilities (workshop, precision mechanics, ...)
2. Lab 2 (201,95 m^2) hosts the microprocessing lab (including microscopy).
3. Lab 3 (180,93 m^2) hosts the Carrier-Envelope Phase (CEP) Laser lab.

[3] The descriptions of the systems and equipments hosted in these labs are included in point 2.2.3.

4. Lab 4 (243,78 m^2) hosts the temporal installation of Phases one and two of the VEGA laser system, manufactured by Amplitude.

Spaces available at the ground floor of the M3 building

The University and the President of CLPU Rector Council signed the contract on June 1st, 2011 and the M3 construction incorporated in the last part some adjustments to host laser laboratories in its basement. The move to this building from the facilities of the University of Salamanca took place in January 2012.

From that moment, several tasks were carried out in the labs:

- **Electrical installation:** Initial analysis and adaptation of the labs, increasing the power input and installing additional switchboards on each lab, as well as a switchboard for the technical corridor of Lab 4. The switchboard in Lab 3 was modified to accommodate the UPS of Phase two of the laser system VEGA.

  Also the electrical load distribution was analysed to adapt the leakage currents of the equipment to the protection systems installed.

- **Temperature control:** Analysis of temperature evolution on each lab to be able to optimize the behaviour of systems after their installation.

- **Uninterruptible Power Supply (UPS):** The UPS used for Phase one of the laser system VEGA at the University of Salamanca was brought to the M3. Their functioning was studied and tried for each system. They were installed as a first phase of the UPS.

- **Optical tables:** Study of needs and installation.

- **Material:** Optomechanical material, technical gases and manometers and pieces of furniture was bought. Also an important amount of material was brought from the

University of Salamanca: the compressor of Phase one, a chiller pump, storage cupboards, helical drilling machine, ABB motor and optomechanical material.

- **Cleanliness of the labs:** Cleaning procedures have been established and material has been bought, such as vacuum cleaners, lab coats, sticky mats ...

2.2.1.3 Physics Building

Also the University of Salamanca keeps the old laser service, with a half terawatt laser operative since March 2003, as already mentioned. At that time it was the record peak power in Spain, and even now is a quite relevant laser. That system is placed at the basement of the Physics Building of the University of Salamanca. This system and some auxiliary equipment is being technically kept by the CLPU staff in order to optimize the resources. The system is the key piece for the formation of new laser specialists in the context of a specifically prepared Master Program on Science and Technology of Lasers. Such graduate courses are taught by laser specialists from the University of Salamanca and from the University of Valladolid as well as the CLPU staff.

2.2.2 Main Equipment: VEGA

2.2.2.1 Main System

From the very beginning, it was decided that CLPU would focus on a compact PW technology trying to reach the PW peak power with pulses as short as possible. At an early stage there was some incertitude between CPA and OPCPA technologies. Soon after the signature of the consortium it was decided that the best approach to have a reliable machine was to go to the Ti:Sapphire technology with pulses on the 30 femtosecond range.

The main equipment of the CLPU is a PW laser system, the VEGA laser system. VEGA is a CPA Ti:sapphire laser system that uses the full potentiality of Ti:sapphire (25 to 30 fs duration) without the complexity of the OPCPA technology.

VEGA has a single front end and three synchronized amplification lines:

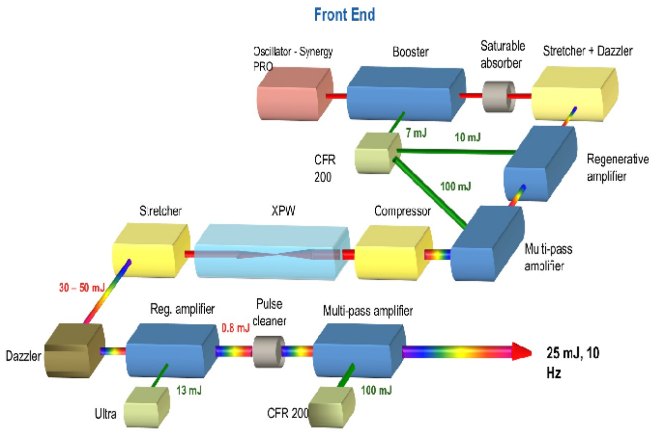
Phase	VEGA System	Energy per shot	Pulse duration	Central Wavelength	Peak power	Repetition Rate	Operation
One	VEGA-1	600 mJ	30 fs	800 nm	20 TW	10 Hz	Since 2007
Two	VEGA-2	6 J	30 fs	800 nm	200 TW	10 Hz	Spring 2013
Three	VEGA-3	30 J	30 fs	800 nm	1 PW	1 Hz	Mid 2014

The VEGA system is based on standard CPA technology using a Ti:Sapphire amplifier. The laser is going to be very relevant because it is going to be running at one Hz (one shot per second) and has the possibility to be upgraded to 5 Hz.

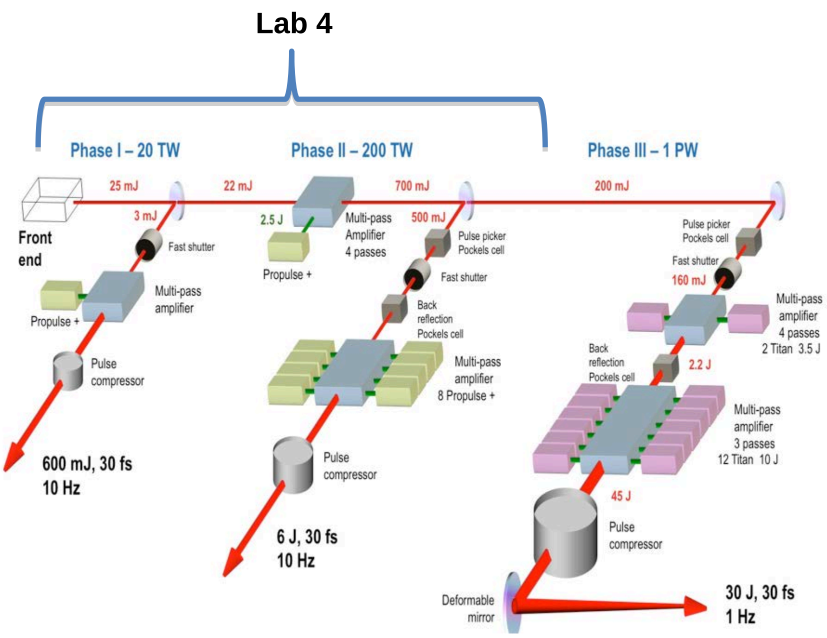
Therefore, finally Phase one (20 TW, 10 Hz), Phase two (200 TW, 10 Hz), and Phase three (PW, 1 Hz), all with durations around 30 fs, will be integrated as a single machine. The integration of all phases in a single machine with a single front-end has advantages and difficulties.

- Advantages:
  - It constitutes a single unique system, probably unique in the world;
  - It allows the use of the 200 TW phase as probe of the PW, opening new possibilities.

- Difficulties:
  - Lack of independence between the three lines, so users can interfere and this must be clearly planned.
  - Any contingence in the front end will affect the three lines simultaneously.



Schematic representation of the PW front end.



Schematic representation of the PW three phases.

The singularity of a PW laser is clear, since is somehow the limit of the reliable technology. VEGA has some quite unique features:

- At present there are just a few lasers arriving to this peak power in the world.
- VEGA is specially prepared with a very high contrast ratio to allow solid targets.
- VEGA is one Hz repetition rate and can be upgraded (changing just the pumps) to 5 Hz.

VEGA has a singular structure with three arms. Those arms are going to be synchronized allowing unique possibilities in pump-probe experiments.

The detailed specifications for the VEGA system are the following:

- Pulse duration: between 25 and 30 femtoseconds. The seeded spectrum is wider than 100 nm and is kept larger than 80 nm all through the chain. This capability is expected to be ensured thanks to the combination of Dazzler and Mazzler. Mazzler optimises the spectral gain, whereas Dazzler ensures the spectral phase control. A loop is set-up thanks to a Wizzler. This Wizzler replaces the Spider in previous installations of the same company. One Wizzler will be installed in each arm (total of three Wizzler devices for the three VEGA arms) so that the loop of each arm may be controlled without having to move and realign any device from one arm to the other. (It must be noticed that the optimisation of the pulse duration through the loop for getting ultra short pulses down to 25 femtoseconds will be possible only in one arm. In such case pulse durations in the two other arms will stay around 30 femtoseconds).
- Pulse energy after compression: >30 J. The compressor efficiency guaranteed by the supplier is 66 percent. With this value, the requested energy before compression must be 45 J. The 66 percent compressor efficiency figure is a very conservative one: this value is the one which must be considered valid still after several years of operation. In practice, the compressor efficiency assuming that the energy density applied on gratings is kept at 100 mJ/cm^2, stays higher than 75 percent for a very long time. In such case the energy requested before compression for ensuring 30 J output is only 40 J. Amplitude proposed a laser system allowing to reach 45 J before compression in safe conditions, which leads to working conditions far from limits for a very long time; with a 75 percent typical compressor efficiency, the output energy could be up to 33,75 J. This gives a margin to compensate for other parameters, such as duration.
- Peak Power: > 1000 TW, 1 Hz. The pulse duration reachable by the laser equipment proposed by Amplitude is 25 fs. Therefore peak power may reach up to 1.2 PW at 1 Hz repetition rate.
- ASE (amplified spontaneous emission) contrast ratio: better than 10^{10}:1 (i.e. better that 100 deciBel). It is guaranteed an ASE contrast ratio better than 10^{11}:1 (110 deciBel) on a daily basis and an optimized contrast ratio better than 10^{12}:1 (120 deciBel) for applications with solid targets.
- Picosecond and nanosecond contrast ratio: better than 10^{8}:1, with the expectation to arrive to picosecond and nanosecond contrast ratio better than 10^{9}:1
- Pulse energy stability: better than 1 percent rms. Pulse to pulse stability is significantly increased thanks to the number of Nd:YAG lasers pumping the last amplifier. Since all Nd:YAG lasers TITAN have a rms stability better than 1,2 percent , the typical overall stability of the PW laser chain is significantly better than 1 percent rms.
- Strehl ratio: better than 0.7 without deformable mirror. The Strehl ratio will be reached through a combination of many parameters including the quality of the materials crossed by the 800 nm beam, the quality of the mechanical mounts bearing all optical components, and the quality of the installation so that no unnecessary stress is applied on optical components. They have been able to improve from 0.25 to 0.75 the Strehl ratio in a 100 TW 10 Hz laser chain thanks to these developments. Also a deformable mirror in order to get a

Strehl ratio better than 0.9 without adjusting the alignment of the laser, and keep the same Strehl ratio even after the replacement of an optical component in case of maintenance.

It is important to remark that a petawatt is a system working close, too close, to the limit. The specific values taken into account in order to keep the laser components reasonably safe are:

- Extraction efficiency: 35 percent leading to total level of pumping energy in final amplifier up to 120 J, 1 Hz at 532 nm.
- Fluence applied on gratings: the fluence will be kept at 100 mJ/cm^2 leading to a beam diameter on gratings equal to 200 mm. Note that beam aperture in the whole system is maintained at 1.5 times the beam diameter to keep contrast ratio as high as possible.
- Fluence applied on Ti:sapphire crystals will stay lower than 1 J/cm^2 and will be even lower (< 0.8 J/cm^2) for pump lasers.

This part is considered very relevant since the objective of CLPU is not to break records, but to be in a compromise between a singular facility and a reliable one.

Moreover, the system includes additional equipments. Among them:

- a Super Booster: for ensuring higher contrast ratio
- three spectral phase active controllers WIZZLER from Fastlite
- a high dynamic cross correlator SEQUOIA
- a second order correlator BONSAI
- a high energy meter PW compatible
- a large Pockels cell of 33 mm diameter with its driver for ensuring safety protection against backs scattering light from target for the 200 TW laser
- a large Pockels cell of 50 mm diameter with its driver for ensuring safety protection against backscattering light from target for the PW laser
- a spatial wavefront controller (Schack Hartmann type)
- a large deformable mirror with the spatial wavefront controller for the PW class laser

The construction of the VEGA system consists of two parts: The first one is the design, construction and installation of the laser itself, with its three phases. The second one is the design and installation of the target areas that optimize the laser performances.

Phase One and Phase Two.- The installation of the VEGA laser system, and therefore its three phases, is closely related to the evolution of the M5 building. For this reason, although the Executive Commission agreed to open the tender dossier in July 2009, the tender was postponed until resolving the problems arose about the building construction. Foreseeing the delays due to this situation, it was decided to look for a proper place to receive and install provisionally the Phase two (called “VEGA-2”) and operate it jointly with Phase one (called “VEGA-1”). Lab 4 of the M3 building was chosen for this purpose.

Finally, the contract for the supply, delivery and installation of the laser system was awarded to SA Amplitude Technologies on December 16th, 2010 and signed on January 17th, 2011.

The total budget for the project is 1.126.400,00 € (VAT not included). The Ministry of Science and Innovation financed 653.312,00 € by means of a grant from the European Regional Development Fund (ERDF) and a repayable advance.

The timeframe for the completion of this phase was of 12 months. According to the tender dossier, the delivery date was expected to be January 18th, 2012.

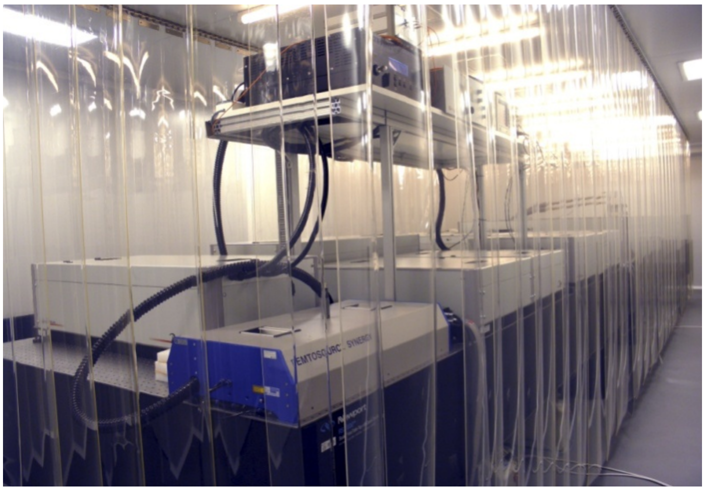
The precise functioning of this system requires very specific and restrictive conditions of temperature stability, control of humidity and cleanliness and air circulation system. These parameters were necessary for the final definition of the technical requirements of the laser, and were only available once the refrigeration and the heating of the M3 building were tested in November 2011. Besides, previously to the installation of Phase two, a cleanroom ISO-8 had to be constructed. The call for tender of this room was launched in December 2011 and it wasn't completed until June 10th, 2012.

The technical corridor was also prepared. The illumination of the cleanroom was modified, the beam path adapted and the access control programmed. The technological staff also studied and modified the laser cooling system for the power supply.

Being obvious the impossibility to meet the deadline for the installation of Phase two, the CLPU requested to the Executive Commission an extension, which was granted until September, 2013.

Phase one (20 TW) had been installed since September 2007 at the Physics building of the University of Salamanca. According to the project, the laser was sent to Amplitude headquarters in July 2011 to be integrated with Phase two. The Factory Acceptance Tests took place in March 2012.

So far, there have been four interventions of Amplitude Technologies related to the installation and tests of the Phase two (including Phase one) in Lab 4 of the M3 building: the first one in July 2012 when the system was installed and the compressor located at the Physics building was brought. Subsequent performances have taken place in August/September 2012, October 2012 and February 2013. Technicians have received training from the manufacturer on all four occasions and during the Factory Acceptance Tests in France.



View of the Phase one and two of laser system VEGA in the grey room ISO-8

The VEGA-2 compressor chamber has being designed and built jointly with the ICTS Synchrotron Alba Cells of Barcelona. This has been a fruitful collaboration since the synchrotron team has taught CLPU technicians on how to avoid vibrations to a quite relevant extend.

After the Acceptance Tests of VEGA-2 in the M3 building, the final acceptance took place on April 26th, 2013.

Next steps in relation to VEGA-1 and VEGA-2 are:

- To insert the optics in the compressor chamber.
- The alignment of the laser.
- As it has already been explained, the installation of VEGA-1 and VEGA-2 at M3 is provisional since the system will finally move to the M5 building, where they will be integrated with VEGA-3.

The installation of Phase one and two at the M3 building has had some costs but has allowed two very important things:

- Allow operation at the multiterawatt level at much better conditions than at the Physics building.
- Be a fantastic training for the CPU technicians.

Phase Three.- The Rector Council also agreed to open the tender dossier for this phase (called "VEGA-3") in July 2009, and due to its relationship with Phases one and two, and especially with the M5 building, the call was also postponed. Finally, the contract for the supply, delivery and installation of the CPA Ti:Sapphire laser system with 1 PW peak power was awarded to SA Amplitude Technologies on April 11th, 2011 and signed on May 4thth, 2011.

The total budget for the project is 6.034.000,00 € (VAT not included). The project is financed by the European Regional Development Fund (ERDF), that contributes 4.984.482,00 €.

The timeframe for the completion of this phase was of 24 months, being distributed the works in eight partial deliveries. According to the tender dossier, the last delivery is expected in May 5th, 2013.

Taking into account the singularity of this laser system and its interactions with the M5 building, several meetings have been held between the technicians from Amplitude Technologies and the CLPU to decide the best configuration and modify the layout, in order to improve the operation and the safety.

On September 20th, 2011 the Centre received the first partial delivery: the front end contrast control equipment.

On May 31st, 2012 the Centre received the second partial delivery: an upgraded version of the Technical Design and drawings, which include all the aspects discussed and decided between the parties since the signature of the contract. Therefore, they represent a modification of the initial design.

These modifications and recommendations make necessary some architectonical adjustments, as well as in the general installations of the M5 building, giving rise to the mentioned delays of that project, and accordingly, of the laser system deliveries. In fact, the Ministry has already granted an extension in relation with the FEDER until March 31st, 2014.

On March 19th, 2013 a meeting was held between the parties for the discussion of the control command system.

Next steps in relation to VEGA-3 are:

- The delivery of the Ti:Sapphire laser, their mounts and two partial pump systems.
- The training of the CLPU technological staff on the petawatt system to prepare its proper installation.
- The delivery and installation of all the control system.
- To select the manufacturer of the compressor vacuum chamber and its delivery and installation.

To sum up, the PW, Phase three, is scheduled to be operative in the M5 building by September 2014. The goal is to install it with its front-end while using an additional front-end to keep operative Phase one and two. Only after correct functioning of VEGA-3, VEGA-2 and VEGA-1 will be transferred to the M5 building. There is not yet a precise calendar for this since the correct functioning of the PW is the key issue for the centre and must be done carefully. It is expected that the whole system with the three phases together and with the whole potentiality for pump-probe (PW pump and 200 TW pump probe) will be opened to users by December 2014. Of course, operation at this early stage will have some restrictions (particularly related to the preparation of the experimental stations)

Besides, there are some issues in which CLPU staff will be working in the following months, previously to the start up, checking and acceptance of the laser system VEGA, which are described in the following points.

2.2.2.2 Target Areas

The intensification of the centre must try to extract the full potentiality of the CLPU main beam, the petawatt. A petawatt system is now, by definition a very singular system. Moreover, the Salamanca petawatt system has **four remarkable features**:

- It has a single front end at 10 Hz prepared specifically to reach PW peak power, with a high contrast ratio and prepared to use the full bandwidth of Ti:sapphire (allowing 25 fs). It can work at 10 Hz or single shot.
- The PW repetition rate will be 1 Hz –an outstanding repetition rate for such extreme power– with the possibility to upgrade this in the future to 5 Hz. The upgrading possibilities of VEGA are more towards higher repetition rate, higher beam quality and higher reliability than going to more peak power.
- It has a 200 terawatt system, at 10 Hz, fully synchronized, because both come from a common front end. This allows unique pump-probe experiments, using a 6 joule probe!
- It has a third beam at 20 terawatt also fully synchronized, that can be used as a second probe or can be used to trigger preplasmas.

The design of the target areas must take profit of these unique features. This presents some problems because of the radioprotection requirements that must be considered in the design of the target areas.

A survey on the users' scientific priorities shall be carried out in order to conduct a discussion concerning users' experimental prospects for the definition of the most adequate baseline target area specifications at CLPU.

One extremely important point in the design of the target areas is the focusing of the laser beam. The petawatt must be able to be focused beyond 10^{22} W/cm^2. However not all relevant experiments require necessarily a tight focus. The first experiment station will be a long focus optical system able to reach only 10^{20} W/cm^2. This has a lot of possibilities for electron acceleration and even from proton acceleration without extreme complexities. This will depend of the user community response, but one of the intensifications of CLPU, at least for the first campaigns is towards experiments requiring a not too extreme peak intensity (10^{20} W/cm^2 or less) but with a big interaction volume.

There are experiments requiring a tight focus, and for that purpose and experimental area trying to focus the system as tight as possible is to be considered. Since the contrast is expected to be very high it makes sense to consider solid targets, for extreme particle acceleration. For this purpose a target chamber is going to be developed. However, such tight focus presents several technical problems as debris coming back from the target to the compressor gratings that made the design complex.

Vacuum polarization is not expected to be found at Salamanca, but once the focusing quality of the petawatt has been demonstrated we plan to design an ultra-high vacuum chamber to analyse vacuum polarization. The development of such chamber can be interesting for ELI. The existence of the 10 Hz VEGA-2 allows new techniques for Extreme High Vacuum that are being designed at CLPU. Also the VEGA-2 arm can be used as vacuum gauge at close to the interaction point inside the target.

One clear intention of CLPU will be in the direction of experiments that do not require a record high intensity but that do require a big interaction volume. The petawatt is going to be used for particle acceleration and for plasma effects of record high interaction volumes by not to focusing the beam too tightly. This is going to be particularly relevant for pump probe (with the 200 terawatt synchronized probe).

Of course, the main problem of the high intensity target areas is the need of radio-protection. With this in mind, we have considered two target areas: **the internal** and **the external**.

The **internal target area** is the front part of the laser bay and already built. It is about 20 meters long by 10 meters wide. Its final design is not yet completely decide, but it must accomplish several requirements that made it very complex.

Next steps in relation to the internal target area include:

- Design and construction of one experimental station accepting the VEGA-3 and VEGA-2 beams simultaneously on a medium to long focal distance bases. The chamber is now predesigned on a modular basis. Such experiments are going to be encouraged for the first round of users since they imply big interaction volumes and longer Rayleigh lengths.
- Design of a short focal system compatible with a solid target position tracking device. Although in this respect CLPU is not planning to move in the direction of big and complex target carrousels developped in other labs.
- Design of a gas jet target able to reach overdense situations. The design will benefit of the three arms architecture of VEGA and will represent new and unique, possibilities for users.
- A beam transport design compatible with the concrete shielding, that minimizes the laser losses and optimizes the beam return risks. Prior to this it has to be decided if the PW beam can be reduced in diameter after compression. Reduction from 16 inch diameter to 8 inch diameter seems now possible with new coated mirrors and this implies a reduction in the transport tubes diameters, with the consequent benefit in the shielding and the simplification of the target chamber mouths.
- Definition and construction of some basics detection systems. Optimizing the user community requirements. However, it is expected that in most cases users will come to CLPU with their own specific detection systems.
- One CLPU specific feature of the internal target area is a system, under study, to allow the exit to air of the petawatt beam, for atmospheric propagation experiments that seem to have also a quite relevant user community.

The **external target area** is pre-designed and fits in a 200 m^2 space in front of the M5 building. The final design of the external target area depends essentially on the radioprotection requirements.

View of the ground in from of the M5 building where the external bunker can be built. It is a 200 m^2 piece of land that can be rigged to the rock bed 10 metres below ground level

Next steps in relation to the external target area include:

- Identification of its real necessity. This will be done by the expected response of the users and by their specific needs. There is now a request, for example, of a neutron source. It this is further justified and preliminary experiments indicate so, probably the external target are can be devoted mostly to neutrons (or to fulfil the safety requirements for them).

- Define the external bunker and its legal issues (property, construction permits, …) in accordance to its basic architectonic design.

- Build the external bunker and equip its experimental stations. This will be done sequentially with the experience acquired with the internal bunker.

2.2.2.3 Secondary Beams

Non-Coherent

As secondary but, probably, more important for the development of the PW applications, other non laser sources are going to be offered to users,

- Relativistic electrons
- Neutrons
- Protons
- Positive ions
- Bremsstrahlung gamma rays

All them, of course, not continuously or in long pulses as in conventional nuclear sources, but at ultrafast bunches. Therefore the brilliance of the resulting beams (divided by time) can be relevantly high. The energies of the resulting particles depend on our ability to focus the PW. In the worst scenario we should be able to reach 10 MeV particles. If everything is optimized we could arrive to 100 MeV energies per particle. In any case these are energies relevant enough to attract an important nuclear physicist community. Of course most nuclear physicists are not expert in lasers, so the CLPU scientific team has to prepare the right experimental conditions to attract that community. This is not trivial, but several other laboratories around the world are working in this direction, so the project is absolutely feasible.

The development of such secondary sources is complex, needs expertise and a wide collaborative effort. The feedback from the users will be determinant for the set-up of the implementation schedule of such beams. In the case of the neutron source, it is even more relevant due to the important radioprotection issues that this can imply. All those will be implemented sequentially as the CLPU team and its users get experience with the machine. Some of them, before being open as secondary sources for users, will need some extra equipment and funding.

Coherent

There will also be five other coherent sources of less high peak power but with more sophisticated properties:

- Soft X Ray Laser source
- Attosecond source
- Few-fs multi-miliJoule source
- IR-VIS-UV tunable fs source
- Terahertz ultrafast source by filamentation

Some of these sources can be obtained with the use of the VEGA laser system and some other with the additional lasers (HRR and CEP lasers), for example the attosecond source will be first prepared with the CEP system, but they can be considered as independent sources for non-expert users. All those sources are laser (coherent) and ultrafast. Each of them represents the state-of-the-art technology. All this will be complemented with OPO tunable sources able to offer to users fs pulses tunable from the IR to the VUV.

Of course the weight of the efforts devoted to each one of the auxiliary beams indicated will depend on the demand on the users community. Being CLPU a user facility the users community is fundamental for the fine design of the centre. All those will be implemented sequentially as the CLPU team and its users get experience with the machine. Some of them, before being open as secondary sources for users, will need some extra equipment and funding.

2.2.2.4 Upgrades

Another approach made by Amplitude was to propose the upgrade of the existing front-end. Whereas the front-end in Phase one and Phase two allows ASE contrast ratio around 10e10:1, we underline that it makes sense to consider a higher contrast ratio at PW level. Indeed the most important issue is to consider that absolute noise level in PW arm must not be higher than the one accepted at 200 TW peak power.

Since 1 PW is almost one decade more than 200 TW, it is important to consider a solution allowing an ASE contrast ratio better than 10^{11}:1. Amplitude has developed a special front end for this purpose. Exceptional performances up to 10^{14}:1 have been achieved and demonstrated in a double CPA laser system at multi mJ energy level. Therefore proposed the upgrade of the existing front-end for getting an ASE contrast ratio at the output of the PW chain better than 10^{12}:1. After the integration of the three VEGA arms, the very high contrast ratio 10^{12}:1 will be present for all beams 20 TW, 200 TW and PW !

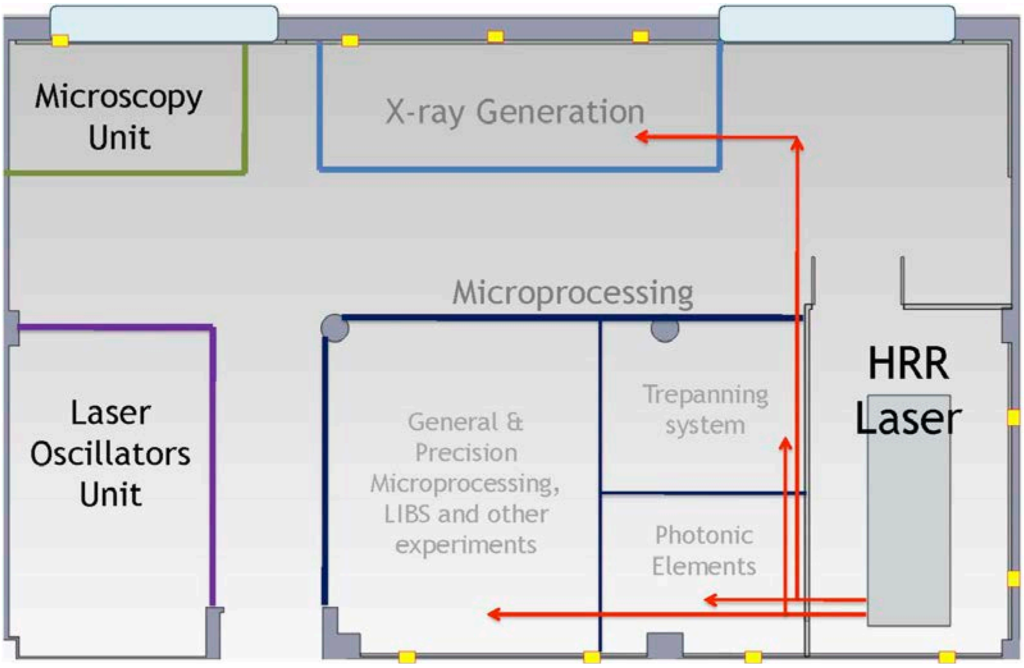
2.2.3 Additional Equipment

Although CLPU main system is the VEGA laser, the other systems (HRR, CEP) are singular complementary sources, but just for the completeness of the project. The CEP system is the only one such system in Spain open to users. There are other HRR systems in Spain but no one is equipped with the experimental stations ready for users as it is the CLPU HRR system. Moreover, the soft X-rays station is unique in Spain.

This equipment is already installed and at this moment, the additional laser systems are being tested. The microscopy and the machining are open to users since January 2013.

2.2.3.1 Microprocessing Lab

The University of Salamanca group has a long tradition in micromachining and microprocessing. Although this is not the main concern of the CLPU, we consider that it is worth to keep this line. Moreover this line has also a long tradition of users service as the Laser Service of the university, and those users deserve continuity in their service.



The foreseen layout of this lab (Lab 2)

The main equipment of this laboratory, located in Lab 2 of the M3 building at the Scientific Park, is the HRR (High Repetition Rate) laser, a Spectra Physics (Spitfire ACE F-7W NSI). It is a **femtosecond CPA Ti:Sapphire laser system with kHz repetition rate**, with a Ti:Sapphire (SP, Mai Tai) femtosecond oscillator, a regenerative amplifier and a singlepass amplifier.

Laser	Energy per shot	Pulse duration	Central Wavelength	Peak power	Repetition Rate	Operation
HRR (High Rep. Rate) Laser	7 mJ	<120 fs	750-840 nm	60 GW	1 kHz	Operative

The laser has the following specs:

- Ti:Sapphire (SP, Mai Tai) oscillator emitting pulses around 100 femtoseconds long with central wavelength around 800 nanometers. Its pumping laser is a SP Milennia, Neodimiun doubled to green. The repetition rate is 84 MHz. The meant power is >400 mW.
- Ti:Sapphire regenerative amplifier, pumped by a pulsed neodimium doubled to green (Empower 30), at 1 kHz. The total energy per shot is 5 milijoule once compressed, and de duration is below 120 femtoseconds.
- Ti:Sapphire singlepass amplifier, pumped by a pulsed neodimium doubled to green (Empower 45), at 1 kHz. The total energy per shot is 7 milijoule once compressed, and the duration is below 120 femtoseconds.

The call for tender for this system was launched in February 2011. Finally, the contract for the supply, delivery and installation of this laser system was awarded to Lasing, S.A. on June 9th, 2011 and signed on June 30th, 2011.

The total budget for the project was 381.355,93 € (VAT not included). The timeframe for the completion of the contract was three months.

View of the femtosecond CPA Ti:Sapphire laser system with kHz repetition rate (HRR)

The Acceptance Tests were carried out at the provisional laboratories of CLPU at the Physics Building. The final acceptance took place on September 30th, 2011. However, taking into account the imminent move to the CLPU facilities at M3 building, Lasing S.A. dismantled and packed up the laser, with the commitment to transfer, assemble and commission it once the new laboratories were operative.

In order to achieve optimal conditions of temperature and humidity and guarantee the cleanest atmosphere for an adequate functioning of the system and avoid damages, in March 2012 an enclosure was built which includes a laminar air flow hood and air-conditioning installed.

Also in March the American manufacturer, Spectra Physics gave training to the technological staff of the centre.

The beam from this laser will be divided into different stations for two main purposes:

a. Microprocessing

It includes stations for general microprocessing and other experiments, trepanning system and photonic elements.

In summer 2012 additional equipment donated by the university consisting of a trepanning system and a LIBS spectroscopy set was installed in the laboratory. Those tools are quite unique due to their specific preparation and to the years of experience of the team.

To reduce vibrations produced by the trepanning system, an enclosure around it has been built.

Although the layout of the stations has already been designed, their set up will be carried out in the next few months.

b. X-ray generation

During these months at the M3 building, the know-how developed at the University of Salamanca has been applied to design and acquire the equipment for an upgraded version of the experiment: an X-ray (bremsstrahlung) source from a laser driven plasma accelerator. It has also been measure the radiation emitted, which has enabled us to elaborate the associated radioprotection plan and its execution, building the adequate radiation shielding enclosure of this area.

Actions are being taken to achieve a license as third-category radioactive facility from the Spanish Nuclear Safety Council (CSN). An image system is expected to be incorporated shortly.

This HRR laser system is expected to be operative and open to users in mid 2013. However some of the industrial contracts of CLPU have been already using this system.

This lab is complemented by **two additional units**:

- ## Laser Oscillators Unit:

An optical table, pieces of furniture, fungible items and small equipment, such as a RF spectrum analyzer have been acquired to this unit. This unit will install a continuous wave (CW) solid-state laser at 532 nm approx. as pump system of Ti:Sapphire laser (CW and Kerr-Lens mode locking) and additionally, a diode laser to pump crystals laser.

This unit is giving already service to industrial users and for terahertz radiation sources.

- ## Microscopy Unit:

Since January 2013 CLPU offers to users a high resolution microscopy service through two complementary techniques: **Atomic Force Microscope (AFM)** and **Scanning Electron Microscope (SEM)**.

- AFM consists of cantilever with a sharp tip (probe) at its end that is used to scan the specimen surface. This technique provides topographic surface images in the range of a few nanometres. Under special conditions this resolution can reach atomic dimensions.

  This microscope was given by the University of Salamanca, where is still located. However, the CLPU manages the service, operating and maintaining the equipment.

  In a near future, this microscope will be brought to the facilities of the CLPU at the Scientific Park, but not until its definitive location is decided, due to the complexity of this system, and after the building of the appropriate enclosure.

- SEM technique can achieve image resolution around a few nanometres. This microscopy operates scanning the samples surfaces with focussed beam of electrons. This device is designed to run in two operating modes: high vacuum and variable pressure.

  The call for tender for this system was launched on February 19th, 2011. Finally, the contract for the supply, delivery and installation of this Scanning Electron Microscope EVO HD MA25 was awarded to Carl Zeiss MicroImaging, S.L. on June 6th, 2011 and signed on June 30th.

  The total budget for this microscope was 254.200,00 € (VAT not included) and the timeframe for the completion of the contract was three months. The final acceptance took place on September 29th, 2011.

Also in February 2012 and January 2013 the provider and the manufacturer gave training to the technological staff of the centre and also to collaborators from the University of Salamanca.

View of the AFM

View of the SEM

2.2.3.2 CEP Lab

The Salamanca group has a long tradition in theory (for many years) and experiments (more recently) on high order harmonic generation. Models as the attosecond generation from a relativistically moving mirror were made at Salamanca.

To continue take advantage of this expertise, this lab was included in the technical design report. The aim is to generate a source of high harmonics suitable for users and suitable for the development of a similar one to that of the Barcelona synchrotron (for pump probe experiments).

CLPU is exploring several ways to reach the water window (the soft X ray region between 2 a 4 nm wavelength) that clearly has a very high importance. These ways include generation in solid density plasmas, generation by bremsstrahlung, and harmonic generation in gases. For some of the most promising techniques of generation of gases, a CEP system seems the most suitable one. This is the reason why the CEP laser was chosen.

CEP lasers, i.e. lasers with control on the Carrier-Envelope-Phase, are few cycle systems where the offset between the carrier and the envelope is controlled and kept stable over a long time.

Besides high harmonics generation, CEP systems have a lot of other applications in coherent control and can be a useful tool for a number of groups in Spain working on femtochemistry. Some of those groups are already collaborating with Salamanca in the framework of the Consolider program or inside other national initiatives.

The main equipment of this laboratory, located in Lab 3 of the M3 building at the Scientific Park, is a **fully CEP-stabilized Ti:Sapphire Oscillator – Amplifier System** consisting of a dispersive mirror oscillator with CEP-stabilization module and electronics, a single-stage multipass amplifier with CEP-stabilization optics and electronics, and a hollow fiber compressor.

Laser	Energy per shot	Pulse duration	Central Wavelength	Peak power	Repetition Rate	Operation
CEP Laser	> 2 mJ	< 25 fs	790-810 nm	80 GW	1 kHz	Mid 2013
Post compressor	> 0.6 mJ	< 6 fs	800 nm	100 GW	1 kHz	Mid 2013

The laser has the following specs:

- The key characteristics of the oscillator are: dispersive mirror based architecture; active beam pointing stabilization of the CW pump laser; active beam pointing stabilization of the oscillator seed beam; temperature stabilized base plate
- The key characteristics of the amplifier are: single-stage multipass chirped pulse amplifier architecture; integrated acusto-optical programmable dispersive filter for dispersion management; CPA stretching to < 10 ps; monolithic glass stretcher; transmission gratings compressor; temperature stabilized base plate and Pockels cell
- The oscillator CEP-stabilization is based on Difference Frequency Generation scheme to detect beat signal and acusto-optical modulator to control the intra-cavity CE-phase slip, including feedback electronics
- The system is also equipped with a hollow fiber compressor and the corresponding chirped mirror compressor

The call for tender for this system was launched on July 26th, 2011. Finally, the contract for the supply, delivery and installation of this laser system was awarded to FEMTOLASER Produktions GmbH on October 19th, 2011 and signed on November 14th, 2011.

The total budget for the project was 639.100,00 € (VAT not included). The timeframe for the completion of the contract was six months. However, soon it became obvious that it wasn't possible to keep to the timetable.

As for the Phase two of VEGA, this system requires very restrictive conditions of temperature stability, control of humidity and cleanliness and air circulation system. These conditions couldn't be assessed until November 2011, when the premises at the M3 building were made available to the CLPU. Only then, it was possible to establish the technical specs for the cleanroom cabin ISO-6, composed of a laminar air flow hood and pvc curtains.

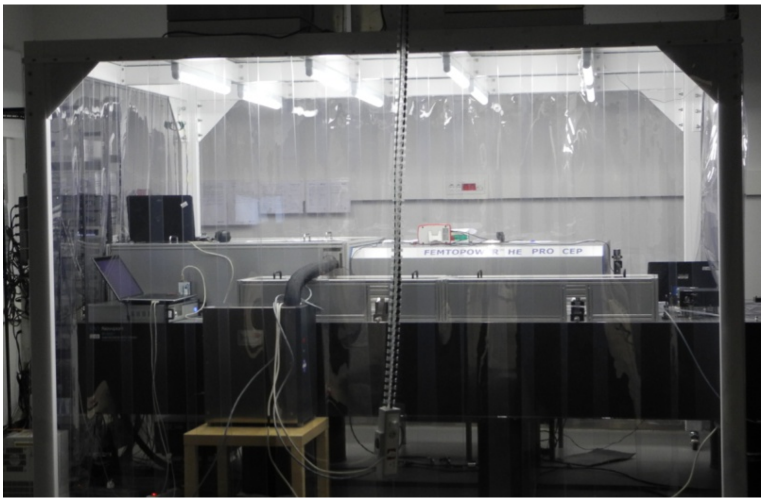
For this reason, the Executive Commission granted an extension of the deadline until September 2012.

The technological staff also studied and modified the chiller pump received from the University of Salamanca and installed an additional vacuum pump.

Some members of the technological staff and Prof. Iñigo Sola, from the University of Salamanca and coordinator of this lab, received training from the manufacturer in Wien, in June 2012. Also the Factory Acceptance Tests were carried out at that moment.

The Acceptance Tests in the M3 building, further training and the final acceptance took place in late July 2012.

View of the CEP laser



This system is one of the firsts CEP 4 in the world. CEP 4 is a new technology developed by Femtolasers that allows a better stability of the relative phase between the carrier and the envelope waves. Due to the innovative character and the extra stress that this technology puts into the oscillator crystal, we needed an extra time of about six months to have the system properly working for users.

2.2.3.3 Mechatronics Lab

The mechatronics workshop is a fusion of mechanical and electronic workshops. It is located in Lab 1 of the M3 building at the Scientific Park. It is operative and open to users since January 2013.

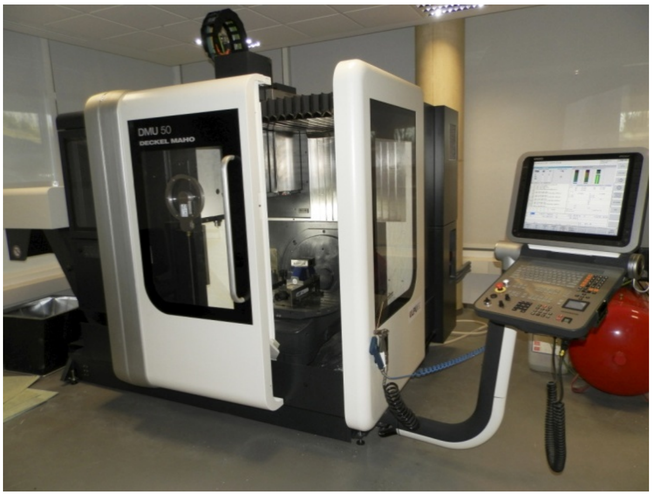
The most important equipment in this lab is the vertical continuous-five-axis-milling machine that can produce pieces of high complexity, from opto-mechanical mounts to customized prototypes. It is one of the few machines of this kind in Spain out of the aeronautical or the automotive sectors.

The call for tender for the vertical continuous-five-axis-milling machine was launched on July 26th, 2011. However, the tender procedure was declared unsuccessful by the Executive Commission on October 17th, 2011. This made necessary to start a negotiated procedure without publication on October 31st. Finally, the contract for the supply, delivery and installation of this machine was awarded to D.M.G. Ibérica S.L.U. on December 19th, 2011 and signed on January 5th, 2012.

The total budget for this acquisition was 194.500,00 € (VAT not included). The timeframe for the completion of the contract was twenty-four weeks. The final acceptance took place on June 13th, 2012.

Prior to the installation, and to prevent negative effects from vibrations in other equipments and labs, the floor was covered with a reinforced concrete slab. Beside, to achieve a proper sound insulation, an enclosure with acoustic treatment has been built around the mechanical workshop. The decibel levels comply with the current legislation on noise pollution.

In July and November of 2012 DMG Ibérica gave training to technological staff of the centre. The staff is also receiving gradual training since then from the provider of the software (MasterCAM) for the design and machining of 3D pieces.



View of the vertical continuous-five-axis-milling machine

The machining workshop is also equipped with a jig saw, a vertical drilling machine, a lathe and other tools for the fabrication of tailor-made complex parts that were also installed in June 2012. The workshop has an area for handling chemicals.

The electronic workshop is equipped for the design and production of customized circuits to be used on experiments that need different sort of sensors or actuators. There are also oscilloscopes and functions and delay generators.

Additionally, also in this lab it has been installed a rack that contains a cluster for accurate calculation and the CLPU server for the M3 building.

2.2.4 Further Activities

2.2.4.1 Radioactive safety

One very important point of all petawatt installations is radioactive safety. And this is particularly true for systems at high repetition rate as the Salamanca one.

To do this conveniently we have established a Radiation Protection Plan, that has received extra funds (1.500.000,00 €) from the central Spanish Government, through a directly awarded grant[4].

The targets of this Plan are to create a protection for the petawatt system and to set radioprotection standards for lasers with a peak power above gigawatt, which operate in Spain.

The main pillars of this plan are the measurement of the radiation generated (at each shot) with the validation of detectors for femtosecond use, the simulation of the experimental targets with codes as FLUKA and PENELOPE, and the generation of an interactive file that includes the most relevant date published so far.

The decision to elaborate our own software for the simulation of the interaction laser-matter and the delays related to the constructions of the CLPU headquarters (M5 building) and the documentation required by the Spanish Nuclear Safety Council (CSN) made necessary to extend the deadline until December 31st, 2014.

Nowadays, and with more than 20 man-years of work, the Plan is now close to completion, with regard to the definition of the target areas, the experimental stations and the needs of protection for safety. Of course it is the first time in Spain that a facility like that is considered, so the project is never fully completed in the sense that new experiments can be foreseen with extra requirements. Also some optimization work is always possible.

2.2.4.2 Detection

Optical detectors

Detecting a femtosecond pulse identifying its duration and its properties is extremely difficult. A focused pulse is like a microscopic bullet of moving obviously at the speed of light. This is difficult when the bullet contains milijoules of energy, and is almost impossible when it contains the 30 joules of VEGA-3. Being state-of-the-art technology it is precisely the challenge that CLPU needs.

CLPU will have a section devoted to ultrafast detection, with detectors such as SSA (Single Shot Autocorrelator), FROG (The Frequency-Resolved Optical-Gating), SPIDER (Spectral Phase Interferometry for Direct Electric-field Reconstruction), RABBIT,… some of them commercial and others specially prepared at CLPU to cover ranges not available with the commercial ones. The

[4] Royal Decree of October 19th, 2009 (Real Decreto 1592/2009), published in the Boletín Oficial del Estado (BOE No. 264 of 2nd November 2009)

detection division will offer also sending the detectors to other ultrafast labs in Spain to help with the ultrafast detection.

Other detectors

We have already mentioned the possibility of secondary sources. When ultra-intense lasers hit matter they create plasmas with very fast moving particles. Fast particles and femtosecond scale are the two key points for CLPU. This presents obviously new detection requirements that include:

- Detection of X-rays and gammas. CLPU will also have state-of-the-art technology in detection of soft X rays, Gamma rays up to 10 MeV.
- Detection of charged particles. Many new systems are going to be designed (most of them home built) to detect ions with energies ranging from several eV to MeV. Of course each range of energies will have its own specific detectors.

Fortunately CLPU is not alone, and users can turn into collaborators. In this respect it is fundamental to point out that Spain has a long tradition on collaboration on particle physics detectors, at CERN and at other international facilities. We are in contact with several key groups in Spain in order to use this know-how to develop femtosecond detectors suitable for petawatt experiments. This can be a surprising strength of Spain.

2.2.4.3 Metrology

Petawatt metrology is particularly relevant, because it is very difficult to measure such extreme fields. There is a preliminary agreement with Amplitude Technologies in order to set a measurement system after compression with unique features.

Spain has had a long tradition in optics metrology and we are establishing new collaborations to develop and to design new tools for measurement after compression. Such collaborations mean also new users, although in a non-conventional sense.

2.2.4.4 Training

The university origin of CLPU is one of its more important strengths. We consider that the collaboration with the University of Salamanca, first, and with other universities, later, is fundamental for the correct development of the centre.

The university gives training and degrees, something impossible from the laser centre. For this reason we have considered that the university must provide regulated laser training. The collaboration University-CLPU in this aspect can be very beneficial for both parts.

At present the University of Salamanca (in collaboration with the University of Valladolid) has a master program on Physics and Technology of Lasers. The expectative is to increase the already important implication of the centre in this program and to open other similar with other academic institutions.

3 Mission, Vision & Values

This Strategic Plan starts up with the definition of CLPU mission, vision and values.

Mission

The CLPU has a twofold mission, as stated in the Statutes of the Consortium for the design, construction, equipping and operation of the Ultra-short Ultra-intense Pulsed Lasers Centre (CLPU):

- On the one hand, to be a scientific and technological facility opened to the use of the national scientific and technological community. The infrastructure will also be open to international co-operation and will participate on European initiatives of co-ordination and collaboration.

- On the other hand, to develop experimentation and research in the field of pulsed intense lasers with its own scientific and technologic staff.

Vision

The Ultra-short Ultra-intense Pulsed Lasers Centre (CLPU) intends to become:

- A world-class user reference centre in ultra-short, ultra-intense lasers thanks to the singularity of its systems configuration, playing also the role of driving force and coordinator of all national facilities related to this field of knowledge.

- An active member of the international scientific community in search of progress through collaborative research and experimentation, especially in cutting-edge knowledge.

- A developer of emerging and leading laser technologies, applicable to commercial innovative projects in collaboration with industry.

- A social and economical invigorating element which meets the challenges and expectations assigned by the Spanish science and technology and innovation strategy.

Values

The referents that guide the Ultra-short, Ultra-intense Pulsed Lasers Centre (CLPU) performance are:

- Pursuit of excellence
- Commitment with knowledge
- Transparency in management
- Impartiality in granting access
- Equal opportunities policy
- Participation in technological and innovative development
- Environmental awareness
- Vocation for public service
- Social engagement

4 Critical Analysis

4.1 SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis

The Ultra-short Ultra-intense Pulsed Lasers Centre (CLPU) has assessed the internal position of the organization, identifying its main positive (Strengths) and negative (Weaknesses) aspects, to act directly on them, in order to either enhance/reinforce or eliminate them.

Besides, the centre has analysed its external environment and identified the factors that are likely to help (Opportunities) and hinder (Threats) its growth. Although these elements are beyond its capacity, they are taken into account for the design of strategies that allow to take advantage of them or to minimise their impact.

Strengths

- Only laser infrastructure in the Spanish Roadmap. Besides, its international singularity for being a facility with a petawatt laser that includes three arms with characteristics which are unique in the world.
- Optimal dimension, both in size and budget, of the facility compared to its potential added value that makes it a feasible challenge.
- Capacity to implement new applications and technologies in the field of lasers and to develop new technology and introduce this technology in new sectors.
- Initiatives undertaken during the construction phase of the infrastructure, which have set the basis for its activity and organization that will allow the centre to reach easily its cruising speed once the headquarters are officially open.
- International position reached, thanks to the participation in committees (ICUIL), projects (ELI, CILEX, IZEST, XFEL) and networks (Consolider SAUUL, LA3NET, LASERLAB).

- Probably it is unique in the sense that it is the only facility in the Spanish Roadmap with a mirror (ELI) at larger scale in the European Roadmap, and is included as Regional Facility of ELI in the ELI White Book.
- Synergies already developed with industry, throughout collaborative projects, both public and private (such as Innpactos, Innpronta), and cooperation with other Spanish research infrastructures (such as Barcelona Synchrotron or Seville national Accelerators Centre).
- High level of knowledge from a group of scientists belonging to our staff and the University of Salamanca who are experts in ultrafast ultra-intense lasers, particle physics and particle accelerators.
- Ongoing training of the scientific, technological and administrative staff, which maximizes their professional capacities in benefit of the centre.
- Recognition and support from public institutions, at national, regional or local level.
- Innovative management, focused on the implementation of a process-based management system, which allows continual improvement through objectives and indicators measurement.
- The implementation of the Centre in a medium size city is very attractive from the cultural point of view. Relation with one of the oldest Universities in Europe that soon will celebrate the 800 anniversary (in 2018).

Weaknesses

- Financing associated to budget items of other institutions, which guarantee the operation but not the in-house research, making it dependent of national and European subsidies and grants.
- Uncertain scenario beyond 2021, when, according to the Statutes of the centre, a decision shall be taken on the expiration or the extension of the Collaboration Agreement signed by the Consortium institutions. The operation of the centre depends on their financing.
- Little stability of scientific and technological staff, with the consequent risk of brain drain towards other European research facilities.
- Poor resources and tools for the attraction of international talent.
- Difficulties to get national and international large-scale projects due to the temporality and lack of stability of the scientific staff.
- Need for the centre upgrading in order to fulfil the requirements of a first category facility by the Consejo de Seguridad Nuclear (Nuclear Safety Council) and granting of licences.
- Lack of experience as user facility at very high power levels.

Opportunities

- High potential for development of laser technology, both in the manufacture of laser systems and in the promotion of users of this technology. Introduce lasers in completely new research and technological fields (biomedical, nuclear medicine, surgery, material science,...).
- We prefer to consider the low technological development in the Spanish industry in relation to femtosecond laser, more as an opportunity of CLPU since it can be the trigger for that. This is justified by several industrial projects in which CLPU participates.
- Possibility, through CLPU, of establishment in Spain of ELI's fourth pillar or to develop some Spanish laser elements that can be useful for the developing European Laser Facilities, as ELI or HIPER.
- Enhancement of national, regional and local development through the activities and projects of the CLPU.
- Academic context with a critical mass that enjoys a tradition of excellence research and teaching in the field of lasers.
- Increasing consciousness of the importance of R+D+i in the economic progress and the industrial development, both at governmental and stakeholders level.
- Development of regulations on safety and protection for similar future facilities.
- Open a large community of users of lasers and secondary sources that make CLPU profitable.
- Support from the new State Plan to the recruitment technological and management project staff.
- Support from most of the leading scientist of this field all across Spain.

Threats

- Competition with future international laser facilities.
- Financing of the centre, threatened by the global economic crisis and the budget cuts affecting the Consortium institutions.
- Scarce innovative culture in industry, especially in small and medium enterprises.
- New unexplored fields may not attract many users at the initial stages.
- Lack of advanced technological industries in our country can be an obstacle for an adequate technological transfer of the results.

- Attitude of society towards the implementation in their surroundings of a facility whose activity may have some influence in the environment.
- Excessive bureaucracy for the processing and justification of research projects and fragmentation of funding resources. Lack of a system for scientific auditioning of the research projects.
- Precarious employment conditions allowed by labour regulations, that don't allow stability and fidelity of scientific and technological staff and avoid the attraction of international talent.
- Lack of high technological qualification in the Spanish research system.
- Dispersion and lack of coordination between national facilities in the field of lasers.
- Poor connections to national and international transportation networks.
- Insufficient public services, including the electric supply in the area.

4.2 Relational analysis: National & international context

4.2.1 Spanish situation

Salamanca is since 2003 the Spanish reference place for ultrafast ultra-intense lasers. However in the last years a number of gigawatt and even terawatt-class lasers have been installed in our country. VEGA is the Spanish ultra-intense laser.

Except VEGA there is no other laser in Spain reaching the ten terawatt peak power level.

The most relevant lasers in Spain, in the peak power context, include:

- The second one is the system at the Basque Country University at Bilbao and the third one is the old ½ terawatt at the University of Salamanca. To our knowledge there are no other terawatt lasers in Spain. There is a multi-terawatt laser system under consideration (construction not yet started) at the University of Santiago de Compostela.
- There are several multi-gigawatt systems at Spain, at the Universidad Complutense, at the Basque Country University, at the Castellon University, at the Murcia University, as well as at several technological institutes at Bilbao, Vigo, and others.
- There is another very relevant system in Spain at ICFO, able to deliver 50 watts of average power at 5 kHz (5000 shots/second).
- Most of those equipments are collaborating though the Consolider SAUUL project entitled Science and Applications with Ultrafast Ultra-intense Lasers (SAUUL) coordinated from Salamanca by the CLPU Director.

The above list has been written on the basis of the information we have, it may not be fully complete. Moreover there is one company in Spain working on the construction of a terawatt laser system.

4.2.2 World Situation

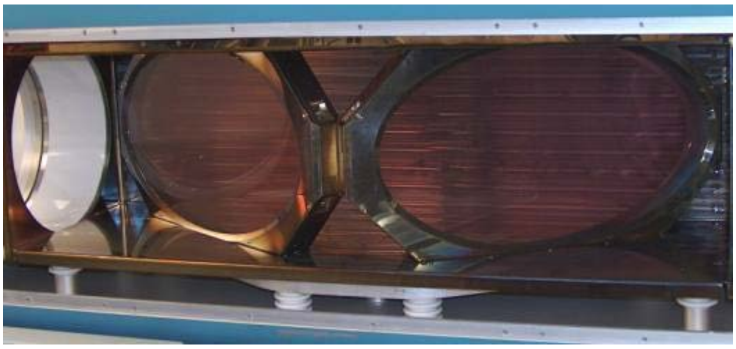
To understand better the international context of CLPU we must concentrate on big lasers. What is big now? Terawatt lasers are now commercialized, by many manufacturers, at prices below one million euros (for one terawatt, sub-picosecond, and repetition rates of ten shots per second, for example). Those systems are now reliable and compact. So it is not point to consider them in this survey. It is hard to say but there will certainly be in the world more than one thousand of such systems.

Reaching ten terawatt is a bit more complex because then a vacuum pulse compressor is needed. However, probably ten terawatt is the limit for a University laboratory. At the moment lasers above 10 terawatt peak power are considered as “big lasers”. There is a list of such systems around the world and they are listed in the web (https://lasers.llnl.gov/map/) prepared by the International Committee on Ultra-High Intensity Lasers (ICUILS), that was formed as an IUPAP Working Group. CLPU appears there. Our tables in this report are based on those data as well as on the information we have directly from the different laboratories.

A few lasers have already reached the petawatt level so far and some of them are under construction. The first laser to break the petawatt barrier was the Nova laser, built at the Lawrence Livermore National Laboratory at Livermore (LLNL), California. They claimed the 1.25 record on 23 May 1996. However, this laser was gigantic and in the long pulse region. Its repetition rate was very low, probably too low. This laser was soon dismantled and some of their key parts have been later used to build new petawatt lasers more reliable. Thus we can say that Nova was the seed of the PW technology across the word, but was the seed for energetic long pulses, more than for ultra-short ultra-intense pulses.

The Vulcan laser at Rutherford Appleton Laboratory, UK, was the first one to reach this barrier in Europe (using technology from Livermore). Phelix laser at GSI Darmstadt also has petawatt half picosecond pulses and uses also some of the Nova Livermore components. The Texas PW (at Austin) is also using some technology from the pioneering Livermore technology, but with many new features added.

The Texas PW laser bay, with the radioactive shielding at first plane.



A 31 cm amplifier disk of the Texas PW that comes from the dismantled Livermore Nova Laser

The petawatt is still now at absolute record of peak power in the world. The most powerful laser so far is the Korean one (APRI-2) arriving at 1.5 petawatt, there are two other that claim to be a bit beyond the petawatt. And that is all. The petawatt is the limit achievable with technology. At present, CPA technology has a limit not much beyond several petawatt due to the size of the grids needed for the compressor. This limit may be passed with modern developments as OPCPA. And this is relevant for CLPU since petawatt technology is the limit of reliable systems.

Going beyond the petawatt can be risky, maybe too risky, for a users facility. This was evidenced, for example, in the workshop entitled *Endeavours of the Petawatt*, held in Salamanca in June 2010. The multipetawatt technology is too unstable for the moment, and needs further developments.

Among other systems for the long term future, the laser with more possibilities to break a world record is Apollon CILEX, near Paris. It is under construction and has been planned as a 10 petawatt system, but with a milestone at 5 petawatt. The 5 petawatt system (75 J / 15 fs) implies OPCPA Ti:sapphire technology because of the very short duration of the pulses and is planned to be operative by the end of 2015. The 10 petawatt (150 J / 15 fs) will arrive after that. So, VEGA-3 is by design, power, and repetition rate, an extremely singular world class laser system.

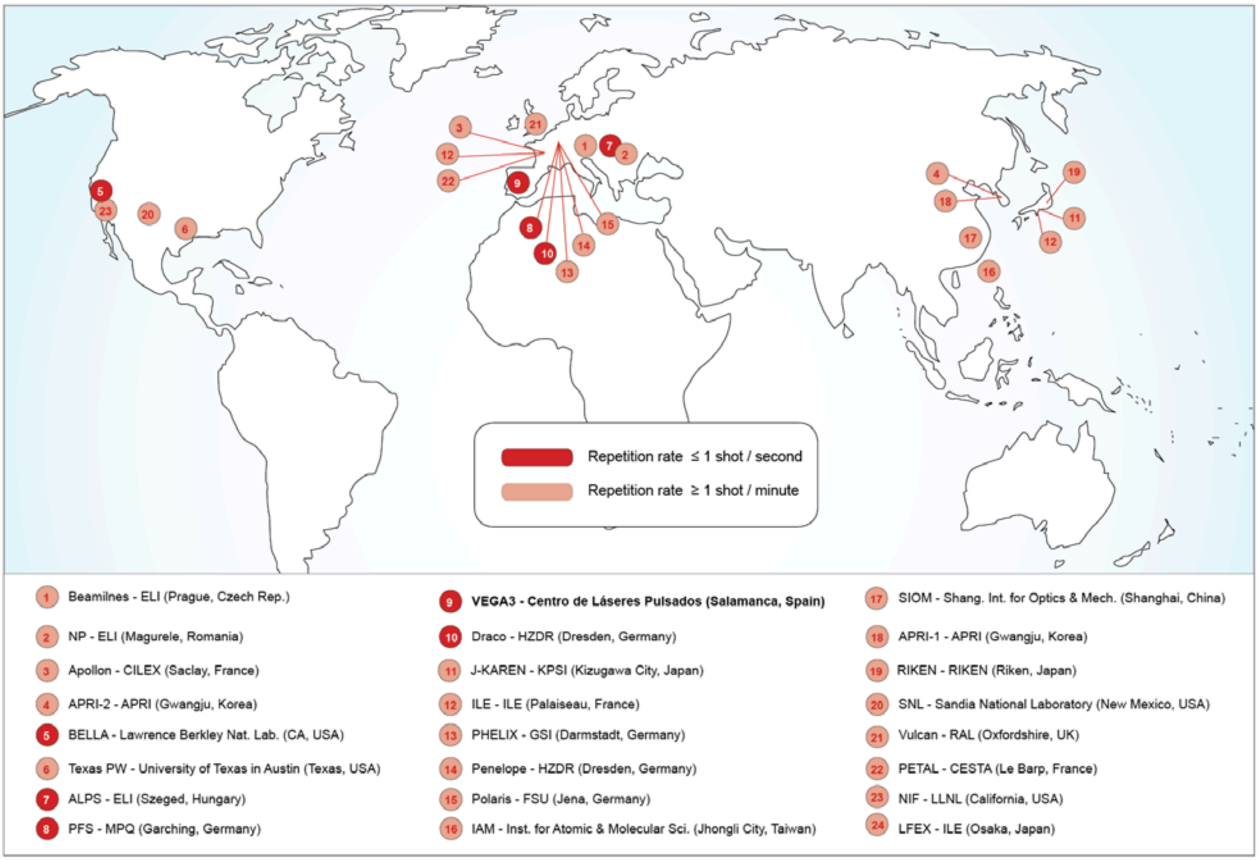
Apollon CILEX, as well as the Korean system works at 0.1 Hz, that means 1 shot every six seconds. The repetition rate of the different lasers is shown in the table below. A laser at one shot per second as VEGA-3 has nothing to do with a laser at several shorts per hour, particularly for a user facility. A user needs repeatability and statistics, so a one-shot-per-second laser is the state of the art at that power level. In this sense VEGA-3 is quite outstanding at world level. So far there is only one system, BELLA at California delivering 1 PW at one shot per second. Moreover the “small” laser VEGA-2 is one of the top 30 more powerful systems in the word, and if we consider the repetition rate of 10 Hz, its position is even higher.

The combination VEGA-3 + VEGA-2 will be unique in the world. So there will be experiments at Salamanca that could not be performed anywhere else in the world. Some of them have been already identified by the scientific team of CLPU. Observe that a 1.2 PW system can eventually be split in 1.0 PW arm plus a 0.2 PW arm. In that case the synchronization is better than it will be at Salamanca, but with the same repetition rate. In Salamanca there will be shots with the probe (0.2 TW at 10 Hz) without the pump (1 PW at 1 Hz). This can be very relevant for signal-to-noise ratios and for preparing extreme vacuum in certain cases.

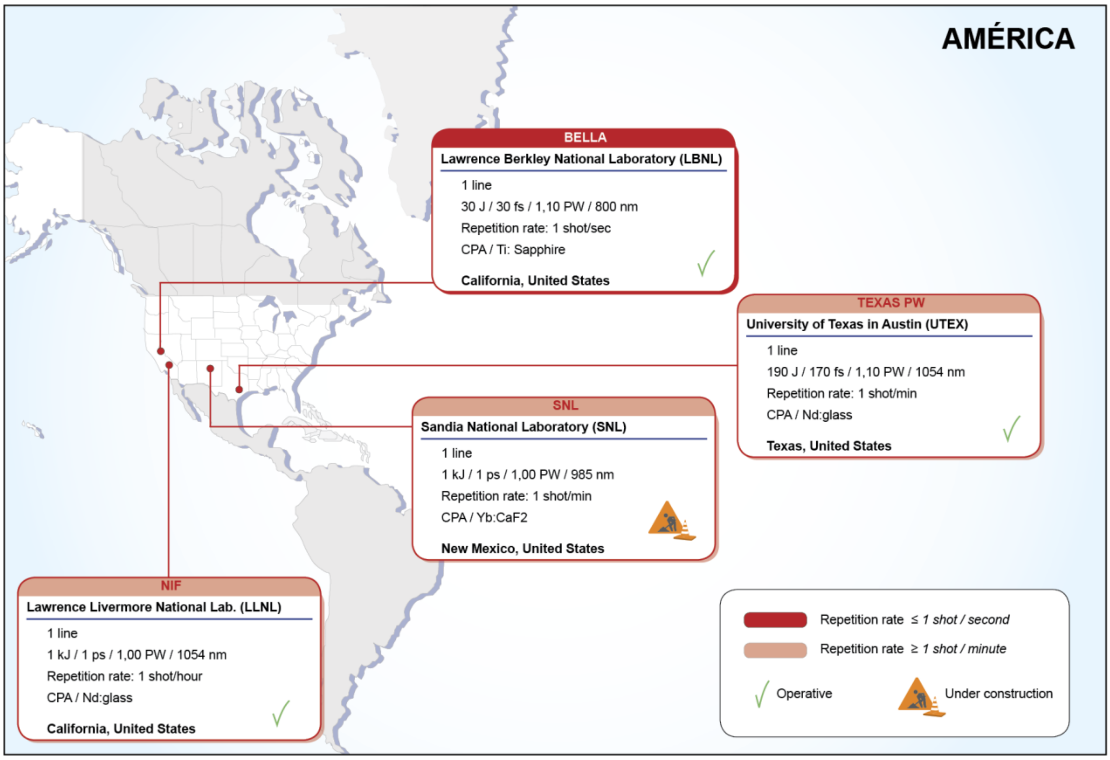
In the table we show a list of the most relevant lasers of the world. This list has been done at our best knowledge, but may not be complete or may contain mistakes. In any case an exhaustive list is not the objective of this document. The main purpose instead is to justify the singularity of these lasers. For simplicity we present in the table systems beyond 100 terawatt, since those are the only ones that can be relevant for the international context of CLPU. Exceptionally, two facilities (National Ignition Facility (NIF), already operative, and Megajoule, under construction) with systems below this power have been included, as they constitute two monster systems due to their huge number of beamlines.

	Name	Center	City	Country	Lines	Pulse length	Power per line PW	Repetition rate	Crystal	Situation
1	Beamlines	ELI	Prague	Czech Rep	2	15 fs	10,00	10 /min	Ti:Sapphire	2018
2	NP	ELI	Magurele	Romania	2	15 fs	10,00	10 /min	Ti:Sapphire	2017
3	Apollon	CILEX	Saclay	France	1	15 fs	5,00	6 /min	Ti:Sapphire	2015
4	APRI-2	APRI	Gwangju	Korea	1	30 fs	1,50	6 /min	Ti:Sapphire	Oper
5	BELLA	LBNL	California	USA	1	30 fs	1,10	1 /sec	Ti:Sapphire	Oper
6	TexasPW	UTEX	Texas	USA	1	170 fs	1,10	1 /min	Nd:glass	Oper
7	ALPS	ELI	Szeged	Hungary	1	5 fs	1,00	1000 /s	Ti:Sapphire	2017
8	PFS	MPQ	Garching	Germany	1	5 fs	1,00	10 /sec	Ti:sapphire	2015
9	VEGA-3	CLPU	Salamanca	Spain	1	25 fs	1,00	1 /sec	Ti:Sapphire	2015
10	Draco	HZDR	Dresden	Germany	1	30 fs	1,00	1 /sec	Ti:Sapphire	2014
11	J-KAREN	KPSI	Kizugawa City	Japan	1	30 fs	1,00	1 /min	Ti:Sappire	Oper
12	ILE	ILE	Palaiseau	France	1	15 fs	1,00	1 /min	Ti:Sapphire	Oper
13	PHELIX	GSI	Darmstadt	Germany	1	500 fs	1,00	1 /min	Nd:Glass	Oper
14	Penelope	HZDR	Dresden	Germany	1	150 fs	1,00	1 /min	Yb:CaF2	2015
15	Polaris	FSU	Jena	Germany	1	165 fs	1,00	1 /min	Yb:CaF2	Oper
16	IAM	IAM	Jhongli City	Taiwan	1	50 fs	1,00	1 /min	Ti:Sapphire	Oper
17	SIOM	SIOM	Shanghai	China	1	30 fs	1,00	1 /min	Ti:Sapphire	Oper
18	APRI-1	APRI	Gwangju	Korea	1	30 fs	1,00	6 /min	Ti:Sapphire	Oper
19	RiKEN	RIKEN	RIKEN	Japan	1	500 fs	1,00	1 /min	Nd:Glass	Oper
20	SNL	SNL	New Mexico	USA	1	1 ps	1,00	1 /min	Yb:CaF2	Constr
21	Vulcan	RAL	Oxforshire	UK	1	500 fs	1,00	1 /hour	Nd:glass	Oper
22	PETAL	CESTA	Le Barp	France	1	1 ps	1,00	1 /hour	Nd:glass	Oper
23	NIF	LLNL	California	USA	1	1 ps	1,00	1 /hour	Nd:glass	Oper
24	LFEX	ILE	Osaka	Japan	1	500 fs	1,00	1 / min	Nd:Glass	Oper
25	Astra Gemini	RAL	Oxforshire	UK	2	30	0,50	3 /min	Ti:Sapphire	Oper
26	Hercules	UMICH	Michigan	USA	3	30 fs	0,50	1 /min	Ti:Sapphire	Oper
27	Orion	AWE	Berkshire	UK	2	500 fs	0,50	1 /hour	Nd:glass	Oper
28	Omega EP	LLE	Rochester, NY	USA	64	10 ps	0,50	1 /hour	Nd:Glass	Oper
29	Scarlet Laser Fac.	OSU	Ohio	USA	1	40 fs	0,40	1 /minute	Ti:Sapphire	Oper
30	FLAME	INFN	Frascati	Italia	1	30 fs	0,33	10 /sec	Ti:Sapphire	Oper
31	SILEX	LFRC	Mianyang	China	1	30 fs	0,30	10 /seg	Ti:Sapphire	Oper
32	Trident	LANL	New Mexico	USA	1	500 fs	0,25	1 /min	Nd:glass	Oper
33	VEGA-2	CLPU	Salamanca	Spain	1	25 fs	0,20	10 /sec	Ti:Sapphire	2014
34	Salle Jeune	LOA	Palaiseau	France	1	35 fs	0,20	10 /sec	Ti:Sapphire	Oper
35	UHI	SLIC-CEA	Gif Sur Yvette	France	1	25 fs	0,20	10 /sec	Ti:Sapphire	Oper
36	Arcturus	HHD	Dusseldrf	Germany	2	30 fs	0,20	10 /sec	Ti:Sapphire	Oper
37	Draco	HZDR	Dresden	Germany	1	30 fs	0,20	10 /sec	Ti:Sapphire	Oper
38	SJTU	SJTU	Shanghai	China	1	25 fs	0,20	10 /sec	Ti:Sapphire	Oper
39	ALLS	ALLS	Varennes	Canada	1	25 fs	0,20	10 /sec	Ti:Sapphire	Oper
40	TIFR	TIFR-M	Mumbai	India	1	25 fs	0,10	10 /seg	Ti:Sapphire	Oper
41	LLC	LLC	Lund	Sweeden	1	50 fs	0,10	10 /sec	Ti:Sapphire	Oper
42	High Field	MBI	Berlin	Germany	1	30 fs	0,10	10 /sec	Ti:Sapphire	
43	DIOCLES	UNL	Nebraska	USA	1	30 fs	0,10	10 /sec	Ti:sapphire	Oper
44	LULI2000	LULI	Palaiseau	France	2	1 ps	0,10	1 / min	Nd.glass	Oper
45	Megajoule	CESTA	Le Barp	France	240	100 ps	0,04	1 /hour	Nd:glass	Const
46	NIF	LLNL	California	USA	192	100 ps	0,04	1 /hour	Nd:glass	Oper

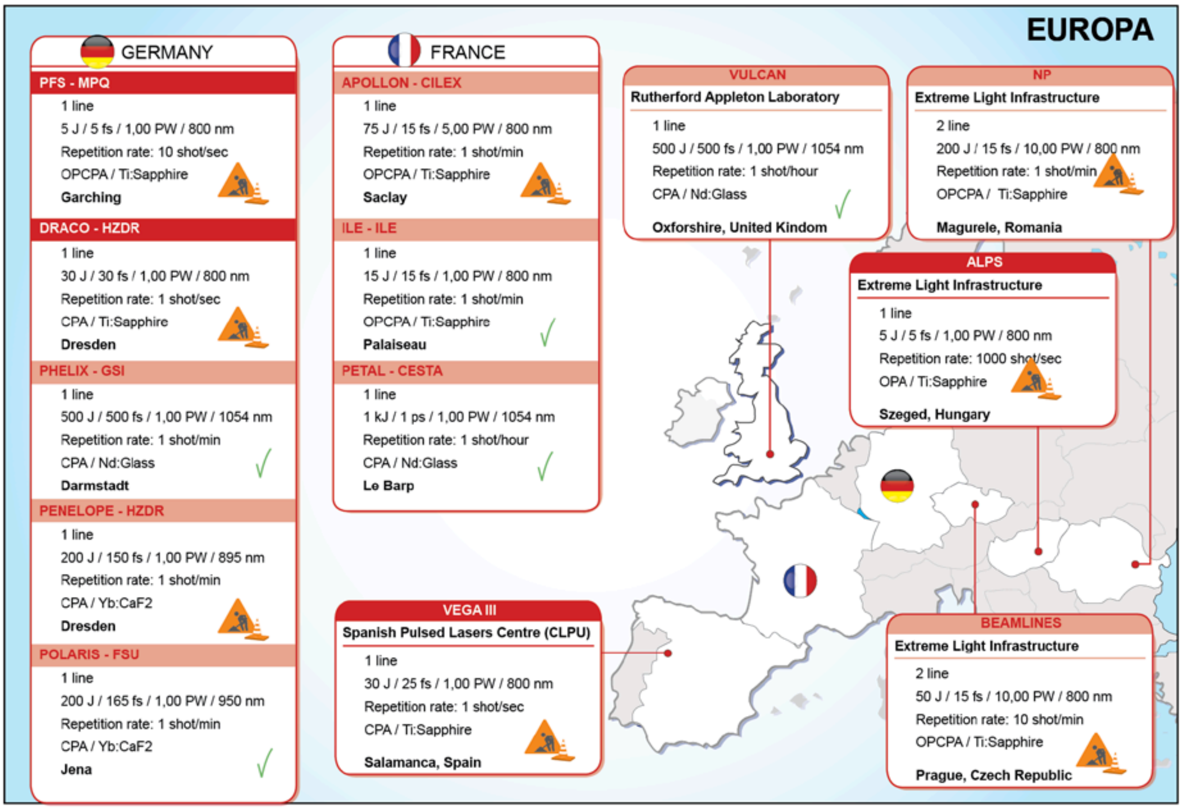
Table of the lasers around the world beyond 100 terawatt peak power. The table is based on the information available at the ICUILS web site and on the direct information we have. It may be incomplete.



Map of the operative and under construction PW laser facilities



American PW laser facilities



European operative and under construction PW laser facilities

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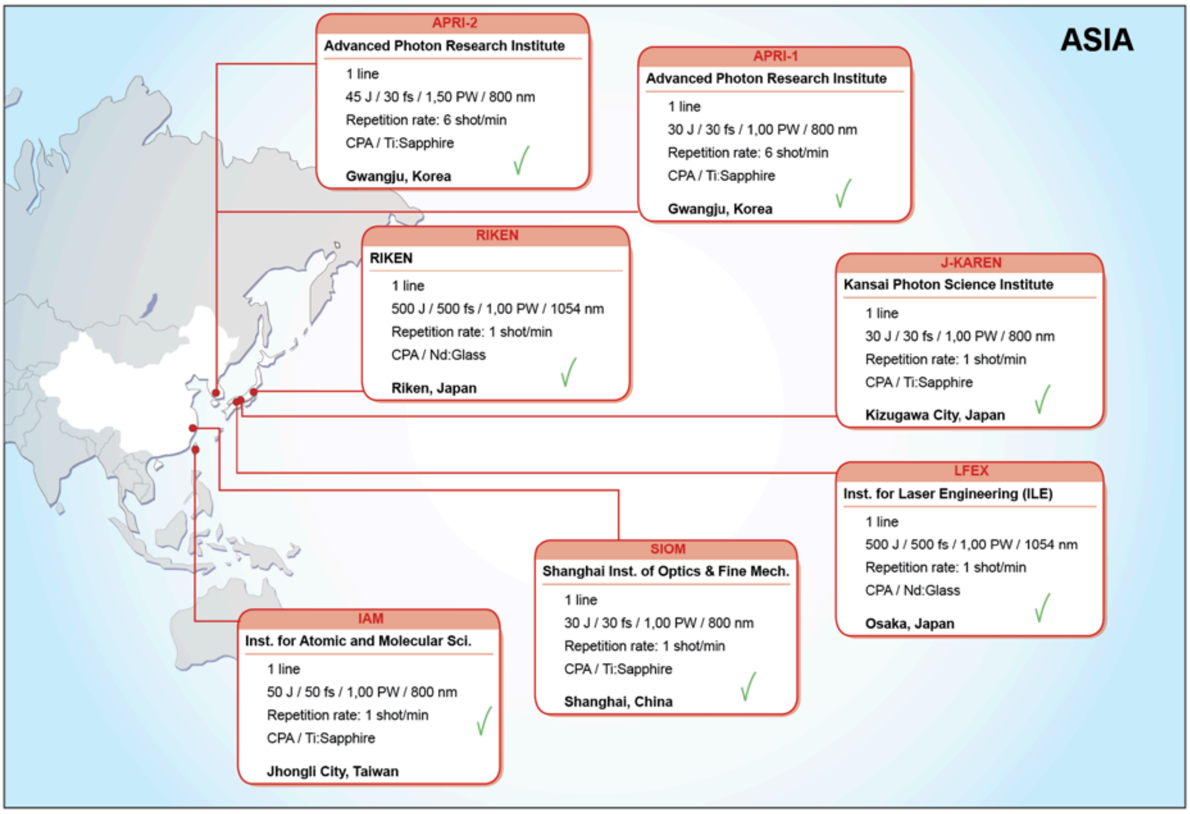


Asian operative PW laser facilities

4.3 Analysis of CLPU competitive advantages

Femtosecond lasers, and particularly intense femtosecond lasers do represent now a scientific and technical revolution. Those lasers, being ultra-short are broadband. They do not share the typical characteristics of a laser beam, they are more “light bullets” than laser beams. Moreover in the ultra-high intensity regime they ionize atoms, accelerate electrons and ions and present a completely peculiar phenomenology.

4.3.1 The CPA technology

The technology behind the lasers at CLPU is the so-called Chirped Pulse Amplification, CPA, technology. This way to amplify a picosecond or femtosecond laser was introduced in 1985 by Gerard Mourou and Donna Strickland at the University of Rochester (NY, USA). At the beginning this was an alternative to reach the terawatt peak power level. The terawatt power was obtained at the beginning of the eighties in Livermore with a monster system (called NOVA, now decommissioned). The word tera (terawatt) fit with the monster aspect of the laser itself (remember that tera come from the Ancient Greek word for monster). Mourou and Srickland work allowed in a few years the appearance of relatively compact terawatt lasers. In fact to stress that, the first of such systems where called T3 lasers (T-cube from Table-Top-Terawatt) stressing the fact that a terawatt is possible just on an optical table.

We comment on this because this gives sense to the Salamanca petawatt. The long-term main-objective of CLPU is to show that such technology is becoming more and more compact and that with a modest centre it is possible to enter such extreme technology to our country.

CPA technology is based on the idea that prior to amplification the pulse has to be expanded in time. There are many ways to do it, but the trick is to stretch the pulse in such a way that it can be finally recompressed after amplification to its initial duration. Thus common elements on such lasers are:

- A femtosecond oscillator, that generates a short pulse. However the importance is not exactly on its short duration, but on its broadband.
- A pulse stretcher, that introduces a convenient delay beteen different frequencies. Typically the pulse is stretched by a 10,000 factor.
- One or several amplification stages to give the pulse the necessary energy. Typically the first amplifier is a regenerative one and the others are single or multipass.
- A pulse compressor, to get the initial duration. Typically this is done with diffractive grattings. Beyond a few terawatt, the pulse compressor needs to work at vacuum.

CPA technology is mature and rapidly evolving towards simpler and more compact systems. One of the most recent advances in the field is the Optical Parametric CPA, or OP-CPA, that allows wider broadbands and shorter pulses. However this OP-CPA technology is still under development and we have considered just working with standard CPA technology and with pulses not shorter than 25 fs to avoid further complications. Looking again to the reliability issues we have decided to go to Ti:Sapphire technology.

Once defined such compromise between new technology and reliable technology we are starting to push it and its applications as much as possible.

4.3.1.1 Competitive advantages of the CPA technology

The most relevant point of the CPA is that it allows extreme fields with not-so-big equipments. The highest electric and magnetic fields on Earth are accomplished with such extreme lasers. At CLPU we expect to reach electric fields above 10^{12} V/cm. Those fields open new experimental possibilities, such as sudden acceleration of electrons an also of protons, with a lot of implications as accelerators. A petawatt laser is not going to be competitive in front of a standard accelerator (linear or circular) in flux or in stability. However a petawatt can accelerate electrons easily to several GeV. The advantage of the laser is its flexibility. The design and construction of a radiofrequency accelerator is complicated, ad quite rigid. In turn, the acceleration possibilities of a laser lie on the extreme fields, and on the way we are able to control the plasma generated by the same laser, are very diverse and one can easily jump from one geometry to other.

Acceleration, being perhaps the most interesting application of such extreme fields, is not the only possibility. At lower peak intensities (weaker laser of less tight focusing) the laser can still ionize atoms, without so much further acceleration after ionization. Such non-relativistic scenarios are extremely interesting for applications as laser processing, femtochemistry, filamentation, cold blade for surgery, … and many more. CPA allows now applications of the intense femtosecond technology that would have seemed utopian a few years ago.

4.3.1.2 Competitive advantages of CLPU using this technology

CLPU is the only user facility specialized in CPA technology in Spain. This gives us a fabulous competitive advantage at the same time that gives a high responsibility in doing this in a proper way. Besides to get users at the petawatt level, CLPU is involved in spreading the possibilities of this technology and the technology itself in Spain.

From the Spanish point of view, CLPU has the following advantages:

- First installation at the petawatt level, attracting the national community interested in this technology.
- First facility specialized fully on intense CPA, with a wide knowledge of the details of the technology that can be attractive to new industries, and with a high capacity for public-private collaboration in a novel technology starting from a very high point.
- Operation for more than ten years at lower level, with a long trajectory and relevant links already stablished.
- A versatility to attract potentially new users. We always say that for us the most welcome user is one that considers impossible that a pulsed laser can be relevant for his/her research or for their industrial process.
- Shortest laser pulses available to users in Spain.

From an international point of view, CLPU has the following advantages:

- There are just a few lasers operative arriving to the petawatt peak power, only one of them at 10 Hz. There are not more that 20 lasers in the worls beyond 100 terawatt at 10 hz. And to our knowledge, there is no other laser that combines both, as we plan to do with the VEGA different arms. ***This uniqueness in the world is our main competitive advantage.***
- Due to its origins and its participation to CPA technology from the very beginning, CLPU has already an international reputation on the field.
- Salamanca is the first petawatt going to be opened for general users. Other petawatts are opened just inside networks, as LaserLab Europe.
- A unique projection to introduce this technology in Latin America. Mexico is already considering a petawatt laser, and CLPU is helping in the definition of the project.

Moreover, there is one important difference of CLPU with other large facilities. We expect that users of the extreme features of our system come continuously for several campaigns. But, more importantly, we expect users that come to Salamanca, check the possibilities of the technology, decide with exact parameters what they need, and then buy its own laser system with the right performances. VEGA is an all-purpose unique laser. Many users will need, once optimized, a much smaller system. Of course, without the big system is not possible get such optimization. Moreover, on top of that, CLPU can trigger Spanish technology and Spanish companies that make such systems.

Just to summarize, CLPU approach is somehow similar to what has happened with computation. Big simulations are done in supercomputers, but many users start with a supercomputer and the go to a network of smaller systems. This is our advantage.

4.3.2 Versatility of the ultra-short laser pulses

One of the most important competitive advantages is the versatility of the CLPU lasers to search applications in all fields and the wide range we can offer in terms of peak power of the different systems, from GWs to TWs up to the one PW of VEGA-3, in such a way that the user will be able to check several possibilities in controlled environment. Most of the existing PW facilities go to extreme focusing to record intensities. This is fundamental for the development of physics, and will be done at CLPU. However CLPU is not going to be concentrated on that. There are many applications of the ultrafast pulses that require not-so-extreme fields but larger interaction volumes, and this is going to be particularly addressed since it can be more beneficial to trigger industrial applications (material science, ceramics, metals, biomedical, …).

Although CLPU will have a one petawatt laser operative, it is not expected that all users of CLPU require such extreme power. We consider more important to attract users at the terawatt or multi-terawatt level in order to create the know-how and the tradition in Spain to use such lasers. Without forgetting the petawatt users, users of lower powers will be specially considered. CLPU consider strategically this versatility in order to create the ultrafast ultra-intense community in our country.

Moreover, the pumping laser technology necessary for the petawatt will also allow new pumping schemes for the terawatt and gigawatt, so high repetition rate multigigawatt lasers will be possible in CLPU, and this has another set of potential users. CLPU has already started industrial collaborations in this line.

The objective of CLPU is pushing this technology in Spain and this has to complement the performance of the laser source, detection capability and the needs of the application. For this the collaboration of the potential users of the crucial CLPU is for the final design.

4.3.3 Radioactive safety

According to Spanish radiological protection regulations, an infrared laser is not ionizing radiation. Spanish regulations consider ionizing radiation sources below 100 nm wavelength. Therefore, CLPU systems at 800 nm are legally non ionizing sources. Of course the regulations were done considering “normal” infrared sources. VEGA is such an extreme system that is on a new region without clear regulations.

Something similar has happened in other countries. The situation in Spain is particularly significant on radioactive safety because of the lack of laser tradition in our country. This is very relevant because we have an opportunity to pave the way for the safety of new laser installations at the terawatt level that sooner or later will arrive to Spain.

The ultra-intense lasers are able to ionize atoms not only by pulling out the external electrons, but also the K-shell ones, and thus to generate free electrons with very high energy (even MeV), and at the same time to accelerate protons or iones. This means that some conventional radioprotection concepts must be reviewed and the legislation modified to have into account additional parameters apart from wavelenght, to define ionizing ratiation.

Of course several scientists of CLPU are specialized in ionization, and this has been foreseen from the early stages of the CLPU project. To get prepared on that, Salamanca took a relevant position in the generation of a radiation generation database in the framework of the Preparatory Phase of ELI. With this information, a specific project was presented to the Spanish PlanE initiatives, on creation of the Radioprotection Division of CLPU, coordinated by Prof. Francisco Fernández, Chair of Nuclear Physics at the University of Salamanca.

The existence of the CLPU and its implications in this point was mentioned for the first time to the Spanish Nuclear Safety Council (CSN) in 2010. Since then several meetings have taken place and many actions are in progress, all of them at the cutting edge of the technology.

CLPU has the advantage to be the installation that in Spain is used to define the safety needs for a laser. The experimental station for the generation of X-ray from a laser driven plasma accelerator will be the first radiative laser facility authorized by the Spanish Nuclear Safety Council (CSN) as 3rd Category (The petawatt laser system will be considered as a radioactive facility of 1st category). This is an outstanding precedent for other similar laboratories, and the research developed at CLPU and the results derived will set the basis for radiation safety in similar facilities, both national and international.

From the radiation point of view the laser accelerates particles and thus is an accelerator. However, there are many differential issues in this case such as:

- Extraordinarily high instantaneous flux at femtosecond scale. No other source is similar.
- Low average flux.
- Saturation of the detectors.
- Electromagnetic pulse generated by the target.
- Possibility of new kind of plasma shieldings.

Moreover CLPU is devoting a great effort to consider laser safety as a whole. There are many hazards relevant to safety, including:

- Radioprotection.
- Electrical hazards.
- Laser injuries in the skin and sub-dermic.
- Laser injuries into the eye (particularly the retina).
- Electromagnetic radiation bursts.
- Generation of nanoparticles.
- Chemical hazards.

4.3.4 Extreme Light Infrastructure, ELI

A few years ago a new type of large scale laser infrastructure specifically designed to produce the highest peak power and focused intensity was heralded by the European Community: the Extreme Light Infrastructure, ELI.

ELI is a European project dedicated to research in ultra-short timescales. The facility is based on four sites, or pillars, three of which are assigned to the Eastern part of the European Community: Czech Republic, Hungary and Romania. The highest intensity pillar (ELI IV) location is still to be decided.

ELI was designed to be the first exawatt class laser, equivalent to 1000 times the National Ignition Facility (NIF) power. This gargantuan power will be obtained by producing kJ of power over 10 fs. Focussing this power over a micrometer size spot, will bring forth the highest intensity. By producing, firstly, the highest electric field, secondly the shortest pulse of high energy radiations in the femto-zeptosecond regime and thirdly, electrons and particules with ultrarelativistic energy in the GeV regime, the laser signals its entry into Nuclear Physics, High Energy Physics, Vacuum Physics and in the future Cosmology and Extradimension Physics.

More precisely, ELI will be the first infrastructure dedicated to the fundamental study of laser-matter interaction in the ultra-relativistic regime ($I > 10^{24}$ W/cm^2). In practice, the infrastructure will serve to investigate a new generation of compact accelerators delivering energetic particle and radiation beams of femtosecond (10^{-15} s) to attosecond (10^{-18} s) duration. Relativistic compression offers the potential of intensities exceeding $I > 10^{25}$ W/cm^2, which will challenge the vacuum critical field as well as provide a new avenue to ultrafast attosecond to zeptosecond (10^{-21} s) studies of laser-matter interaction.

ELI will afford wide benefits to society ranging from improvement of oncology treatment, medical and biomedical imaging, fast electronics and our understanding of aging nuclear reactor materials to development of new methods of nuclear waste processing.

CLPU has been very much related with ELI form the initial steps. In fact CLPU Director was the Spanish representative of the ESFRI High Power Lasers committee that suggested the laser facilities eligible for European facilities. Salamanca coordinated the Spanish effort in the Preliminary Phase and now CLPU conveys the Spanish participation in ELI, as Regional Partner Facility of ELI.

ELI authorities have considered CLPU will help in the construction of ELI for cheking ideas and parts of the construction of their three pillars. Beside, the CEP, an attosecond beamline, can be relevant for the additional interaction with the ELI-Hungary.

One strength of CLPU, and of the University of Salamanca, as stated in the ELI Whitebook[5], is a high level training, transferred to the PhD Program and Master on Science and Technology of Lasers. Since multi-PW experiments are very demanding and expensive, in certain cases and for non laser-expert users training on the possibilities of such lasers and preliminary proof-of-concept

[5] ELI - Extreme Light Infrastructure – Whitebook - Science and Technology with Ultra-Intense Lasers, THOSS Media GmbH, 2011

can be done at CLPU at lower price and risk. Users having a clear experimental evidence that a PW is not enough for their needs are the ideal users of multi-PW facilities.

Not only CLPU is directly involved in ELI, other ICTS, the ALBA synchroton at Barcelona is involved in the ELI construction and we consider strategic to join efforts between these two infreaestructures as well as some high level research centers in Spain to push for the Spanish participation in ELI.

Beside, one clear strategic advantage of CLPU is that it can be very relevant for the installation of the so called fourth pillar of ELI in our country. On the basis of the ACI_Promociona Project (ACI2009-1008) specifically devoted to enhance the Spanish Participation at ELI, CLPU has undertaken a series of actions, the one most relevant for the future is the stablishment of the ELI4-Spain Lobby, a group of scientific leaders from diverent universities and research centers in favor of the installation in Spain of the fourth pillar of ELI. It is particularly relevant for this the synergy between CLPU and ALBA, as well as with other research centers.

4.3.5 CILEX

ELI represents a challenge in the laser technology pushed to the limit and beyond. To make the challenge feasible several countries have undertaken national actions to implement multi-petawatt systems. The most advanced of those national actions is CILEX (Centre Interdisciplinaire de Lumiere Extreme, or Interdisciplinary Center for Extreme Light). CILEX is constructing a 10 PW system, with a milestone at 5 PW, with absolute state-of-the-art-technology. CILEX 5 PW system is expected to be operative in 2016 at the Orme des Merisiers, reusing the bunker of a decommisioned accelerator, and very close to the SOLEIL French Syncrotron.

CILEX will probably be by 2015 the world most powerful system (75J/15fs) arriving to 5 PW with an exceptionally low duration –for that extreme power- of just 15 fs. It will be based on OPCPA technology and its construction will be relevant for the rest of the systems, including Salamanca (although VEGA pulses are longer, 30 fs, and based on simple CPA technology to ensure reliability). CILEX will have a long-focal target area and a short-focal target area.

The strategic strength of CLPU is that it has been from the very beginning close to the CILEX project. CLPU director has participated at the early stages and now is part of the Scientific Advisory Council of CILEX. Moreover, CILEX –that now is just a FRENCH project- will eventually be open to the international community, in that moment Spain and CLPU will be in a very good starting point.

4.3.6 User community

CLPU has the challenge to introduce laser technology in scientific and technical communities that never had considered a laser as a useful tool for their research work.

CLPU is going to represent a breakthrough in laser technology in Spain. To properly understand the implications of the centre it is worth considering that this kind of laser technology is advancing very rapidly. It is a revolution somehow similar to the personal computers revolution. Computers are each year much cheaper and much more powerful. Most of the calculations made ten years ago with a supercomputer are now feasible with a multiprocessor personal computer.

Applications of CLPU now regarded as avant-garde will become undoubtedly popular in twenty years, and the petawatt laser we are designing will be also archaic. But this is how technology develops. If the Salamanca Petawatt is used during some years to show the possibilities of the technology to its users, then they will be able to catch this laser revolution in good conditions. Otherwise, Spain will be, once more, out of one important technical revolution.

Therefore CLPU has to create in Spain the Ultrafast Ultra-intense users community. This community will be the external users of CLPU beams, but the most important thing, will be the ones pushing this technology and developments in twenty years from now.

Besides, prospective studies shall be carried out among users to analyse data, such as the expected experiments to develop at the facility or the most requested systems and instruments, in order to help CLPU to establish scientific priorities, define the target areas, point out problems and formulate further improvements.

4.3.7 Consulting for lasers

We strongly believe that intense femtosecond lasers are going to arrive to many laboratories and industries, and not necessarily to people specialized in lasers. As well as many biologists and chemists use now synchrotron radiation, many will be using in the next decade such lasers. CLPU will be the key facility to introduce this technology in Spain. Being common do not mean that they are cheap or easy to operate for non specialists.

CLPU will provide training and consulting for scientists or technicians facing to introduce these new devices. A convenient orientation, with preliminary experiences at Salamanca, may result in a sharp acquisition of exactly the necessary equipment without useless parts. Convenient preliminary training may result in a reduction of errors and a reduction of accidents, since these systems work and will always work close to the damage threshold of their components.

4.3.8 Wide range of applications

Another competitive advantage is the outstanding range of applications, at the disposal and request of the scientific and technological community, thanks to the versatility of the CLPU lasers. Moreover CLPU is involved specifically in finding new applications to incorporate new scientific and technological teams as potential users of the femtosecond intense technology. These fields include many applications that are summarized in the following table and explained briefly below.

The table below shows the most relevant groups of possible applications of the Salamanca CLPU. The applications are listed in powers of ten (10 GW, 100 GW, 1 TW, and so on). They do not coincide with the peak powers of the different CLPU systems. Of course when possible, it is preferred to go to the smallest systems (that also coincides with the highest repetition rate).

Laser					Application
Peak power	Intensity W/cm^2	Pulse duration	Rep rate	Other requirements	
>10 GW <100 GW	10^{15}	< 120 fs	Khz		Photonic structures
	10^{15}	< 120 fs	Khz		Micro/nano processing
	10^{15}	< 120 fs	Khz		Femtosecond micromachining
	10^{15}	< 120 fs	Khz		Laser Induced Breakdown Spectroscopy
	10^{15}	< 120 fs	Khz		Low order harmonic generation
	10^{15}	< 120 fs	Khz		Surgery (femtosecond) cold blade
	10^{17}	< 120 fs	Khz		Soft X ray generation
	10^{15}	Few fs	Khz	CEP stabiliz.	High harmonic generation in tunnel regime
	10^{15}	Few fs	Khz	CEP stabiliz.	Attosecond pulses
>100 GW <1 TW	10^{16}	30 fs	10 Hz		Ionization channeling and filaments
	10^{16}	30 fs	10 Hz		Multifilamentation and its control
	10^{16}	30 fs	10 Hz		High harmonic generation in barrier supression regime
	10^{18}	30 fs	10 Hz		KeV electron acceleration
	10^{18}	30 fs	10 Hz		Soft X ray generation in vacuum
>1 TW <10 TW	10^{17}	30 fs	10 Hz		X ray lasers
	10^{17}	30 fs	10 Hz		High harmonic generation in barrier supression regime
	10^{18}	30 fs	10 Hz		MeV electron acceleration
	10^{18}	30 fs	10 Hz		KeV proton acceleration in gases
	10^{18}	30 fs	10 Hz		Brehmsthatlung in the water window
	10^{18}	30 fs	10 Hz		Deuterium - deuterium fusion
	10^{18}	30 fs	10 Hz		
	10^{19}	30 fs	10 Hz		keV proton acceleration in solid targets
>10 TW <100 TW	10^{17}	30 fs	10 Hz		Multifilamentation
	10^{18}	30 fs	10 Hz		Extreme high vacuum detection
	10^{19}	30 fs	10 Hz		Multi MeV electron acceleration
	10^{19}	30 fs	10 Hz		Relativistic filaments
	10^{19}	30 fs	10 Hz		Coherent X-Ray diagnostic
	10^{19}	30 fs	10 Hz		High contrast X-Ray imaging
	10^{19}	30 fs	10 Hz	High contrast	Plasma mirrors

>100 TW < 0.5 PW	10^{19}	30 fs	10 Hz		Plasma mirrors
	10^{19}	30 fs	10 Hz		Nuclear Physics
	10^{19}	30 fs	10 Hz		Novel neutron sources
	10^{19}	30 fs	10 Hz		Particle acceleration
	10^{19}	30 fs	10 Hz	High contrast	Nuclear Pharmacyshort lived isotope production
	10^{20}	30 fs	10 Hz	High contrast	New radiation sources for medical applications
	10^{20}	30 fs	10 Hz		Extreme high vacuum production
	10^{20}	30 fs	Hz		Intra operatory radiation therapy
	10^{20}	30 fs	Hz		Novel techniques in nuclear beta decay
	10^{20}	30 fs	Hz		Proton-therapy superficial
Close to 1 PW	10^{15}	30 fs	Hz		All of the above using a cm scale waists
	10^{17}	30 fs	Hz		All of the above using mm scale waists
	10^{19}	30 fs	Hz		Electron bubble acceleration for 30 fs pulses
	10^{19}	30 fs	Hz		Electron bubble acceleration for 30 fs pulses
	10^{20}	30 fs	Hz	High contrast	Proton acceleration al MeV ranges with large currents
	10^{22}	30 fs	Hz		Extreme electron acceleration at GeV ranges
	10^{22}	30 fs	Hz	High contrast	Extreme proton acceleration at multi MeV ranges
	10^{22}	30 fs	Hz	High contrast	Inner-body proton therapy
	10^{22}	30 fs	Hz		Pump-probe nuclear spectroscopy
	10^{22}	30 fs	Hz		Pump probe plasma analysis
	10^{22}	30 fs	Hz	High contrast	Vacuum polarization and minicharged particles
>> 1 PW	10^{23}	30 fs			CILEX and ELI limit frontierland

1. **Micro/nano machining.** Laser radiation is a unique tool for machining any material. Due to the short time, the material remains unchanged and therefore its physical or mechanical properties are not altered.

2. **Threshold damage of materials.** No known material can resist the impact of a conveniently focused femtosecond laser system.

3. **Nanoparticles generation.** The femtosecond laser ablation produces intense ionization in part of the material. These ions drag something from the surrounding material and form nanoparticles.

4. **Analysis of microdroplets.** Microdroplets, or clusters made of about 10^{10} atoms, may have a very interesting dynamical behaviour in a laser field because its diameter is comparable with the laser wavelength.

5. **Photonic structures.** With the femtosecond laser we can drill holes or just be close to the damage of the materials and induce permanent refractive index changes.

6. **Simulation of radioactive damage** to an electronic circuit. Since a sufficiently intense femtosecond pulse is able to ionize the material, it is possible to perform a conduct preliminary analysis of the damage by using this type of lasers.

7. **Glue laser welding.** The laser is something good attached in many industrial fields. Solder femtosecond is conceptually different because you can create a very fine tip ablation with a minimal amount of molten material. The result is an extraordinarily good welding quality.

8. **Surface preparation in industry.** Femtosecond laser processing of a surface can increase its resistance to friction and thus its duration. The structural changes produced at the surface by the ultrafast laser are conceptually different from other laser processing procedures.

9. **Surface treatment for medical prosthesis.** As with other material surfaces, laser processing of a surface can increase its resistance to friction and thus its duration, something extremely important for medical applications.

10. **Second and third harmonic generation** of femtosecond pulses. Femtosecond laser systems based on Ti:Sapphire technology produce pulses in the range of 700-900 nm. For many applications other spectral ranges are required.

11. **Femtosecond spectroscopy.** It allows to view the motion of atoms and molecules. During the process, atoms or molecules are subject to two laser fields with some delay. The first pulse supplies the energy for the reaction and the second probes the resulting dynamics.

12. **Femtosecond tunable lasers.** One of the advantages of having a sufficiently intense pulse is that you can generate a continuous, meaning it can make a material irradiated at a level strong enough not only to emit at the incoming frequency but to lase in a continuum of frequencies.

13. **Laser Induced Breakdown Spectroscopy**. LIBS is a type of atomic emission spectroscopy which utilises a highly energetic laser pulse as the excitation source. LIBS can analyse any matter regardless of its physical state, be it solid, liquid or gas.

14. **Applications of LIBS in biomedical science**. Laser-induced breakdown spectroscopy with femtosecond lasers can be applied to the study of calcified tissues such as tooth and bone. In vivo detection of caries in teeth or biopsies of hard tissues when the usual methods do not work fine are some of the applications of these techniques

15. **Cold scalpel.** A blade that cuts without thermal damage is a conceptually different tool for medical use. In most cases the final scare is reduced because the walls of the scare are biologically intact.

16. **Femtosecond nanosurgery** of cells and tissues. Femtosecond lasers can be used to modify the structure of cells and tissues in the nanoscale. These nano-modifications can be induced by several processes such as plasma formation in water, thermoelastic stress generation or stress-induced bubble formation

17. **Femtosecond osseous tissue surgery.** Femtosecond lasers have been used to cut bone tissue without generating temperature transients which inactivate proteins. This way, cellular membrane integrity is disrupted for only a few layers (less than 15 microns) making such lasers a great tool for non-invasive bone surgery

18. **Femtosecond dental surgery.** Femtosecond lasers have been proven a great tool in minimal invasive treatment of carious tissue and can achieve more precision than longer pulse lasers and mechanical tools due to the absence of cracks and thermal damage in the surrounding area

19. **LASIK surgery with femtosecond laser**. Currently, the femtosecond laser poses considerable advantages over the conventional laser both in the preparation of the flap as in the carving of the corneal stroma.

20. **Phacoemulsification with femtosecond pulses**. The application of laser eye surgery is very widespread. One of the most common eye diseases is opacification of the lens (cataract). Modern techniques for extracting the

crystalline resort to a pre-emulsification (phacoemulsification). It is possible to produce phacoemulsification with femtosecond pulses.

21. **Laser ablation of the lens** to improve presbyopia. Presbyopia occurs when the lens loses its power of accommodation. Very preliminary studies indicate that conducting a series of cuts in the interior of the lens in an appropriate manner by a femtosecond laser can correct presbyopia in part because the crystalline loses some of its excessive rigidity.

22. **Intracellular noninvasive femtosecond ablation**. As the cellular membranes are nearly transparent to IR radiation, femtosecond pulses of Ti:Sapphire laser systems propagate inside the cell and can be successfully used for high precision surgery manipulating subcellular organelles.

23. **Intracellular cavitation.** Femtosecond lasers can generate a cavity at the focal point, and still leave the cell alive. This is going to be a brand new basic tool in cell biology.

24. **Strong field femtochemistry.** Femtochemistry is the study of the dynamics of chemical reactions with femtosecond temporal resolution.

25. **Time-gated imaging.** The short temporal duration of femtosecond pulses makes them suitable for been used as stroboscopic lamps. Events occurring at a very short time scale can be "frozen" by illuminating with femtosecond pulses.

26. **Soliton light.** Just before the onset of ionization, intense lasers can propagate in the form of Townes solitons. This is a new propagation regime discovered in Salamanca.

27. **Ultrafast laser axicons.** The properties of these pulses are controllable so that it is possible to generate Bessel beams or axicons. They are light beams that are spread out very differently than conventional (Gaussian beams) do and have no diffraction.

28. **Vortices of light.** When you have enough intensity you can manipulate the way that a large part is lost but the remainder have unexpected properties. One of these is the generation of vortices of light.

29. **Atmospheric femtosecond optics**. Propagation of ultrafast ultra-intense light in the atmosphere gives rise to many new effects due to the extreme nonlinear propagation.

30. **Filament ionization.** Filaments are nonlinear propagation lines that do not diffract. This is due to the ionization and the plasma channel generated that balances collapse due to Kerr effects.

31. **Short lived electrical wires**. Since filaments are evanescent wires, we can induce electrical discharges in air or another gas that go along the filament

32. **Laser lighting rod**. The possibility of having femtosecond lightning rods is being under consideration for the protection during storms of key buildings

33. **Generation of high-order harmonic**. In the same way that the nonlinear effects in most materials are capable of generating harmonic order under (the third harmonic is relatively common.

34. **Terahertz radiation.** The "terahertz region" (10^{11}-10^{13} Hz) is a spectral region were sources and detectors are rare, although in the last years there has been an increasing number of improvements. Recently, it has been shown that a laser

filament can produce coherent radiation in the region of 0.1 THz.

35. **Pulses of light with a single optical cycle.** Usually we understand a laser beam as a monochromatic wave. Obviously, in the case of femtosecond pulses this is not possible and pulses have to cover a frequency band much broader. This can lead to the limit and take pulses of a single cycle or nearly so. This is where the pulse electric field makes a single oscillation.

36. **CEP pulses.** The stabilization phase, CEP, or Carrier-Envelope Phase stabilization, is another technique that has been developed very recently. Without reaching the edge of a single cycle, but taking pulses of few cycles, it is important to know which is the phase of the field at the time of maximum amplitude. Depending on the purpose of this pulse of this phase should be different. In CLPU it is intended to make available to users a system of CEP.

37. **Ultrahigh electric fields.** With a laser we can generate electric fields unreachable with static techniques. It is obvious that the laser is a wave and therefore those fields will not be static but oscillating. But the period of an infrared laser is 2.6 femtoseconds. That allows a huge field during a fraction of femtosecond, that at macroscopic scales is not much time, but at the atomic scale opens a new frontier. In CLPU we expect to reach electric fields above 10^{12} V/cm.

38. **Ultrahigh magnetic fields.** For similar reasons, Gigagauss magnetic fields are possible.

39. **Relativistic electrons.** Electrons at the focus of a petawatt field can be accelerated to MeV energies in just one femtosecond or two. This is the fastest particle accelerator ever made.

40. **Microsatellites laser.** Ablation plume can give the momentum needed for propulsion, while energy comes from the laser. It is a conceptually the scheme for lasers that can soon be used for microsatellites.

41. **Water window femtosecond lasers**. It is a window in the X-ray domain of the electromagnetic spectrum where oxygen and carbon have different absorptions. It can be used to see proteins in cells

42. **Exoenergetic nuclear fusion.** Petawatt lasers are suitable to induce D-D fusion reactions in deuterated targets. This is not relevant for energy production, but it is a promising neutron source.

43. **Femtosecond plasmas**. We can create electron relativistic plasmas far from equilibrium.

44. **Plasma mirrors**. At very high intensities, above 10^{18} W/cm^2 a laser incident on a solid target can create in a few femtoseconds quite dense plasma of electrons moving at relativistic speeds. On the few femtosecond scale, electrons have no time to thermalize and the plasma dynamics opens new fundamental applications. Among them the most rema

45. **Relativistic optical elements.** Continuing in the line described above, plasma mirrors are easily accelerated to relativistic speeds. Such extremely fast oscillations give rise to new unsuspected properties, as Doppler shifts. The most relevant one is the generation of attosecond pulses or the generation of trains of attosecond pulses.

46. **Nuclear isotope transmutation**. The possibility of transmuting long lived radioactive isotopes into short lived ones

which by decaying very fast do not represent any storage thread, is one challenging applications of ultra-intense lasers. A preliminary proof of principle of this idea has been demonstrated with iodine 129.

47. **Nuclear Medicine.** The lightness of the laser head can open conceptually new applications, by sending the laser to points otherwise inaccessible.

48. **Nuclear Pharmacy.** As indicated, lasers may substitute cyclotrons in the future to produce the tracer isotopes at a lower cost and with fewer requirements. The idea of having smaller plans of nuclear pharmacy seems very attractive since the transportation of such isotopes is not a trivial issue.

49. **Laser-induced Positron Emission Tomography**. Lasers may substitute cyclotrons in the future to produce the tracer isotopes at a lower cost and with fewer requirements. This will eventually spread the use of PET scanners.

50. **Laboratory astrophysics.** The plasmas at the focus of a petawatt laser mimic —for a few femtoseconds— some of the extreme conditions existing in the interior of certain stars. Therefore the so called laboratory astrophysics has been developed recently as an alternative branch of observational astrophysics.

51. **Proton therapy.** One petawatt is a bit too low intensity to accelerate protons to energies relevant for proton therapy final applications. However, the energy of the protons is mainly related to the intensity at focus than to the peak power. It is possible, thus, that a very good focusing of the Salamanca Petawatt makes some of these applications feasible.

52. **Laser dosimetry.** The use of femtosecond pulses intense enough may result in ionizing radiations. The measurement of those radiations is a bit different than the conventional dosimetry in the sense that all dose arrives at a sudden time (less than a picosecond) and detectors can saturate.

4.4 Socio-economic impact analysis

4.4.1 Geographic information

Salamanca is a city in north-western Spain, the capital of the province of Salamanca in the community of Castilla y León. Its Old City was declared a UNESCO World Heritage Site in 1988. It is situated approximately 200 km (120 mi) west of the Spanish capital Madrid and 80 km (50 mi) east of the Portuguese border.

The University of Salamanca, which was founded in 1218, is the oldest university in Spain and the third oldest western university, but the first to be given its status by the Pope Alexander IV who gave universal validity to its degrees.

The Scientific Park, sponsored by the University of Salamanca, is located in the municipality of Villamayor, very close to the city of Salamanca. The Scientific Park opened its door five years ago to research, development and innovation and has become a major economic force in the province of Salamanca. At present, 32 companies and institutions and almost half a thousand workers are offering their services from the five buildings of the Park. Thanks to their synergies new initiatives are being launched, allowing the expected transfer of knowledge.

The development plan for the Scientific Park foresees its division in three different areas:

- At the north, Biotech Area *(pending)*
- At the east, Innovatech Area
- At the south, Agrobiotech Area

Biotech Area

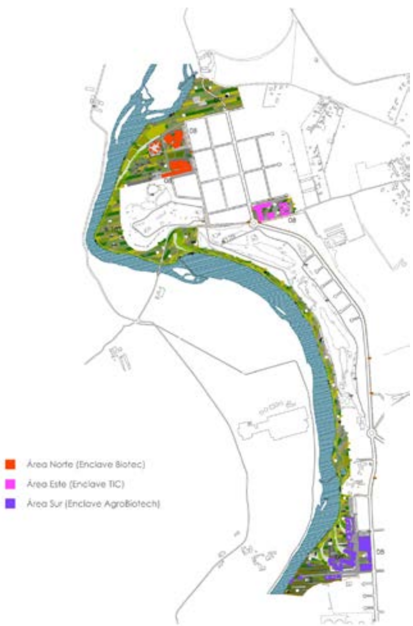
Innovatech Area

Includes:

- M5 building (CLPU headquarters)

- M3 building (4 CLPU laboratories)

Agrobiotech Area



Scientific Park of the University of Salamanca

4.4.2 Demographic information

The population of the province of Salamanca is around 352,000 inhabitants (0.5% less from 2010).

The metropolitan population is around 160,000 inhabitants. Salamanca attracts every year thousands of international students (30.000), generating a diverse and cosmopolitan environment.

The population density is 29 inhabitants per km^2.

The province has a high aging rate, in comparison to the national average: 24% of the population is more than 64 years old, whereas the average is 17%.

The 5% of the total population are foreigners, of which 43.7 % are from Europe, 35.6 % from Latin America and 16% from Africa.

4.4.3 Economic activity information

4.4.3.1 Economic activities around CLPU

The economical sector distribution in Salamanca is:

- Agriculture 5.5 % (Spanish rate 2%)
- Industry 11.5 % (Spanish rate 14%)
- Construction 8.3% (Spanish rate 8%)
- Services 74.7 % (Spanish rate 77%)

Besides, Salamanca is the most important university city in Spain and supplies 16% of Spain's market for the teaching of the Spanish language. Therefore, the university is, together with tourism, a primary source of income in Salamanca.

The unemployment rate is 20.76% (Spanish rate 25.1%).

4.4.3.2 Scientific & Technological activities around CLPU

The main scientific & technological activities of this area rotate around the University of Salamanca, the CSIC (Spanish National Research Council) and CLPU.

The USAL hosts more than a hundred "Acknowledge Research Groups" (GIR) that belong to all scientific fields. These groups are formed by researchers and professors who share the same or complementary lines of work. This allows them to participate in international, national or regional calls to obtain funds. Besides, the USAL also houses more than forty Groups of Excellence of the Junta de Castilla y León.

The University Research Institutes are focused on the scientific, technical or artistic research and also on postgraduate and doctorate programmes. The USAL hosts 9 institutes, one of them jointly with the CSIC. Some of these institutes are:

- Instituto de Biología Funcional y Genómica (IBFG)
- Instituto de Física Fundamental y Matemáticas
- Instituto de Neurociencias de Castilla y León
- Instituto Universitario de Biología Molecular y Celular del Cáncer
- Instituto Universitario de Ciencias de la Educación (IUCE)
- Instituto Universitario de Estudios sobre la Ciencia y la Tecnología

The CSIC comprises a network of centres and institutes distributed throughout the country, including joint centres run in conjunction with universities, regional governments and other organisations.

The CSIC's centres and institutes are classed in eight major scientific and technological areas based on the type of the research they perform. In some cases the lines of research carried out in a given centre or institute are such that it is assigned to more than one scientific or technological area.

Some of the CSIC centres located in Castilla y León are:

- Estación Agrícola Experimental (EAE) - León
- Instituto de Biología y Genética Molecular (IBGM) - Valladolid
- Instituto de Biología Molecular y Celular del Cáncer (IBMCC) - Salamanca
- Instituto de Microbiología Bioquímica (IMB) - Salamanca
- Instituto de Recursos Naturales y Agrobiología de Salamanca (IRNASA)

4.4.3.3 Scientific & Technological activities around the laser field

CLPU and the University of Salamanca concentrate the most important know-how in Spain related to pulsed lasers.

In December 2003 the Optics Department of the University of Salamanca inaugurated a femtosecond laser. Since then, singular projects have been developed, some of them in collaboration with other research and academic institutions, such as the Synchrotron Alba Cells or the University of Seville. Projects involve different research lines as for example, filamentation in gases, or materials micro-processing. In particular, some efforts were devoted to the generation of gold nanoparticles, with biomedical applications or to nano-composites generation from ceramic materials. These investigations, among others have positioned Salamanca on the avant-garde of the laser field.

4.4.4 Foreseen socio-economic impact

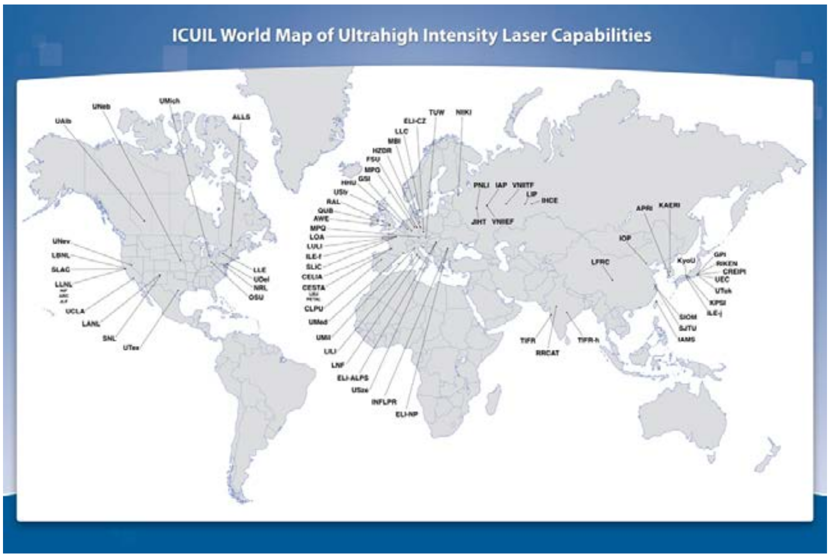
4.4.4.1 Geographic impact

CLPU will draws international attention to the city of Salamanca at scientific level through the positioning of the centre into some of the most prestigious maps of scientific infrastructures, such as those of Laserlab Europe, ICUIL or the Spanish ICTS map.

Map of Laserlab-Europe Facilities

[Laserlab-Europe] brings together 28 leading organisations in laser-based inter-disciplinary research from 16 countries. Together with associate partners, Laserlab covers the majority of European member states. 20 facilities offer access to their labs for European research teams.

The International Committee on Ultra-High Intensity Lasers (ICUIL), already mentioned in point 4.2.2. “World situation”, is an organization actively concerned with the growth and vitality of the whole international field of ultra-high intensity laser science, technology and education.



ICUIL world map of ultrahigh intensity laser capabilities

The Spanish roadmap for unique scientific and technological infrastructures (ICTS) has been designed to improve and increase the competitiveness of science, technology and innovation in Spain. The ICTS provide services to the scientific and technological community as an essential tool in developing cutting-edge, top-quality science and technology in our country, and to promote the transmission, exchange and preservation of knowledge and the transfer of technology[6]. CLPU, as part of the ICTS system, shares the same missions.

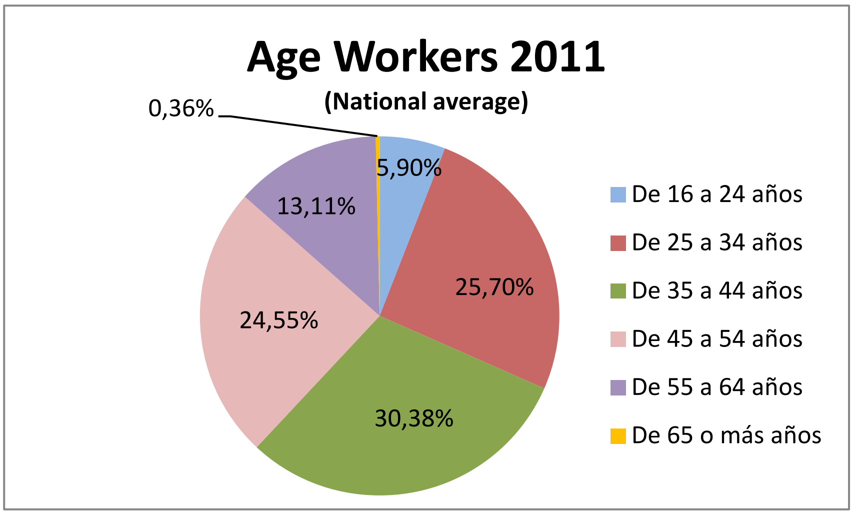
Spanish roadmap for Unique Scientific and Technological Infrastructures

6 Information from “Spanish RoadMap for Unique Scientific and Technological Infrastructures”, Ministerio de Ciencia e Innovación, 2010

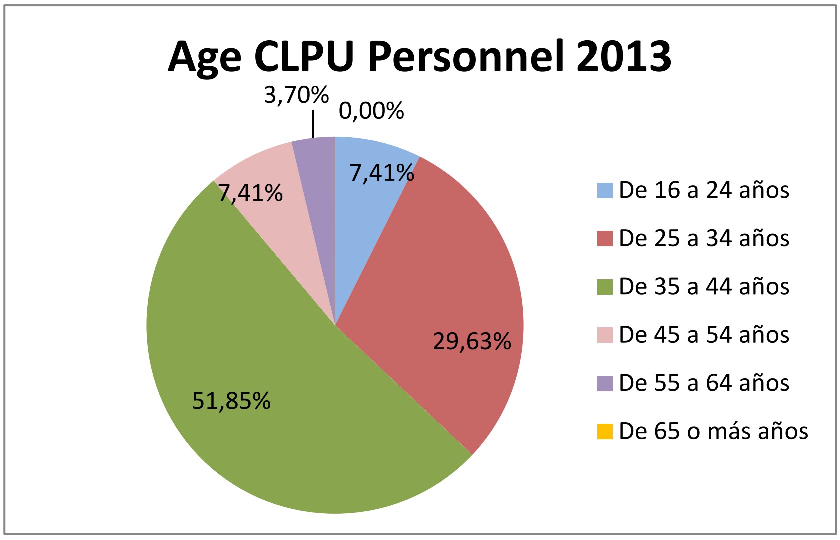
Salamanca is included in the trans-European road network and the trans-European high-speed passenger rail network, although not in the airports network. The development and growth of the area as a scientific and technological focal point might call for the reconsideration of this circumstance.

4.4.4.2 Demographic impact

Besides, the creation of these ICTS infrastructures plays an important role in the economic promotion of businesses near the facilities. CLPU, as any of these infrastructures, will bring advantages, such as the fixing of working age population and the improvement of aging ratios.

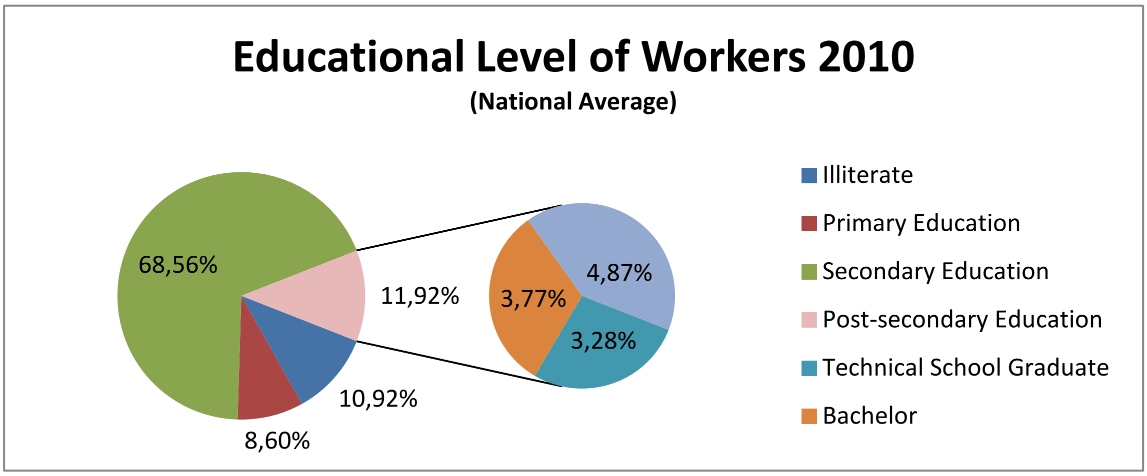


Age of Workers according to National Statistical Institute (INE)

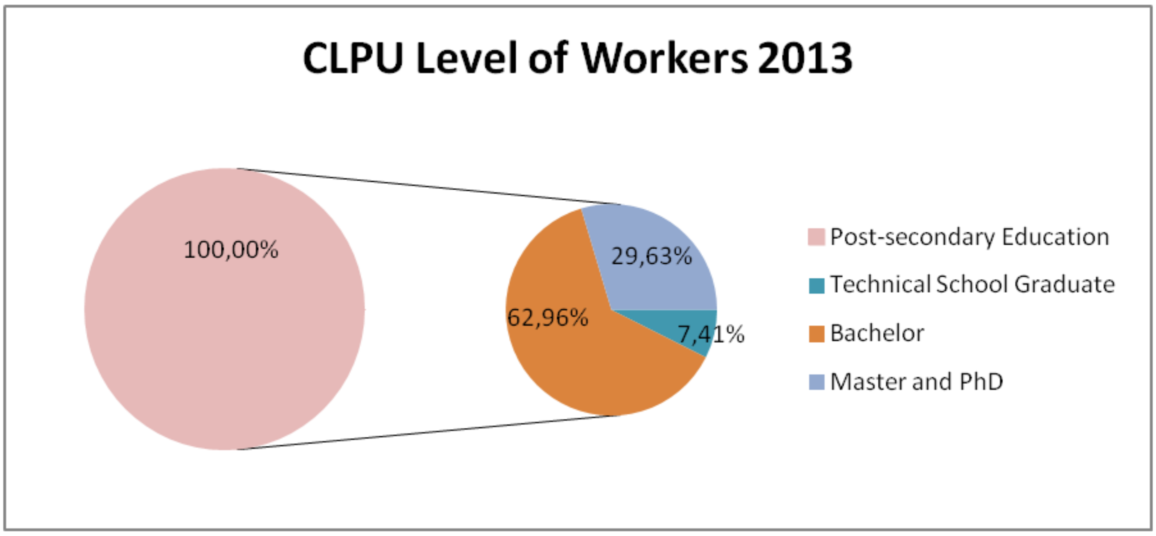


Age table of CLPU staff

CLPU foments highly qualified employment. Additionally, it will also attract other national and international foreign users.



Spanish Educational Level of Workers according to National Statistical Institute (INE)



Educational Level of CLPU staff

All this can contribute to the demographic development of the area surrounding the facility, especially in Villamayor.

4.4.4.3 Economic impact

- According to the recently issued "Innovation Union Scoreboard 2013"[7], a comparative assessment of the research and innovation performance of the EU27 Member States, Spain is categorized into the group of "Moderate innovators", ranked 16 in list of EU-countries, with a performance below the European average.
- In this sense, in order to improve its consideration in Europe, Spain must improve many aspects, such as patent revenues from abroad and the science-based sector (entrepreneurship).
- In a closer geographical context, only 4.4% of the innovative companies existing in Spain during the period 2009-2011 were established in Castilla y León.

In order to improve this statistics, CLPU may contribute by

- Establishing synergies with SMEs, especially in the regional environment, in order to increase their investment in R+D+i.
- Increasing the up-to-now low-rate industrial sector, enhancing the innovative companies based on laser technology
- The expansion of the role of the Scientific Park of Salamanca into a Technological Park, improving the services in the area is also foreseen with the thrust of the centre.
- Other important objective of the centre is the encouragement of a know-how in the nearby academic circles.
- All this will contribute to increase the possibilities of Spain as part of the ELI project, attracting European investments.

[7] http://ec.europa.eu/enterprise/policies/innovation/files/ius-2013_en.pdf

4.5 Analysis of capacity of use

4.5.1 Annual capacity

The installation of a petawatt system is far from trivial, and its performance at full power on a target, particularly a solid target, has a lot of risks not only for the technological staff but also for the machine itself (for example debris that enters back the compressor …). For that reason we have planned a diagram for gradual operation of the Centre, particularly the VEGA system.

VEGA-1 and VEGA-2 are going to be operative at M3 from July 2013. This does not mean full operation of them. They are going to be operative just for commissioning of experiments, for training of the technicians and for testing the technology. With those restrictions, they are going to be partially opened to users. It is scheduled that this part last about one year, until summer 2014.

Related to operation of the systems, the milestones are:

- VEGA-1 and VEGA-2, in a restricted mode, operative at Lab4 M3 from July 2013.
- Installation of VEGA-3 at M5 ends in September 2014.
- After that VEGA-1 and VEGA-2 must be moved from M3 to M5 for integration with VEGA-3.
- Full integration of the three arms of VEGA is expected, therefore, at the end of 2014.

VEGA-3 by itself is never going to be operational for users. It will be operative a few weeks for internal training and for control of all the involved variables. Once that is clear, it will be integrated with VEGA-2 and VEGA-1, with the aim to get a laser unique in the world.

All these considerations are needed to justify that 2013 and 2014 the whole VEGA system is not going to be opened to users. In 2015 due to the integration with the experimental stations, it will have a limited operation time that is going to be extended in 2016 until arriving to the full performance of the system in 2017.

Experiments at PW level are complicated, some preliminary tests can be due on days, but this seems very unusual. An experimental campaign can last for several weeks of beam time (plus the weeks needed for preparation), so we plan to distribute the time in weeks of beam time (a user can be at Salamanca one or two weeks in advance to prepare the experimental set-up. During those weeks, the user can have reduced access beam if possible, to test the set up).

The distribution of the weeks we propose is the following:

Year 2013.- This year is essentially devoted to the installation of VEGA-1 and VEGA-2 and the start of its operation.

- During 10 weeks, VEGA-1 and VEGA-2 opened for commissioning of experiments, as well as internal training of interaction with users.

Year 2014.- This year is essentially devoted to the installation of VEGA-3 and the global integration of the three arms.

- During 10 weeks, VEGA-1 and VEGA-2 opened for commissioning of experiments, as well as internal training of interaction with users.

Year 2015.- This year is the beginning of the petawatt operation. During this year a lot of effort to develop experimental stations has to be done, reducing consequently the beam time for users. It is not possible to prepare such stations without beam time, reducing consequently the beam time for users. Our plan is:

- 20 weeks beam time for users
- 10 weeks preparation of the experimental stations
- 22 weeks for maintenance[8]

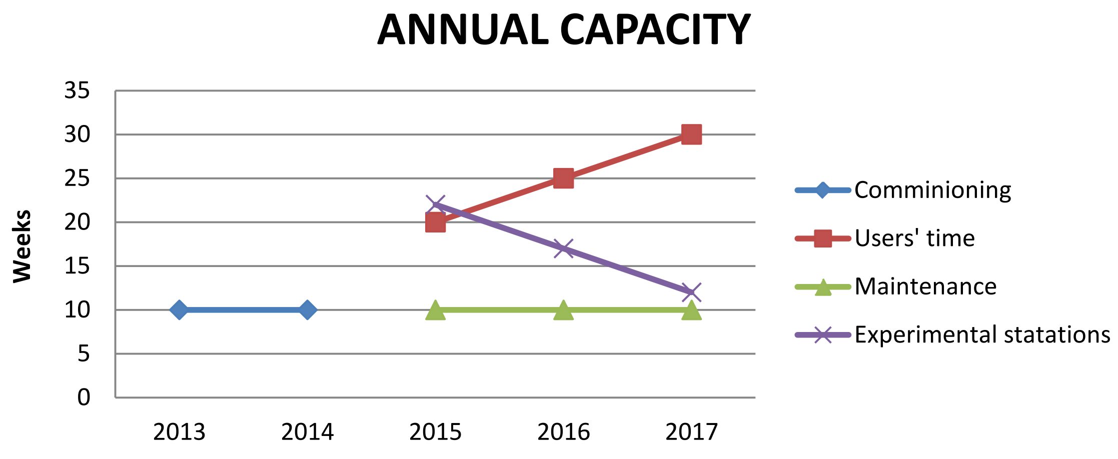
Year 2016.- This year is the consolidation of the petawatt operation. During this year we plan to end the construction of some stations useful for different purposes. It is not possible to prepare such stations without beam time. Our plan is:

- 25 weeks beam time for users
- 10 weeks preparation of the experimental stations
- 17 weeks for maintenance

Year 2017.- Although this year is out of the time span of this report, we consider to include it since it will be the first year of steady operation. Our plan is:

- 30 weeks beam time for users
- 10 weeks preparation of the experimental stations
- 12 weeks for maintenance

[8] *The term "Maintenance" includes preventive, predictive and corrective maintenance, configuration and updates of the laser system*



Educational Level of CLPU staff

4.5.2 Opening to users

4.5.2.1 Potential users

CLPU users community is slowly but steadily formed by several actions, including:

- The first and the second users meeting. Our idea is to have one every December in order to make publicity of the potentialities of the centre, to listen their needs, and to create working groups between users that share similar needs.
- Bilateral contacts with research centres and companies. Those include other ICTS, Universities, research centres, companies, technological parks, …

Potential users of CLPU include: Laser and Optics specialists, of course; Low energy nuclear physicists, cell biologists; material sciences researchers; surface treatment experts; all communities interested in micro/nano processing; nuclear medicine experts; surgeons; molecular chemists; art works curators; and many more.

For this reason, and based in our previous experience at the University of Salamanca, we are completely sure that CLPU will generate a new ultrafast ultra-intense community in Spain.

In five years of the operation period we are sure that many scientists that today do not even imagine what is a femtosecond laser, will be able to make novel studies in their fields thanks to the present effort.

In conclusion, the construction of CLPU at Salamanca is a unique opportunity to develop a pole on laser science and technology in our country.

The main opportunity and perspective of CLPU is to operate for the first time in the history of Salamanca world class laser system, attracting scientists and technicians from all over the world.

Besides keeping its tradition on optical lasers, Salamanca can be a key piece in the development on laser induced nuclear physics, or photo-nucleonics. Spain has a long tradition in particle physics and for the first time this community is becoming interested in petawatt lasers.

If this goal is successfully achieved Salamanca has also a chance to host the fourth pillar of ELI and has also a chance to establish conceptually new relations with other European facilities as European XFEL or Laserlab Europe.

But all this goes through the correct operation of the petawatt (operation of the systems and development of novel target areas). And during the forthcoming years all CLPU main effort must go in that direction.

4.5.2.2 Preferential Lines of Research

Taking into account the European, national and regional policies on scientific research, technological development and innovation, access will be preferentially granted to projects that tackle societal challenges, such as:

- Medical imaging
- Development of new molecules for medical therapy
- Sustainable nuclear energy
- Reduction, capture and storage of CO_2
- Protection and preservation of the cultural heritage
- Development of innovative technologies and solutions that address security gaps and lead to a reduction in the risk from security threats
- …

Besides, priority will be given to research that ensures the efficient transfer of knowledge into industrial innovation.

4.5.2.3 Access System

An Access Protocol is being elaborated at present. Its main document is the Access Policy.

The access system depends on complexity and features of the different systems and equipments.

There are **two ways of access**:

- ## Competitive Access

It is the foreseen access for the development of basic research, applied research and scientific and technological transfer projects/experimental development that require the Petawatt Laser System (VEGA). The access will be granted through an open and competitive process, after the evaluation of the proposals by the appropriate assessment bodies.

CLPU will publish one or several calls for proposals per year, depending on the available or assigned resources.

- ## Non-Competitive Access

Proposals included in this category may be submitted at any time upon if required:

- VEGA laser system, in case of industrial or commercial proposals or public-private or public-public partnership proposals. It will be also applicable for urgent proposals, proofs of concept, exploration of CLPU further potential or extension of ongoing experiments.
- other systems and equipments, provided the offer of time exceeds the demand.

4.5.2.4 Assessment Bodies

- ## Internal Committee

The internal committee is in charge of:

- Elaborating and publishing the call for proposals.
- Assess technical feasibility, availability of material, human and economic resources and safety of all proposals.
- Assess of the alignment with strategic objectives and scientific merit of non-competitive access proposals.
- Analysis of urgency of projects, if necessary.
- Prioritising, if necessary, the proposals to which competitive access does not apply.
- Review and decide the administrative appeals filed by access applicants.

Access Committee

The Director of CLPU will invite experts in high power laser field to enter the list of referees. Experts shall work on different research lines. At least one of the members shall be a member of CLPU staff and the rest shall belong to national and international institutions, different from those of the Consortium.

The internal committee is in charge of:

- Giving advice to the Director of CLPU on the allocation of beam time to those proposals with higher quality and scientific interest.
- Studying, assessing and writing a report on the proposals received by the centre, according to the general assessment criteria and, if applicable, the particular criteria established for the call.
- Elaborating a prioritized list of proposals.

4.5.3 Limiting factors of use

It should be noted that in spite of being open to the international scientific and technological community, the Salamanca Petawatt has been paid basically with Spanish public money and its benefit must, partially at least, return to the Spanish sector. This will be encouraged, but maybe will also be a limiting factor due to the lack of fund at present in many national institutions.

Three main groups of limiting factor may be considered:

Technological Limiting Factors

VEGA is going to be one of the first systems in the world, if not the first, 1 PW / 1 Hz open as user facility combined with a 200 TW / 10 Hz synchronized line. Ti:Sapphire technology at 25-30 fs has been selected because we consider that this is the most reliable technology to arrive to the petawatt at such repetition rate. However there is a lack of tradition in the world with such systems. Most relevant technological limiting factors include:

- Misalignment or slight malfunctioning of the system resulting in the degradation of some of the laser parameters such as contrast ratio, beam quality, final pulse duration (with particular emphasis on users that require beam conditions close to the limit).
- Target area development, because target area is going to be design at the beginning on a very basic scheme in order to increase its complexity and potentiality progressively.
- Detection systems, due to the same reason.
- Centralized control of the systems, in order to get data from the laser pulse as well as data for the detectors and to integrate in the system detectors brought by the users.

Limiting Factors related to Safety

VEGA is going to be the first laser facility that generates ionizing radiation and needs license from CSN (Consejo de Seguridad Nuclear, Spanish Nuclear Safety Council). The obvious requirement of the highest degree of safety requires the integration of several complex requirements, particularly the integration of laser safety with nuclear safety. At CLPU early stages this can be a limiting factor since the combination of requirements may represent a slowing down of the development of the experiments. We plan during the first years of operation of the system to get a deeper insight on the control in order to get progressively less and less person time inside target areas.

Economic Limiting Factors:

At present, and in response to the global economic situation, the policy of the Ministry of Economy and Competitiveness, MINECO, is to offer payment services to users, without any foreseeable direct financial support through the ICTS. Although the final estimate of access costs (including equipment and running costs) is not defined yet, taking into account the costs per experiment in similar infrastructures (e.g. Rutherford Appleton Laboratory or Laserlab Europe), the costs per standard experiment in the PW laser system are expected to be around 10.000 euros/day.

Therefore, all non-industrial users will need to count on funding prior to applying for access to CLPU, which will obviously constrain the service demand, as there have been general cutbacks on the national and European budgets for funding accesses to research infrastructures. To avoid that, special fares for certain groups of users have been approved by the Rector Council that include just running costs.

5 Strategic objectives 2013-2016

5.1 Strategic Axes

Four main axes constitute the dorsal spine of the strategy of CLPU:

- **Infrastructure and services:** As a user facility, the main aim of CLPU is to install and provide users with a state-of-the-art facility oriented towards research and experimentation in all fields of ultra-short and ultra-intense lasers and to make possible in a near future the expansion of its capacities, keeping them among the most relevant worldwide. Related to this aim, it is also essential to maintain the facility at the technological forefront by means of appropriate upgrading and strategic surveillance, in order to offer the scientific and technological community avant-garde services for the development of their projects and experiments.

- **Research and results:** CLPU will promote research at the highest international level of excellence, in relevant areas according both the national and the European strategy and open the use of ultra-short lasers in transversal areas of knowledge, especially in those in which the use of these techniques may become a breakthrough and forge new paths. Therefore, the Centre will promote and participate in the transfer of the knowledge generated in CLPU to society, mainly through innovative projects, developed jointly with public and private institutions and companies, stimulating the concentration and specialization in this field.

- **People:** Other fundamental aspects the Centre takes into account are the Human Resources. Therefore, the Centre will take special care in encouraging and supporting high-standard performance, according to the processes established and developing the staff capacities and taking advantage of their talent. Beside, CLPU will promote mobility and exchanges of scientific and technological personnel at international level, as a means of increasing the added value of the services offered.

- **Society:** As a public funded organization, CLPU must carry out its management on the basis of efficiency, transparency and budget stability through an economic and financial control system that guarantees the sustainability of the centre.

  Another challenge for CLPU will be the promotion of a scientific and innovative culture, whose main targets are society, the scientific and technological community, the industry and the Consortium institutions, through informative events and the improvement of the centre's digital supports for giving publicity to our activities. The proficiency in this area will make possible the incorporation of CLPU as a Spanish research facility in the maps of the main international technological infrastructures.

The development of these axes and the interaction between them, leads us to the following Strategic Objectives.

5.2 Description of the objectives

This Strategic Plan develops several strategic objectives focused on achieving the mission of the centre. These set of objectives are long-term, continuous strategic areas that make possible the connection between mission and vision.

1. **To install and open a state-of-the-art infrastructure** in the ultra-intense pulsed lasers field.
2. **To give high-class support and service to the scientific and technological community**, adapted to its demands.
3. **To enhance and develop excellence research**, oriented toward the societal challenges.
4. **To promote the transfer of knowledge** to enhance the laser technology and to increase economical activity around CLPU.
5. **To have motivated and proficient personnel** aligned with the organization and its processes and procedures.
6. **To undertake an efficient and responsible management of the resources and the organization.**
7. **To increase the dissemination** of the scientific culture on the laser field to all stakeholders.
8. **To promote the international visibility** of the Centre and its achievements as a Spanish research facility.

5.3 Strategies, action plan and indicators

The strategies are defined in order to reach the outlined objectives, trying to take advantage of the strengths of the centre, capitalize the external opportunities and shore up the weaknesses. At the same time, these strategies result in specific performance targets, short-term goals that constitute the action plan. Indicators have been set up to control/monitor the evolution and fulfilment of the plan.

Legend of Acronyms	
D	Direction (Director & Managing Director)
SKS*	Senior Key Scientist
HTA	Head of Technological Area
HSC	Head of Scientific Area
HMA	Head of Management Area
TA	Technological Area
SA	Scientific Area
MA	Management Area

This post is pending, although its functions could be performed by an external advisor.

AXES: **INFRASTRUCTURES & SERVICES**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
1. To install and open a state-of-the-art infrastructure	1.1 Offer state-of-the-art facilities.	1.1.1 Install the petawatt laser system and study and design its best configuration, including target areas and experimental setups, adaptable and tailored to any projects that users are interested in developing.	2013	Continuous	Director	EA, TA, SKS*, SA Investment budget	▪ *Conclusions of survey on users' scientific requirements* ▪ *Validation of the configuration options by the Scientific Advisory Committee (CACT)* ▪ *Validation as a ICTS by CAIS* ▪ *% of TDR investment budget execution* ▪ *Offered time/requested time*
		1.1.2 Keep a permanent surveillance of the state of technology and science to maintain the infrastructure specialization, searching for new solutions needed for the laser system and target areas functioning, such as vacuum, control, electronics, maintenance, motorization,…	2015	Continuous	Director	EA, TA, SKS*, SA Investment budget, General budget	▪ *No. of specialized discussion forums (meetings, congresses, users' groups…) where CLPU has taken part* ▪ *No. of scientific and technological committees in which members of CLPU take part*
		1.1.3 Participate in state or European programmes for promoting, maintaining and upgrading scientific and technological infrastructures open to users.	2016	Continuous	Director	EA, TA, SKS*, SA, MA External funding	▪ *No. of national or international programmes for supporting infrastructures in which CLPU participates*
	1.2 Optimization of use of equipments and systems.	1.2.1 Optimization of the use of the infrastructure and the equipment.	2015	Continuous	HTA	EA, TA, SKS*, SA, MA General budget	▪ *Total time allocated vs. time offered to users* ▪ *No. of first time users/Total users* ▪ *Increment of offered time to users* ▪ *No. of CLPU research projects with access to the ICTS*
		1.2.2 Optimization of Spanish network of laser infrastructures.	2013	Continuous	HSC	EA, TA, SKS*, SA, MA External funding, General budget	▪ *No. of projects developed jointly with other national laser infrastructures* ▪ *No. of national users vs. total*
		1.2.3 Coordinated management (use and acquisition) of equipments between different national infrastructures.	2015	Continuous	HMA	EA, TA, SKS*, SA, MA External funding, Investment budget	▪ *No. of projects developed jointly with other national infrastructures for joint acquisition or use of equipments*

AXES: **INFRASTRUCTURE & SERVICIES / PEOPLE**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
1. To install and open a state-of-the-art infrastructure	1.3 Maintain the facility at the technological forefront with high standards of safety	1.3.1 Elaborate an adequate maintenance programme of the facility and systems.	2013	Continuous	HTA	EA, TA, MA General budget	▪ *Ratio of unplanned Vs. planned working orders* ▪ *% of planning compliance*
		1.3.2 Continuous check of the state of systems and equipments to predict the need for their renewal and plan the purchase of new ones, so as to be able to obtain funding in due time and adequate quantity.	2014	Continuous	HTA	TA, MA General budget Investment budget	▪ *No. of maintenance (predictive, preventive & corrective) revisions* ▪ *No. of breakdowns due to stress in systems and equipments* ▪ *Hours (or No. of shots) of operation Vs. lifespan according to manufactures*
		1.3.3 Suitable choice of suppliers who guarantee a high-quality after-sales service.	2014	Continuous	HTA	TA, MA	▪ *Response time to call* ▪ *Quality of service according to the evaluation of CLPU staff involved*
		1.3.4 Develop and implement a Radioprotection Plan against risks derived from the use of the laser systems of the centre.	2013	2014	Director	EA, MA, SKS*, SA, TA General budget, External funding	▪ *Radioprotection Plan* ▪ *Obtaining the certificate from the CSN*
		1.3.5 Control possible pollutants.	2013	Continuous	HTA	EA, MA, SKS*, SA, TA General budget	▪ *System for the storage and collection of pollutants*
	1.4 Expand its capacities, providing the centre with worldwide relevance.	1.4.1 Improvement of services and experimental capabilities (such as laser characterization) or development of new ones (such as secondary sources).	2016	Continuous	HTA	EA, TA, SKS*, SA, MA External funding, Investment budget, Investment budget	▪ *No. of new services or experimental stations or set-ups offered to users*
		1.4.2 Create a strong technological team.	2013	Continuous	HTA	EA, TA General budget, External funding	▪ *No. of member of the technological staff who have attended training activities* ▪ *No. of technologists with a PhD or Master Degree*

AXES: **INFRASTRUCTURE & SERVICES / RESEARCH & RESULTS / SOCIETY**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
2. To give high-class support and service to the scientific and technological community	2.1 Offer user time for the development of research and experimentation projects.	2.1.1 Establish the annual capacity, planning the use of systems, including available time for users and time dedicated to maintenance and development of experimental capacities.	2015	Continuous	Director	EA, TA General budget	▪ *No. of users or services performed per year.* ▪ *% time need to complete the experiment vs. time allocated (fulfilment of project plan)* ▪ *% of users per access modality (competitive, under request, etc)* ▪ *% of access by type of service (delegated, assisted, unassisted)*
	2.2 Offer high standard services oriented to the institutional priorities and needs of the scientific and technological community and civil society in general.	2.2.1 Identify and channel the demands or necessities of final users, enhancing discussion forums (users' meetings, congresses, users' groups…) and taking part in technological platforms.	2013	Continuous	Director / SKS*	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of events organized* ▪ *No. of attendees to the events* ▪ *No of users involved* ▪ *No. of technological platforms in which CLPU takes part*
		2.2.2 Increase visibility of the services offered, designing a modern and user-oriented website and other communication channels in order to provide the appropriate information to users.	2014	Continuous	Managing Director	EA, SKS*, TA, SA, MA General budget	▪ *No. of applications received via website/Total applications received* ▪ *No. of registered users*
		2.2.3 Offer quality lab services, enabling an easy integration of experiments, thanks to a project management approach and supported by a proper management of safety, equipments and control data system.	2014	Continuous	HTA	EA, SKS*, TA, SA, MA General budget	▪ *% time for the setup configuration vs. total time allocated to the experiment*
		2.2.4 Achieve users' satisfaction.	2014	Continuous	HSA	EA, SKS*, TA, SA, MA	▪ *Satisfaction rate according to surveys.* ▪ *No. of recurrent users/year*

AXES: **RESEARCH & RESULTS / PEOPLE**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
3. To enhance and develop excellence research	3.1 Strengthen the participation and leadership of the CLPU in national and European singular research projects focused on cutting-edge knowledge and the development of emerging technologies.	3.1.1 Improve the preparation of projects and their adaptation to call for proposals for national and European projects.	2013	Continuous	HMA	EA, MA, SA, TA	▪ *Increase in No. of proposal submitted* ▪ *No. of proposal approved/Proposals submitted*
		3.1.2 Enhance the participation of researchers in national and European projects.	2013	Continuous	HAS	EA, SKS*, TA, SA, MA External funding	▪ *No. of national projects* ▪ *No. of international projects*
		3.1.3 Increase the number of projects led by CLPU.	2013	Continuous	HAS	EA, SKS*, TA, SA, MA External funding	▪ *No. of projects led by CLPU* ▪ *Projects led by CLPU/Total No. of projects in which CLPU takes part*
	3.2 Enhance the competitiveness of our research groups at international level, searching for new alliances with renowned R+D+I centres.	3.2.1 Promote and strengthen the nexus with other leading centres and research groups, encouraging mobility, exchanges and joint research.	2013	Continuous	Director / SKS*	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of MoUs or LoIs with national/international institutions*
		3.2.2 Improve the results of joint research with top-level international institutions or researchers.	2013	Continuous	Director / SKS*	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of joint publications with high-level international institutions or researchers*
	3.3 Promote the interaction and cooperation with researchers from cross-cutting areas of knowledge (medicine, nuclear, etc…)	3.3.1 Promote interdisciplinary research projects including those oriented to societal challenges.	2013	Continuous	Director / SKS*	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of interdisciplinary research projects in which CLPU takes part* ▪ *Scientific background of users (chemistry, biology, medicine…)*

AXES: **RESEARCH & RESULTS /SOCIETY**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
3. To enhance and develop excellence research	3.4 Support and encourage the publication of scientific results of the research developed by CLPU personnel or prepared with the collaboration of our staff.	3.4.1 Increase the number of scientific publications among the most cited publications worldwide.	2013	Continuous	HSA	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of papers in journals included in international citation indexes (such as WoS) or databases (such as Scopus)* ▪ *No. of papers published in journals placed on the first quartile of the most cited publications worldwide* ▪ *No. of papers published in journals placed on the first decile of the most cited publications worldwide* ▪ *H-index of the CLPU personnel* ▪ *No. of high-impact papers per operative euro* ▪ *No. of citations per paper*
		3.4.2 Increase the scientific results where CLPU is acknowledged.	2013	Continuous	HSA	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of papers published by users where CLPU is acknowledged* ▪ *No. of books or book chapters published* ▪ *No. of conference proceedings published* ▪ *No. of specialized reports for external institutions* ▪ *No. of national and international patents applied* ▪ *No. of national and international patent applications with favourable search report*
	3.5 Support and encourage high level scientific debate, encouraging basic research oriented to the global societal challenges[9].	3.5.1 Organize scientific and technological events at CLPU.	2013	Continuous	HSA	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of conferences hosted at CLPU* ▪ *No. of workshops hosted at CLPU* ▪ *No. of seminars hosted at CLPU*
		3.5.2 Participate in national or international scientific events.	2013	Continuous	HSA	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of presentations & invited talks to national/international conferences*

[9] Scientific, technological and social priorities of R+D+i oriented to global societal challenges include: (1) Health, demographic change and well-being, (2) Food security and quality; sustainable and productive agriculture, natural resources, marine and maritime and inland water, (3) Secure, clean and efficient energy, (4) Smart, green and integrated transport, (5) climate action, resource efficiency and raw materials, (6) social changes and innovatations, (7) Digital economy and society and (8) Security, protection of freedom and citizen rights. *(Source: Plan Estatal de Investigación Científica, Técnica y de Innovación 2013-2016)*

AXES: **RESEARCH & RESULTS / PEOPLE / SOCIETY**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
4. To promote the transfer of kwoledge	4.1 Promote, develop and consolidate links with the industrial sector through programmes for business leadership in R+D+I and taking part in technological or industrial clusters or similar networks.	4.1.1 Search for new alliances with industrial partners willing to increase their R+D+I capacities in strategic areas for Spanish economy[10] or key enabling technologies[11].	2013	Continuous	Director	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of contracts for transfer of technology signed*
		4.1.2 Participate jointly with business actors and private R+D+i centres in programmes for the improvement of the transfer of scientific-technical knowledge and innovation for the elaboration of new processes, products and services.	2013	Continuous	Director	EA, SKS*, TA, SA, MA External funding	▪ *No. of collaboration projects signed with business actors and private R+D+i centres* ▪ *No. of industrial users/total users*
	4.2 Set up a core of specialization on laser technology that brings together capacities and manages knowledge transfer.	4.2.1 Promote the participation in the exploitation of patents to attract industry interested in the development of laser technology and promote the collaboration with it.	2015	Continuous	Director	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of patents with commercial operation* ▪ *No. of national or international patents applied for jointly with companies* ▪ *No. of these application that have received a favourable research report*
		4.2.2 Enhance the productive skills of the region by promoting the dissemination and the innovation transfer.	2013	Continuous	Director	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of events science – industry* ▪ *No. of companies attending*

[10] Such as the following sectors: automotive, rail, naval construction, aerospace industry, security, activities linked to advanced infrastructures and constructions, chemistry, pharmacy, machinery, capital goods, clothing industry and other traditional manufacturing. (Source: *Plan Estatal de Investigación Científica, Técnica y de Innovación 2013-2016)*

[11] Such as photonics, micro- and nanoelectronics, nanotechnology, advanced materials, biotechnology, information and communications technology, advanced manufacturing & processing and space (Sources: *Plan Estatal de Investigación Científica, Técnica y de Innovación 2013-2016 and the Framework Programme for Research and Innovation (2014-2020))*

AXES: **RESEARCH & RESULTS / PEOPLE / SOCIETY**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
4. To promote the transfer of kwoledge	4.3 Transfer of research knowledge to education, enhancing and developing alliances with research centres and renowned universities.	4.3.1 Promote Collaboration Agreements with research centres and renowned universities.	2013	Continuous	HMA	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of Collaboration Agreements signed with research centres and universities for transfer of knowledge.*
		4.3.2 Participate in academic or training programmes.	2013	Continuous	HSA	EA, SKS*, TA, SA, MA General budget, External funding	▪ *No. of researchers collaborating in academic programmes.* ▪ *No. of students or researchers who benefit from fellowships or training programmes (postdoctoral, predoctoral, etc) at the centre.*

AXES: **PEOPLE / SOCIETY**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
5. To have motivated and proficient personnel	5.1 Have an efficient and competent staff, engaged with excellence and the centre.	5.1.1 Execute the recruitment plan to ensure the proper operation of the centre.	2013	2015	Managing Director	EA, EA, TA, SA, MA General budget	▪ *Level of compliance with the plan* ▪ *No. of contracts of indefinite duration* ▪ *No. of contracts of definite duration* ▪ *No. of contracts funded with the general budget*
		5.1.2 Establish and upgrade a system for the recognition of staff efficiency, excellence and professional promotion.	2013	Continuous	Managing Director	EA, MA, TA, SA	▪ *Official system of incentives for staff based on individual merit* ▪ *Rate of fulfilment of personal objectives*
		5.1.3 Promote flexible work schedules that allow work-life balance and gender equality.	2013	Continuous	HMA	EA, EA, TA, SA, MA General budget	▪ *Flexible work schedule system* ▪ *Rate of men/women per area*
	5.2 Develop the professional capacities of the staff by means of training, promotion of mobility and exchanges of staff with similar R+D+I institutions.	5.2.1 Design specific ongoing training programmes.	2013	Continuous	Director	EA, EA, SKS*, TA, SA, MA General budget	▪ *No. of training activities organized* ▪ *No. of members of staff who have attended the activities*
		5.2.2 Promote agreements with other prestigious R+D+I centres, in order to temporarily exchange personnel for training and research purposes.	2013	Continuous	Director	EA, EA, SKS*, TA, SA, MA General budget	▪ *No. of training visits and research stays of CLPU personnel in other centres* ▪ *No. of training visits and research stays at CLPU of personnel from other centres*

AXES: **PEOPLE/SOCIETY**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
5. To have motivated and proficient personnel	5.3 Attract researchers and technologists of high level that shall provide training to other members of CLPU team on priority topics.	5.3.1 Participate in incentive programmes for the recruitment or mobility of prominent researchers and technologists.	2013	Continuous	Director	EA, SKS* General budget, External funding	▪ *No. of prominent researchers and technologist (Post-Doc) working in CLPU* ▪ *No. of programmes for the recruitment and mobility of prominent researchers and technologist*
	5.4 Attract early-stage researchers and technologists with a promising future who want to develop their careers in our centre.	5.4.1 Participate in national and international programmes for early talent attraction.	2013	Continuous	HSA	EA, SKS*, TA, SA General budget	▪ *No. of prominent researchers and technologist (Pre-Doc) working in CLPU* ▪ *No. of programmes for the recruitment and mobility of early stage researchers and technologist*
	5.5 Encourage fluid internal communication to enhance the motivation and identification with the centre and its objectives.	5.5.1 Improve and enhance the internal information and participation systems.	2013	Continuous	Managing Director	EA, MA	▪ *Development of intranet* ▪ *No. of informative meetings held*
		5.5.2 Create a channel for the reception of suggestions from personnel and their analysis.	2014	2014	Managing Director	EA, MA	▪ *No. of suggestions received*

AXES: **PEOPLE / SOCIETY**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
5. To have motivated and proficient personnel	5.6 Define the processes developed in the centre, establishing working procedures.	5.6.1 Elaboration and updating of consensual regulations and procedures for making easier and safer the workflow of the centre.	2013	Continuous	HMA	EA, MA, SA, TA	▪ *Elaborate a Process Diagram* ▪ *No. of approved procedures* ▪ *No. of updated procedures*
		5.6.2 Implementation of ISO 9001 quality system, compatible with the ISO 14001 environmental management system.	2016	2016	HMA	EA, MA, SA, TA General budget	▪ *Obtaining of the ISO 9001 Quality Certificate* ▪ *Obtaining of the ISO 14001 environmental management Certificate*
		5.6.3 Carry out prevention campaigns and health surveillance.	2013	Continuous	HMA	EA, MA, SKS*, SA, TA General budget	▪ *No. of courses given by the Prevention Service* ▪ *No. of attendees to the courses* ▪ *% of medical examinations done* ▪ *No. of safety incidents or dangerous occurrences at work*

AXES: SOCIETY / INFRASTRUCTURE & SERVICES							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
6. To undertake an efficient and responsible management of the resources and the organization	6.1 Enhance the economic, financial and budgetary management of the Centre.	6.1.1 Set up an information system for the economic and administrative management.	2013	2014	HMA	EA, MA	▪ *Set up a specific software system (e.g. ERP)* ▪ *Identify economic and financial ratios*
		6.1.2 Assess periodically the economical and financial ratios.	2013	Continuous	HMA	EA, MA	▪ *Evolution of the ratios vs. previous periods*
		6.1.3 Budgetary implementation.	2013	Continuous	HMA	EA, MA	▪ *% of budget execution*
	6.2 Implement a tariff system for the exploitation of equipments that allow covering the costs, as well as their foreseen improvements and technological upgrades.	6.2.1 Implement a tariff system for the services provided with the human and material resources of the centre.	2013	2013	HMA	EA, MA, TA, SA	▪ *Average income per access* ▪ *% of costs covered by the tariffs paid*
	6.3 Increase fundraising from public and private institutions, both national and European, to enable the fulfilment of the strategic objectives of CLPU.	6.3.1 Search for new different funding sources for research, especially those from European funds: FP or Horizon 2020, ERC, EIT, improving the analysis of prospects and the information of researchers.	2013	Continuous	HMA	EA, MA	▪ *% incomes from research projects* ▪ *% incomes from European, national and regional*
		6.3.2 Improve ways of commercializing the technological services of the centre in order to increase the commercial agreements and obtaining patents.	2013	Continuous	HMA	EA, MA	▪ *% incomes from commercial agreements*
		6.3.3 Involve industry in public R+D+I projects, both national and international.	2013	Continuous	Director	EA, MA	▪ *% incomes from research projects developed in partnership with industry* ▪ *% incomes from public/private funds*
		6.3.4 Increase the contributions from private or public sponsorship for research and divulgation.	2013	Continuous	Managing Director	EA, SKS*	▪ *% incomes from sponsors*

AXES: **SOCIETY / RESEARCH & RESULTS**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
7. To increase the dissemination of the scientific culture on the laser field	7.1 Strengthen the corporative image of CLPU as a scientific and technological model, so that creates a positive social perception of the Centre.	7.1.1 Dissemination of the Centre activities in regional and national media.	2013	Continuous	HMA	EA, MA, TA, SA General budget	▪ *No. of the press releases* ▪ *No. of the published news* ▪ *No. of the interventions in the audiovisual media*
		7.1.2 Optimize the media resources to improve the effectiveness of the communication (all by stages: regional, national, international), through a thorough analysis of agencies and media and the creation and updating of CLPU media agenda.	2013	Continuous	HMA	EA, MA, TA, SA General budget	▪ *Ratio press releases/published news* ▪ *Annual report of the Centre*
		7.1.3 Organization of CLPU promotion activities for the general public (open days, talks to increase the visibility position of the Centre…).	2013	Continuous	HSA	EA, MA, TA, SA General budget	▪ *No. of visitors (general public)* ▪ *Analysis time/person (visitor) on tour* ▪ *No. of the talks to increase the visibility position* ▪ *Analysis of the interaction between target – speaker (No. of questions from the public, topics, ...)*

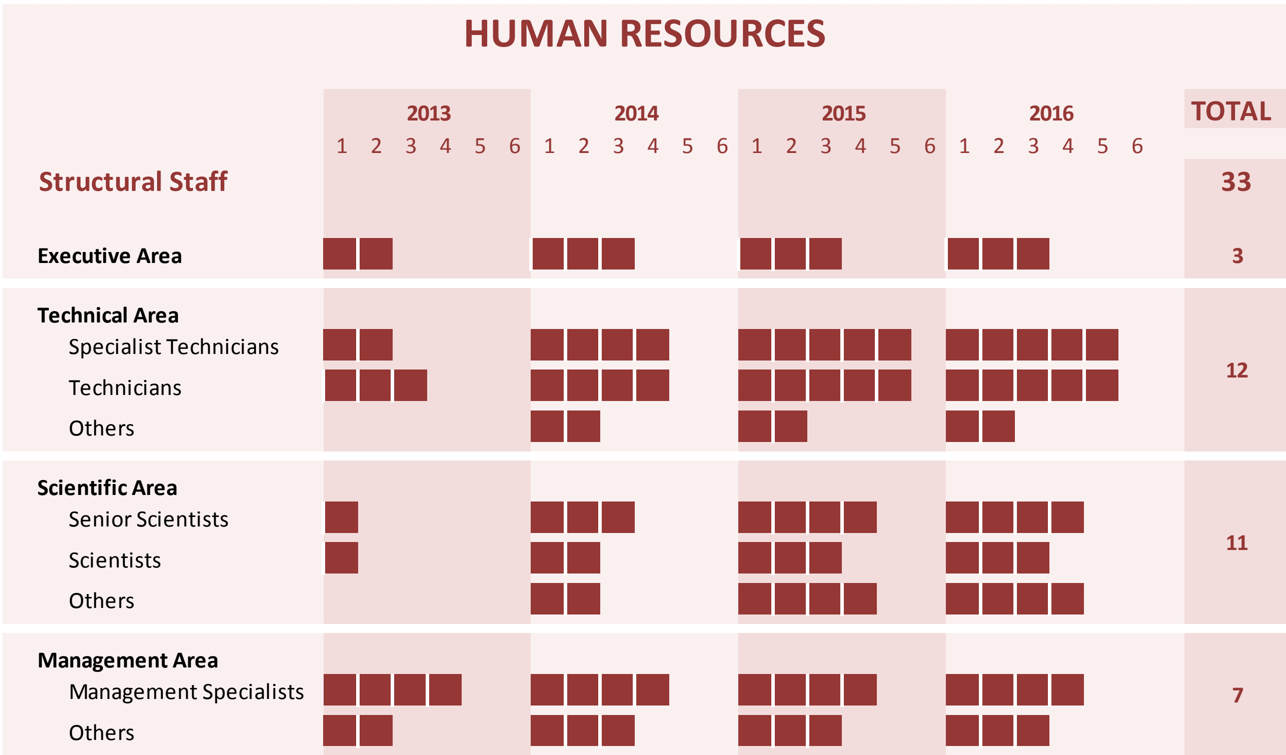
AXES: **SOCIETY / RESEARCH & RESULTS**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
7. To increase the dissemination of the scientific culture on the laser field	7.2 Encourage the scientific and technological culture, essentially related to the laser science and technology developed in the Centre.	7.2.1 Strengthen the resources of external communication (newsletter, web…) to promote the dissemination of science and laser technology and to publish interesting news for the sector.	2013	Continuous	HSA	EA, MA, TA, SA General budget	▪ *No. of newsletters* ▪ *No. of receivers of newsletter* ▪ *No. of external collaborations*
		7.2.2 Update and extend the web contents, including interesting topics and information on the research resources of the centre.	2013	Continuous	HMA	EA, MA, TA, SA General budget	▪ *Design of a new website* ▪ *No. of visitors of the website*
		7.2.3 Motivate the scientific vocation and the laser specialization by dissemination activities to university students and to high school students.	2013	Continuous	HSA	EA, MA, TA, SA General budget	▪ *No. of organized activities by typology of information activities* ▪ *No. of informative materials elaborated by typology* ▪ *No. and class of the education centres involved* ▪ *No. of the students involved in the activities*
		7.2.4 Organization of events for the dissemination and promotion among general public of information and knowledge related to the laser field.	2013	Continuous	HSA	EA, MA, TA, SA General budget	▪ *No. of organized events by typology of events, according to the target* ▪ *Technical report of the event (test of the effective communication)*

AXES: **SOCIETY/RESULTS**							
OBJETIVE	STRATEGIES	ACTION PLAN	INITIAL DATE	DEADLINE	PERSON IN CHARGE	RESOURCES	INDICATORS
8. To promote the international visibility	8.1 Promote the international visibility of the Centre as a model of development, research and innovation in pulsed lasers.	8.1.1 Increase in the international visibility of CLPU.	2013	Continuous	Director	EA, MA, TA, SA General budget	▪ *No. of scientific maps which show CLPU* ▪ *No. of references in international publications.* ▪ *No. of participations at international organizations (such as IZEST, ICUIL, ELI, Laserlab…), clusters and companies of the field* ▪ *No. of international users vs. total*

5.4 Resources

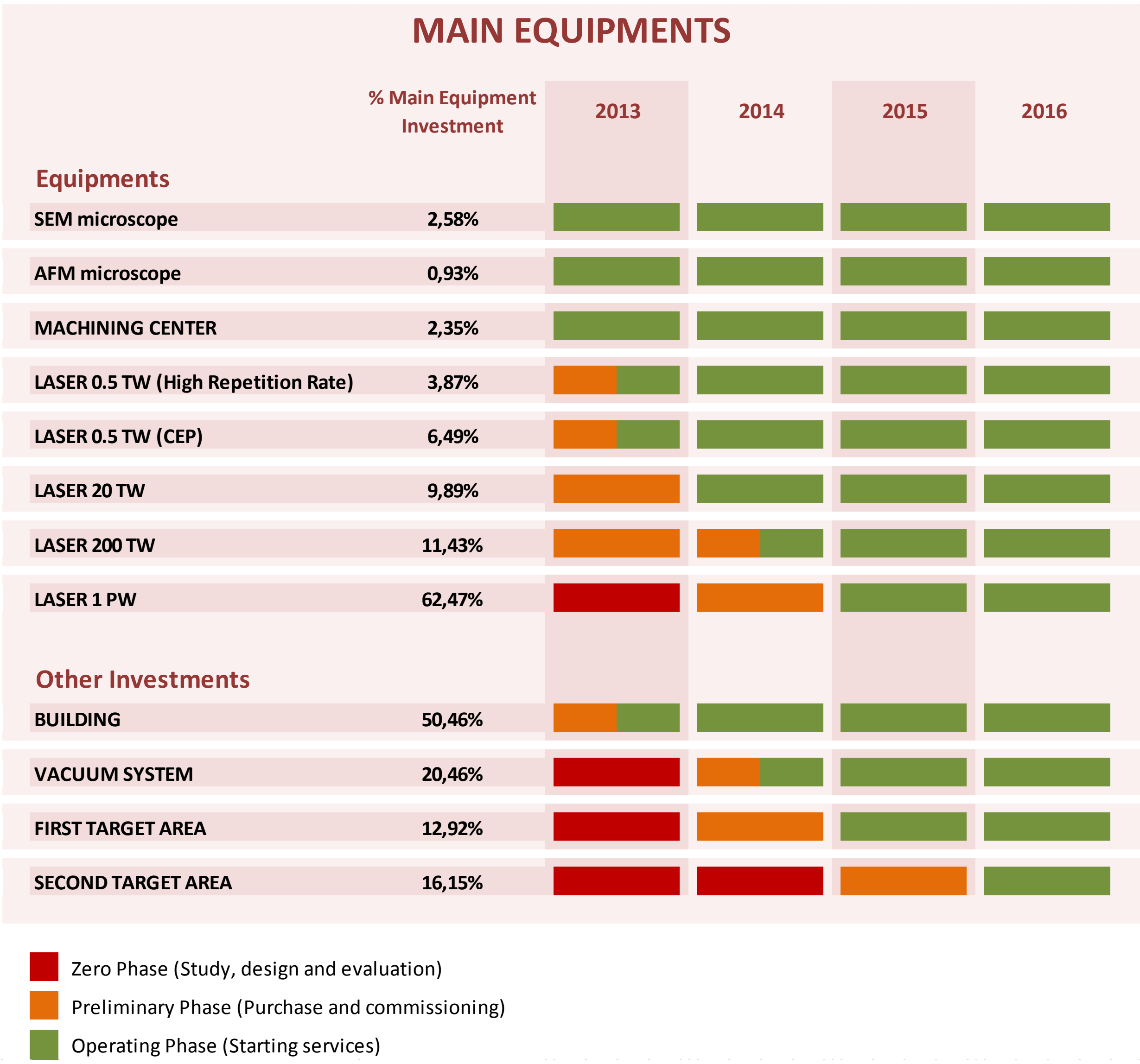
5.4.1 Human Resources

These figures represent the average of structural staff. The staff will be completed with casual personnel around research and technological projects.



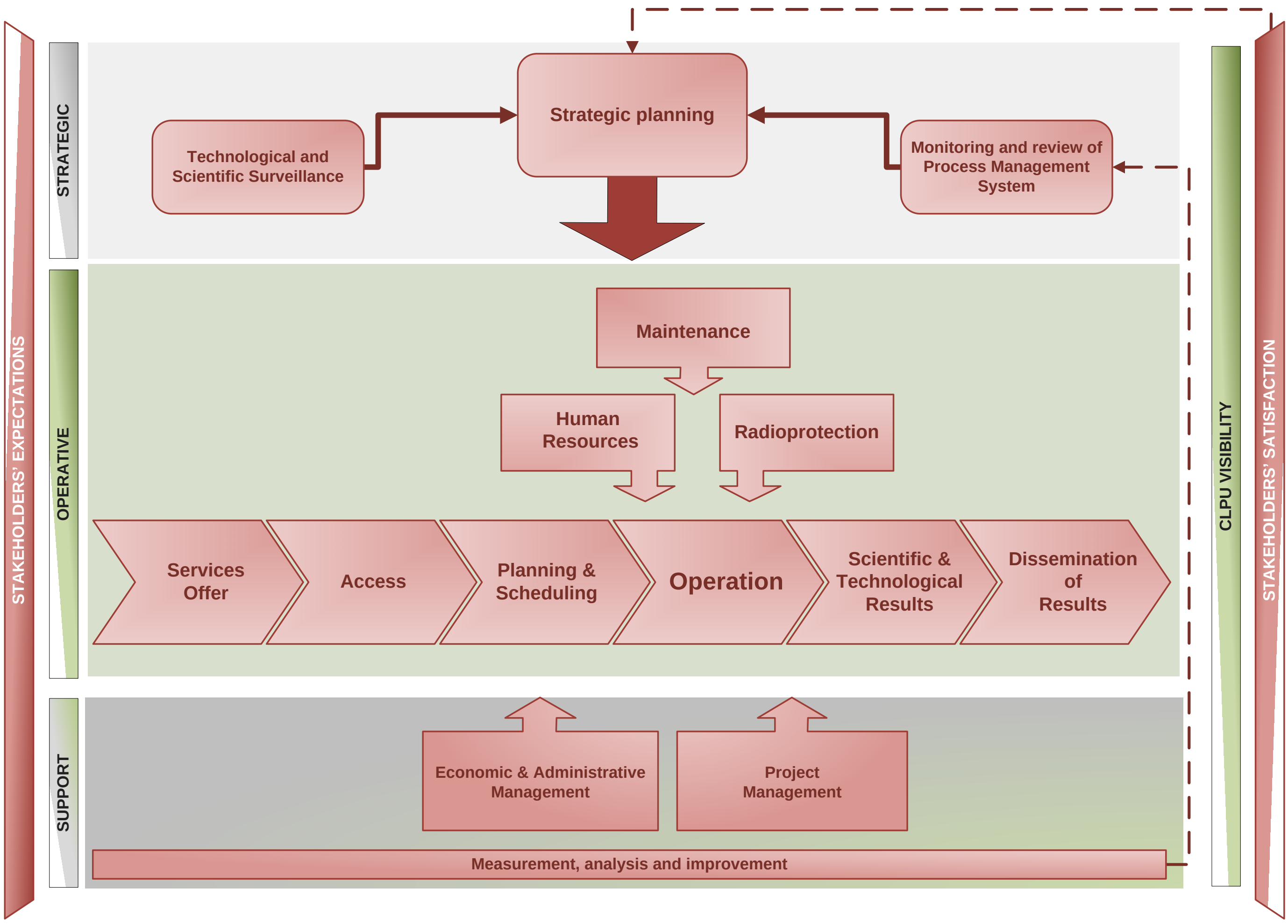
5.4.2 Material Resources

The following graphic gives details of the main systems and equipment of the centre, which represent the most significant investments made. The percentages of investment in comparison with the total amount invested in each block are also included. Colours represent the stage of evolution of the investment.



5.4.3 Organizational Resources

In order to achieve an efficient and effective development of the activities carried out in the centre, the main processes have been identified. Their sequence and interactions are described in the following diagram:



6 Monitoring & Review of the Strategic Plan

This Strategic Plan will be reviewed periodically by the competent bodies of CLPU, through several actions:

- **Approval of the Annual Budgets**. Annually the Executive Commission shall render a proposal of Annual Budgets for CLPU to the Rector Council. The Annual Budget will determine the resources at the disposal of the Centre to programme activities and accomplish objectives.
- **Follow-up of the set of indicators** defined to check the implementation of the different actions designed for achieving the main objectives of the Centre. The frequency for the assessment of each indicator will depend of its nature. However, they shall be checked at least annually.
- **Revision of the diagram of the main processes** of the Centre will take place bi-annually in order to analyze possible opportunities to improve the interaction between them, and therefore to increase the efficiency of the operation.
- **Revision of the level of adherence to the schedule estimated for the action plan**. This revision shall be conducted bi-annually. In case that due to obvious deviations from the timetables, some actions were unlikely to be completed in the specified timeframe, they will be re-scheduled and the reason for the delay shall be justified.
- **Comprehensive review of the Strategic Plan**. The Committee shall check the degree of compliance of the objectives set at the Plan and analyse their validity or whether, on the contrary, new measures should be taken to place CLPU as a state-of-the-art facility for the scientific and technological research and development. This will be carried out at least a year in advance to the elaboration of the next Strategic Plan.

SCHEDULE

	Competent Body	2013	2014	2015	2016
Approval of Strategic Plan	Rector Council	■			
Approval of Annual Budgets	Rector Council	■	■	■	■
Follow-up of Indicators	Internal Committee	■	■	■	■
Revision of Processes Diagram	Internal Committee		■		■
Revision Action Plan	Internal Committee		■		■
Revision of Strategic Plan	Internal Committee			■	

7 Economic Criteria

7.1 Financial philosophy

The financial philosophy of the centre can be summarized through the following action principles:

- Economic self-sufficiency
- Reduced, but reasonable, fixed costs
- Variable costs linked to external collaborations
- A reasonable allocation of resources to training and qualification of personnel
- Active policy of transparency and accountability
- Sustained increment of external funding to be able to accomplish more activities
- Attract and retain permanent collaborators among those who participate in programmes or institutional collaborations
- Lightweight and cost-effective infrastructure
- Contracts linked to programmes which depend on the approval from external funding bodies
- Handling budget with reasonable austerity
- Optimization of investments, through a high utilization rate of the equipments purchased, including the possibility of sharing systems and equipments with other centres.

7.2 Budget forecast

Mil euros (k €)	2013	2014	2015	2016	%
INCOME	**2,452**	**2,611**	**2,713**	**3,130**	**14.4 %**
Consortium Funds	2,040	2,080	2,122	2,164	6.1 %
Projects Incomes	312	365	400	450	36.5 %
Services Incomes	112	166	191	516	93.0 %
EXPENSES	**2,452**	**2,611**	**2,713**	**3,130**	**14.4%**
Personnel	1,387	1,454	1,499	1,514	9.2 %
Running Expenses	987	988	1,036	1,225	14.0 %
Equipment Upgrade	78	169	178	391	145.0 %

CROSS-REFERENCE TABLE	
MINECO INDEX	**CLPU INDEX**
-----	**1. Introduction** 1.1. Executive summary 1.2. Methodology
1. General information of the infrastructure	**2. General information & Progress of the project** 2.1. General Information 2.2. Progress of the project
-----	**2. Mission, vision and values**
3. Critical analysis	**4. Critical Analysis**
2.1 SWOT analysis	4.1. SWOT (Strengths, Weaknesses, Opportunities,Threats) analysis
2.2 Relational analysis of the evaluated facility comparing to other existing or planned facilities in its field in the national or the international context	4.2. Relational analysis: National & international context
2.3 Analysis of the infrastructure competitive advantages	4.3. Analysis of CLPU competitive advantages
2.4 Socio-economic impact analysis	4.4. Socio-economic impact analysis
2.5 Analysis of the infrastructure annual capacity and its opening to users, describing factors that may constrain use	4.5. Analysis of capacity of use 4.5.1. Annual capacity 4.5.2. Opening to users 4.5.3. Limiting factors of use
3 Objectives 2013-2016	**5. Strategic objectives 2013-2016** 5.1. Strategic Axes
3.1. Description of the objectives	5.2. Description of the objectives
3.2. Strategies for achieving the objectives	5.3. Strategies, action plan and indicators
3.3. Development of strategies (Action plan)	
3.4. Resources	5.4. Resources
3.5. Schedule & monitoring	**6. Monitoring & Review of the Strategic Plan**
-----	**7. Economic criteria** 7.1.1. Financial philosophy 7.1.2. Budget forecast

CLPU CENTRO DE LÁSERES PULSADOS