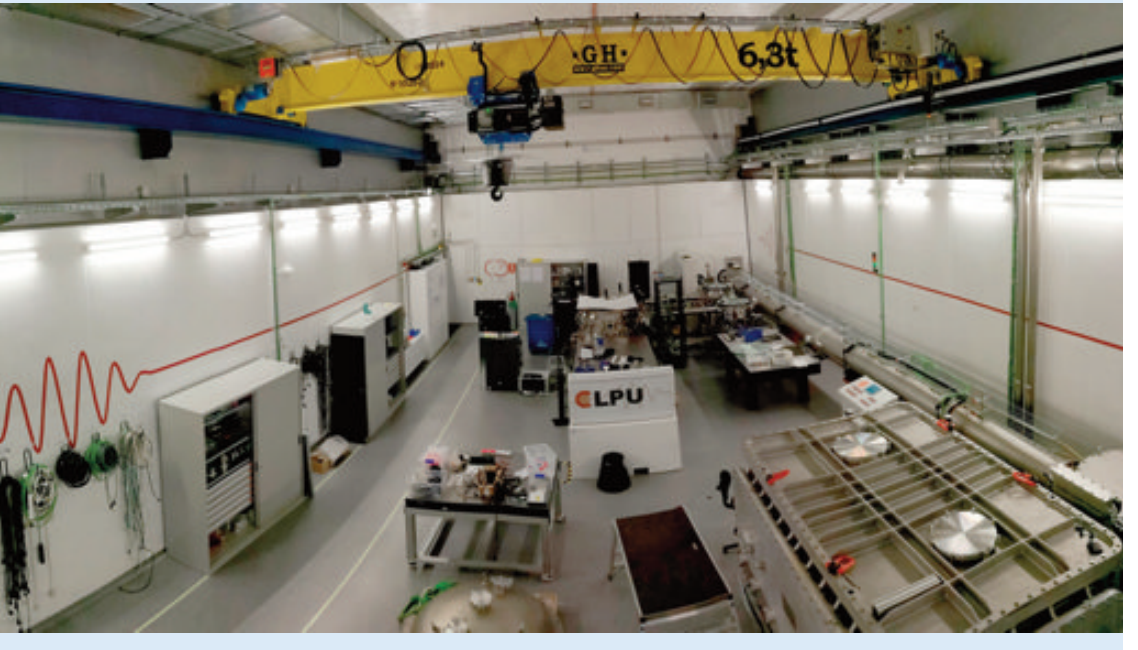
CLPU

CENTRO DE LÁSERES PULSADOS

Activities Report

2019



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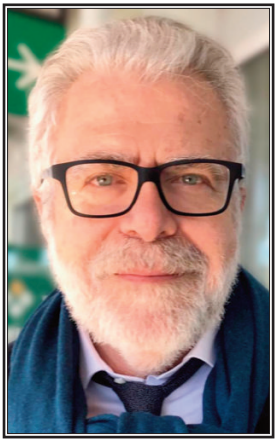
I N D E X

CLPU CENTRO DE LÁSERES PULSADOS



Welcome once more to this Activities Report where we will show you the most important actions that the Spanish Centre for Pulsed Lasers has undertaken this year. I am aware that I always tell you that the year in question has been relevant to development, but it is every bit as true: each year, and this one no less, has been a step forward that has allowed us to progress in our full consolidation as a unique scientific and technical infrastructure. Specifically, 2019 has been a landmark year because we have carried out the first experiment of competitive access to the last phase of the laser system, the petawatt one, the one that defines our uniqueness, that is, VEGA-3. Through this campaign, the Spanish Centre for Pulsed Lasers has moved out from its phase of construction to become a fully operational infrastructure. This, however, does not mean that we have put an end to the development of our equipment, nor that we had not already used our system. In fact, seven experimental campaigns were carried out in 2019, one of them, January's, framed within the first open call for competitive access; the next four belonging to the second call (whose runtime extends over 2019 and 2020); and the last two corresponding to internal campaigns of a strategic nature. Likewise, our specialized technical staff continues to work to enhance the laser equipment's versatility, quality and uniqueness, operating both on its main and on its complementary equipment, which is a genuine added value to VEGA.

On the other hand, publications linked to the first experimental campaigns for competitive access that were conducted in 2018 in VEGA-2 are beginning to gradually materialize. Thus, the results of the institution as a user centre and support facility for international scientific progress are starting to show.

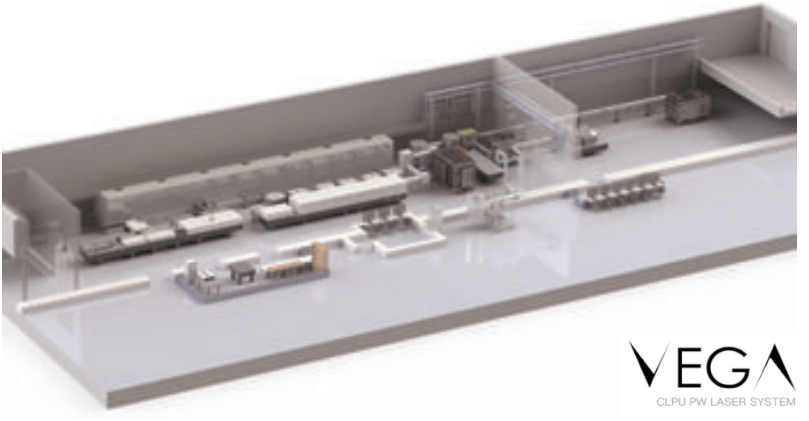
As part of the commitment that our knowledge has an impact on society, several technology transfer actions have been carried out, some aimed at new high-intensity laser demonstrators and others at the development of secondary electron and proton sources. In addition, a specialized conference on high dose rate radiotherapy was co-organized with the Institute of Biomedical Research of Salamanca —IBSAL— in December.

This new setting that we are progressively shaping, consolidating ourselves as a unique scientific and technical infrastructure, validates our power of attraction. As a result, at the end of 2019 we were granted the privilege to organize an important international event in our area of expertise: the *European Physical Society Conference on Plasma Physics*, to be held in 2024. We will most certainly tell you all about it in the appropriate report! For the time being, I will leave you to take a look at how the Pulsed Lasers Centre moves forwards on its journey for the sake of science, development and innovation.

Luis Roso
CLPU Director

CUTTING-EDGE INFRASTRUCTURE

Since its foundation at the end of 2007, the Spanish Centre for Pulsed Lasers (CLPU) has been identified as a Unique Scientific and Technical Infrastructure (ICTS). As gathered in the book published by the Ministry of Science and Innovation at the end of 2019, the term ICTS "refers to state-of-the-art research, development and innovation infrastructures that (…) provide services for the development of top-quality cutting-edge research, as well as for the transfer, exchange and preservation of knowledge, technology transfer and the promotion of innovation". At the different stages of its design, building, furnishing and start-up, the CLPU was subjected to all the relevant assessments, and still holds its ICTS status according the update approved by the Science, Technology and Innovation Policy Council (CPCTI) on 6 November 2018. The national map currently consists of a total of 29 ICTS that include 62 facilities that either form a network or are part of what is known as Distributed ICTS, depending on the level of integration and coordination of their capacities; otherwise, they are single-location ICTS, such as the Spanish Centre for Pulsed Lasers. All of them facilitate the promotion of science and innovation, work as driving forces for sustainable economic growth in line with the 2030 agenda and, therefore, provide development for social welfare in the medium and long term. The CLPU is a cutting-edge infras-



tructure that contributes to these aims through its unique system, VEGA, a high-repetition-rate petawatt laser system that enables it to promote competitive and high-quality scientific-technological research at the international level.

Equipment

VEGA: Laser accelerator

a) Main system

VEGA is a Ti:Sapphire laser system whose unique architecture includes three outputs with different powers that share the same pulse generation system and can, therefore, be synchronized.

VEGA-3. Capable of reaching one petawatt peak power with 30 joules of energy / pulse duration of 30 femtoseconds. Towards the end of the year this report is concerned with, the CLPU obtained the approval of the Nuclear Safety Council to launch this third phase after carrying out its commissioning experiment, led by Dr. Dino Jaroszynski, a researcher from the Scottish University of Strathclyde.

VEGA-2. This phase can give output of 200 terawatts peak power with energies of 6 joules / 30 femtoseconds pulses. Five experimental campaigns have been conducted in 2019.

VEGA-1. The system's least powerful output, delivering 20 terawatts with energies of 600 millijoules and 30 femtosecond pulses. This facility has not yet been offered in calls for competitive access, giving priority to the two above, since they provide more uniqueness and are therefore more appealing to the international scientific community. It is currently being relocated in the experimentation area and will be offered in future calls.

b) Complementary systems: added values

- **Carrier Envelope Phase – CEP laser system**: this fourth generation Femtopower laser system is capable of delivering carrier-envelope-phase stabilized few-cycle ultrashort pulses. For years, it has been in itself one of the facilities offered among the Spanish Centre for Pulsed Lasers services, but in 2019, after the appropriate technological adjustments and upgrades, it became part of the VEGA platform as a result of a strategic redesign of the infrastructure. This system operates in the near-infrared region in a spectral band of 50 nanometres FWHM after amplification and a little above 200 nanometres in the oscillator and post-compression stage. Thus, a synchronized output of 6-femtosecond pulses is added to the 30-femtosecond laser (VEGA). This allows us to provide the possibility of conducting '*pump-probe*' type experiments with VEGA, using a very short duration VUV or XUV system as a '*probe*'.
- **Quanta Ray laser system**: this equipment offers the possibility of synchronizing its frequency with VEGA's repetition rate (10 Hz / 1 Hz), delivering 1-nanosecond / 1 joule pulses, with wavelengths

of 532 and 1064 nanometres. It can be used to carry out experiments where the combination of both laser types (VEGA and Quanta Ray) provides extra value to a certain interaction. In 2019 it was installed on the VEGA platform, its operationalization being imminent.

- **Metrology bench**: the metrology bench was installed alongside the VEGA-2 and VEGA-3 compressors on the laser's platform, where it has already been operative for some years. Highly specialized, its purpose is to analyse the laser beam just before it enters the bunker of the test area. It performs measurements in a whole range of parameters that characterize the beam, providing fundamental value to users' experiments.
- **Reflection attenuator:** installed in 2019 for the main amplifier of VEGA-2.
- **Prototype system for shot control:** independent from the control system offered by the equipment manufacturer. The acquisition system, designed using *labview* and synchronized with the elements of the laser chain, allows remote triggering and the acquisition of images at VEGA's repetition rate, as well as the storing of all the information in the shots database located in the Centre's server.
- Aimed at improving the existing equipment's capacities, several optimization studies have been carried out this year: the study for installing a closing shutter so that VEGA-3 can be used in single-shot mode keeping the thermal characteristics of the main amplifier constant with the purpose of increasing the stability of this branch of the system; a theoretical study and first trials of a prototype in-line interferometer using a saturable absorber, and a study and proposal for the initial prototype of an interlock module towards the Personal Safety System (PSS), gathering information from the pumping q-switch to replace or accompany the currently existing attenuator system.

c) Summary of modes of operation of the VEGA unique system

Selection Synchronized Lines
Available in 2019
VEGA-1 – 20 TW – Main equipment
VEGA-2 – 200 TW – Main equipment
VEGA-3 – 1 PW – Main equipment
VEGA-1/VEGA-2/VEGA-3 + CEP
Project started in 2019
VEGA 1/VEGA-2/VEGA-3 + Quanta Ray – Transferred in 2019, expected to be operative by the end of 2020 or beginning of 2021
VEGA-2 + VEGA-3
VEGA-2 + VEGA-3 uncompressed
VEGA-1 + VEGA-2
VEGA-1 + VEGA-3
VEGA-1 + VEGA-3 uncompressed
Repetition Rate Selection ***(Always synchronized with devices from the test area)***
Single - Shot
Nominal Frequency Mode
Nominal Frequency Dividers
Burst mode
Energy Selection (For any VEGA output)
High-energy mode
Low-energy mode

d) Secondary sources

Because of its high intensity, the VEGA laser instantly ionizes the target it impacts generating a plasma. For this reason, one of the Centre's long-term objectives is to be able to provide users with secondary radiation sources. Indeed, the second open access call for competition issued in June 2018 already included some of these secondary sources. The goal of the infrastructure is for them to be optimized and continue to be offered in subsequent calls. These sources provide an extraordinary opportunity for scientists who are interested in measu-

ring and using pulsed radiation in the femtosecond regime. The interaction laser beam used to obtain these sources is VEGA-2. The secondary sources are as follows:

- Electron source with several hundred MeV energy using the *Laser Wakefield Acceleration (LWFA)* technique.
- Betatron X-ray radiation source in the KeV range eventually offered together with a *Kirkpatrick-Baez* focusing mirror system.
- Proton source (1-10 MeV) using the *Target Normal Sheath Acceleration (TNSA)* mechanism.

Alongside the above, work has been carried out on secondary sources of VEGA-3 that will be included in future calls.

ULAMP

ULAMP is a femtosecond laser system capable of delivering pulses at 7 millijoules operating at a high repetition rate of up to one kilohertz. Like the VEGA unique system, it is also based on CPA technology. It operates in the near-infrared spectrum within a bandwidth of around 800 nanometres and is characterized by the high quality of its laser beam (M^2<1.3) and excellent 'shot-to-shot' stability (< 7 µrad rms).

With 60 GW peak power, ULAMP's characteristics make it a highly appropriate system to study the interaction of ultrashort pulses with solid targets and its applications in materials processing. Because of this, the test laboratory that is attached to the laser system is designed for microprocessing and is fitted with three specialized workstations and a more general one aimed at fostering the development of other innovative laser applications:

- WS01 - High precision: this workstation includes a large optical table that is located just at the laser output window to prevent possible beam instability. Two micro-processing laser systems have been set up on it (each of them with three axes connected to a programmable multi-axis and controlled by a shutter and an at-

tenuator) along with two other multiprocessing systems with a galvanometer for better beam control, faster processing and reproducibility close to that of industrial settings.

- WS02 - General microprocessing: a highly versatile experimental area with an optical table prepared for other microprocessing activities such as LIDT, single-shot micromachining with laser filamentation, etc., and which, if necessary, can be adapted for experiments that are not directly related to materials processing.
- WS03 - Trephine and automatization process: isolated from the other experimental areas, it is located in a room where a robust optical has been set up following a design intended for work with large dimensioned samples and the production of microstructures at scales between 10 and 100 μm. Circular structures with controlled dimensions and conicity can also be produced.
- WS04 - CO_2 processing station: it includes a CO_2 laser system connected to a galvanometer and its sample positioning station. This system is ideal for the processing of plastic and other materials with low laser damage thresholds and high absorption at 10 μm.

Our FARO (Facility Access Request Online) platform has registered 5 service requests in 2019: 80% of them were directly linked to the competitive experimental campaigns developed in VEGA over such year, and the remaining 20% were from external users who requested the service for their own experiments.

Other Units

a) LITeL – Laser Technology Innovation Laboratory

The main purpose of this laboratory is to improve technological transfer in the field of lasers and optics. Laser applications are integrated at different levels into every area of society and industry. However, constant improvement of optical/laser equipment and laser services, together with new laser applications allow us to assist the scientific and industrial community in areas such as aeronautics, medicine, environment, industry 4.0, defence and security… Our speciality is the use of short pulse laser systems, although we also work with others, including continuous wave laser systems. Ours is also a centre that is

specialized in high-power and pulsed laser applications, which makes us one of the first references to consult regarding the latest market applications.

Thus, we offer the support of qualified staff and equipment for such needs in different modalities: consulting, specialized studies, customized designs…

Among the extensive equipment in this laboratory, we can highlight several laser systems (fibre-coupled diodes, Verdi system, Ti:Sapphire continuum…), autocorrelators, photodetectors, spectrometers, oscilloscopes, pulse picker and pockels, etc.

In 2019, this laboratory focused on the development of work linked to ULTRALASER project and that convened by the European Defence Agency (for further details, see the section on technological development projects of this report).

b) Microscopy – SEM (Scanning Electron Microscope)

The Spanish Centre for Pulsed Lasers includes an EVO HD25 characterized by an electron thermionic gun with a LaB6/li cathode. It is equipped with a turbomolecular pump and is able to operate at variable pressures between 10 and 400 Pa. Apart from the equipment's 3 original detectors, the CLPU has added three more, thus enhancing the system's value and the quality of the service provided:

- STEM – Scanning Transmission Electron microscope: a transmission electron microscope (TEM) where electrons pass through the sample but that operates at low voltages (maximum 30 keV), so that the sample must be thin enough.
- EDS – Energy Dispersive X-Ray Spectroscopy: a device used to obtain the chemical composition of a sample through an X-ray scattering analysis.
- EBSD – Electron backscatter Diffraction: A SEM based on a microstructural-crystallographic technique to measure the crystal orientation of, in principle, any crystalline material.

During 2019, 16 requests to use the SEM were received, 62% from researchers of the University of Salamanca and 38% from other external users. The total of operating hours was 27.5.

c) Mechatronics

The mechatronics workstation is a complementary laboratory that provides the Centre with great versatility, contributing new competitive value to the infrastructure. It is a specialized engineering unit that consists of two individual laboratories: machining and electronics.

The main equipment in the machining section is a continuous 5-axis milling machine that is used to produce complex and customized pieces for users' experimental set-ups, as well as for the Centre's own equipment. With it are a wide range of additional tools such as a lathe with 1 metre between centres, a bandsaw with a cutting capacity of up to 200 millimetres/diameter, a vertical drill, an electrode/TIG welder, metrology equipment, an ultrasonic cleaning system, etc. that allow the CLPU to offer highly specialized quality added value.

Likewise, the electronics workstation also plays the same role in supporting researchers and users in the development of their experiments and in contributing to the Centre's technological evolution, thanks to its specialized technicians and an equipment that includes, among other devices, oscilloscopes and function and delay generators.

In 2019, the mechatronics service received 30 applications, 30% associated with competitive open access experimental campaigns, 63% for internal technological development, 3% related to projects undertaken by the Centre and 4% from external users.

Experimental campaigns

The campaigns launched by the Centre are divided into two main types: competitive campaigns for users, which, since they involve the unique laser system, have been selected in one of the open access calls for competition; and internal campaigns, which are of a strategic nature and are allowed beam time either because they contribute to the improvement of the experimental area's technological development, or because they enhance the know-how of the specialists who provide services to our users.

As a user centre, it is appropriate to note the competitive campaigns that were planned and undertaken during the year. The first belonged to the first call for open access competition, while the rest of them already correspond to the second call.

01_2019 (Call 01) Parametric study of the enhancement of laser absorption using wavelength-scale nanostructured targets and subsequent improved ion acceleration at high-repetition-rate

Principal Investigator: Fahrat Beg (University of California, USA)

Dates: 8 January to 1 February

Objective: High-intensity ultrashort-pulse laser-accelerated ion beams used on very thin targets are very promising for a broad range of applications and have been a topic of interest in the last decade. However, for ion accelerators to be effective, it is important to optimize the laser's energy to accelerated ion conversion. A promising method to significantly improve laser absorption is the use of periodic nanostructures with periods at the same wavelength of the laser as interac-

tion surfaces at the front. The purpose of this campaign was to study the role played by the nanostructure's dimensions in the optimization of energy transfer. The experimental test was carried out using VEGA-2. This laser system is ideal for parametric studies because of its high repetition rate, which is also of interest in the context of laser-driven ion accelerators for biomedical applications where a high flow of ions is required (e.g. 10^{10} protons per second for proton therapy tumour treatment).

VEGA operational data:

Days of high energy use of VEGA-2 (percentage in relation to days offered)	14 (93,3%)
Total shots	274
Average energy	4.375 J post-compression (156 TW)
Average hours high energy use of system/day	1 h 45 minutes

Results: Data analysis is being carried out. Results are still under discussion.

02_2019 (Call 02) Laser driven secoundary sources for material science application

Principal Investigator: Matteo Passoni (Polytechnic University of Milan, Italy)

Dates: 20 to 31 May

Objective: The main purpose of this experiment was to conduct a thorough examination of the possibilities afforded by laser generated radiation sources for materials sciences applications. Two specific applications were assessed: the study of damage caused by nanomaterial radiation in a high-radiation environment and an analysis

technique using proton-induced X-ray emission. The space industry is the most promising as regards large-scale application of nanomaterials, since this technique meets the requirements of bulk and cost reduction, thus enhancing performance. In this context, high-energy ions and protons play an important role in the fields of outer space radiation. Therefore, it is important to study the effect of radiation bandwidth, such as ion beams in the multi-MeV range, on the properties of new materials that may be used in the next generation of space probes. Likewise, ion beams in the multi-MeV range can also be used to model the radiation field that will affect the first shielding in a future fusion reactor, which is essential to the search for fusion energy. For this purpose, the use of the VEGA-2 laser has been particularly appropriate because of its combination of high peak power and high repetition rate.

Likewise, this experiment sought to perform the first demonstration of a differential test of the *Particle Induced X-ray Emission* (PIXE) and *High Energy Dispersive X-ray* (HEDX) techniques using a laser-generated source, since their combined use could open up yet unexplored powerful possibilities.

VEGA operational data:

Days of high energy use of VEGA-2 (percentage in relation to days offered)	9 (60%)
Total shots	375
Average energy	4.5 J post-compression (161 TW)
Average hours high energy use of system/day	2 h 48 minutes

Results: This study examined a laser-generated particle source to conduct HEDX and PIXE analyses. This shows how laser generated electrons can be used to quickly identify the presence of certain elements in samples. Surprisingly, the HEDX technique offers the possibility of analysing large artifacts in air and testing the presence of heavy elements at millimetric depth. Additionally, the possibility of using a laser-generated PIXE technique to characterize non-homogeneous structures has been experimentally shown for the first time. Hence,

laser-generated HEDX and PIXE techniques have proved to be complementary tools for elemental analysis. As well as electrons and ions, these new sources can also generate neutrons and gamma rays. These types of radiation can be exploited to obtain other characterization techniques such as ultrafast radiography and photon activation analysis. As regards state-of-the-art laser technology, these results are a strong starting point towards the development of a laser-generated compact and versatile radiation source that may be used for a variety of studies in the area of materials science. The results are under analysis for potential publication. Some of the pieces and the experimental setup have been designed and manufactured at the CLPU's machining workstation.

03_2019 (Call 02) Enhancement of electron guiding and proton generation using orbital momentum modes

Principal Investigator: Robert Fedosejevs (Universidad of Alberta, Canada)

Dates: 3 to 24 June

Objective: The generation of proton beams in the MeV energy range to produce radioisotopes and medical applications is an emerging direct application for high-intensity lasers. Quasi-continuous proton beams have been obtained using ultrashort laser pulses and laser-proton conversion efficiencies between 12% and 15% have been obtained using femtosecond lasers in the 500 to 800 nanometre range. This experiment tested the use of a new type of laser beams involving orbital angular momentum (OAM) or vortex-shaped beams and their effects on electron and proton generation. These beams can be generated using reflecting mirrors that are customized for specific angles and wavelengths. Angular momentum-electron coupling is expected to generate spin currents and increase the magnetic field produced. This, in turn, might modify the interaction between light beam and plasma, resulting in a potential increase in absorption and the collimation of the high energy electrons produced. The high current den-

sity of the generated electrons, in turn, can lead to an increase in proton generation and their energy. Such result, the increase in collimation of the generated protons had already been proven in an experiment carried out in GSI in 2015 with 650-femtosecond laser pulses. The purpose of the experiment was to explore how such increase in proton beam collimation escalates towards shorter 30-femtosecond pulses and we identified the mechanisms that produce such increase in detail. Electron and proton generation and propagation was characterized for a set of OAM modes including Laguerre-Gaussian modes LG+1, LG-1 and LG+2 and it was compared with the results obtained using standard TEM_{00} modes.

VEGA operational data:

Days of high energy use of VEGA-2 (percentage in relation to days offered)	10 (90%)
Total shots	310
Average energy	4.45 J post-compression (158 TW)
Average hours high energy use of system/day	2 h 48 minutes

Results: Proof was achieved that OAM modes can be obtained at intensities within the range of several 10^{19} W/cm^2 using 100 terawatts and 30 femtoseconds in the VEGA-2 laser system. The CLPU has hosted the first experiments using such short pulses and generating OAM focused on solid targets. Both generation and divergence of electrons and protons in the MeV energy range have been studied and results using OAM modes have been favourably compared with those obtained using TEM_{00} Gaussian modes. In overall terms, particle generation in the energy range was found to be similar with LG OAM and with TEM_{00} modes when lower intensities were used. It is now possible to engage in the study of alterations in the physics of the interaction because of the extra angular momentum coupled with such modes on the plasma. Future expectations are that the increase in the magnetic fields generated by such modes can be directly measured. Results are being analysed. Part of the pieces required for the experimental setup were designed and manufactured at the CLPU's workstation.

04_2019 (Call 02) Extreme high charge beams using PW lasers and applications in producing high energy THz pulses (VEGA-3 Commissioning Experiment)

Principal Investigator: Dino Jaroszynski (Strathclyde University, United Kingdom)

Dates: 7 to 31 october

Objective: Recent research has proved that *Laser Wakefield Acceleration* (LWFA) laser-driven electron acceleration can generate not only high energy (over one GeV), highly collimated (milliradian divergences), low dispersion and relatively moderate charge (around 10 pC) electron beams, but also low energy electron beams with a relatively high charge. The interaction of ultra-intense (10 TW-PW) ultrashort (10 fs) lasers with plasmas also produces electrons with extremely high-charge (10 nC), low energy (MeV) and a wide emission cone (up to 60º in relation to the laser's propagation axis). This electron source was first identified in the experimental setup of the University of Strathclyde (Alpha-X). Based on these results, the Strathclyde team has theoretically proved how very highly charged electron beams can produce a THz high-energy (μJ - mJ) radiation beam when propagated from plasma to vacuum or through a thin film of material.

In this context, the main aims of the experiments were as follows:

- Prove the generation of electron beams with relatively high charge and high angular distribution using a PW laser.
- Characterize the properties of the electron source in relation to the experimental parameters (laser pulse duration, energy,...).
- Spatial and spectral characterization of the coherent THz radiation generated for two situations: plasma/vacuum limit and thin Al films.
- Study of the correlation between high energy electrons accelerated in the longitudinal direction of propagation and lateral electron beams.

VEGA operational data:

Days of high energy use of VEGA-3 (percentage in relation to days offered)	12 (86%)
Total shots	1,011
Average energy	25.36 J post-compression (0.84 PW)
Average hours high energy use of system/day	3 h 34 minutes

Results: Success in carrying out the first experiment based on research on electron beams with wide angular distribution using the VEGA-3 PW laser system. This involves having obtained beam profile energies determining their energy, charge and dependence with the experimental parameters. Generated THz was also measured and its spectral properties were characterized. Finally, the intensity of the electromagnetic pulse (EMP) generated by the one-petawatt laser was examined, which is relevant to the different devices that are sensitive to this type of pulses and are usually fitted in the immediate area of the plasmas generated in subcritical density targets. It must be noted that the pieces of the experimental setup were machined ad hoc by the CLPU's mechatronics service. In conclusion, the experiment's main objectives have been successfully achieved. Attention must be also drawn to the display of an unprecedentedly high charge density using a PW laser, which could open new pathways in dosimetry for potential therapeutic applications (using high dose rates).

05_2019 (Call 02) Thomson scattering based vacuum gauge

Principal Investigator: Wendell T. Hill III (University of Maryland, United States)

Dates: 6 to 26 November

Objective: Ultrashort laser pulses in the hundreds of Terawatt (TW) to a few petawatt (PW) range allow research at previously unfeasible levels. For example, such focalized pulses accelerate free electrons

to ultra-relativistic energies in an optical cycle. Electrons are the most relevant actors involved in the laser-matter interaction, and *Thomson scattering* at relativistic energies is ubiquitous, providing a setting for the observation of details regarding pulse and electron distribution. In the complete absence of matter, i.e., in a perfect vacuum setting, petawatt lasers could fulfil an almost 90-year dream, which is to test the essence and nature of quantum vacuum. Alongside the fundamental aspects, extreme intensities will lead to technological development and the design of applications to meet society's needs, laser-driven particle acceleration being an example. Against this background, the project's aim was to develop a photonic vacuum gauge that could measure pressures below 10^{-12} mbar, which is necessary for the study of quantum vacuum. Thus, this experimental campaign had a twofold mission: the demonstration to test the photonic vacuum gauge at pressures between 10^{-5} – 10^{-7} mbar, where there are reliable commercial gauges; and a detailed study of relativistic *Thomson scattering* spectral and angular distributions at intensities between 10^{18} and 10^{19} W/cm^2, where no experimental quantum studies on *Thomson scattering* have been conducted.

VEGA operational data:

Days of high energy use of VEGA-2 (percentage in relation to days offered)	7 (70%)
Total shots	25.889
Average energy	4.3 J post-compression (165 TW)
Average hours high energy use of system/day	4 h 31 minutes

Results: Measurements were performed using VEGA-2 at a repetition rate of 1 Hz in series of 32 to 256 shots and at energies in the 1 to 6 J range with intensities focused between 10^{18} and 10^{19} W/cm^2. Relativistic nonlinear Thomson scattering of free electrons, released through *in situ* N_2 ionization, has been identified using a set of detectors arranged as shown in Fig. 1. The signals obtained during the campaign will be use for the two abovementioned purposes.

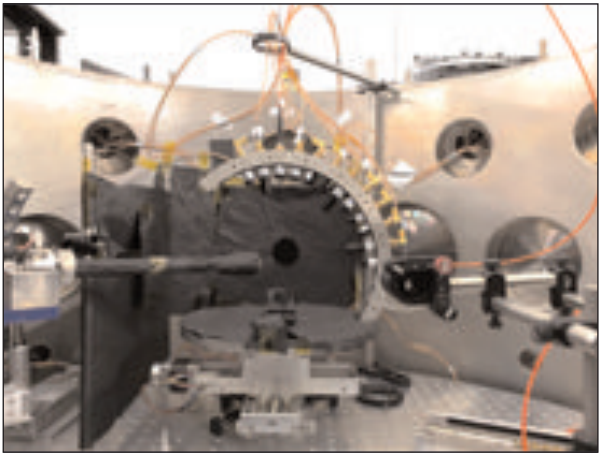


Fig. 1. In the direction of the laser beam, picture of the device placed in the vacuum chamber of VEGA-2 used in the study. The instrumentation consists of a nozzle to introduce gas into the chamber and a mechanized bow mounted with 17 individual detectors to capture the light diffused from the source. The bow is fixed on a rotatory base so that it can capture the light of almost an entire hemisphere around the source.

In December 2019, two additional strategic campaigns were launched with the purpose of preparing a series of elements for the competitive access campaigns envisaged for 2020.

06_2019 (Strategic) Test and characterization of a permanent dipole magnet to select proton energies

Principal Investigator: Luca Volpe (USAL/CLPU)

Dates: 2 to 5 December

Objective: One of the competitive access campaigns accepted and planned for 2020 required a proton energy selector to carry out precise measurements of a plasma's opacity. Since the CLPU had not yet produced a selector with such degree of accuracy, it was considered strategic to prepare such a system.

VEGA operational data:

Days of high energy use of VEGA-2 (percentage in relation to days offered)	5 (125%)
Total shots	228
Average energy	4.39 J post-compression (156 TW)
Average hours high energy use of system/day	4 h 18 minutes

Results: The system was successfully designed and tried during the strategic action and will be used in some of the competitive campaigns envisaged for next year.

07_2019 (Strategic) Test and characterization of the special flat liquid target at CLPU

Principal Investigator: Luca Volpe (USAL/CLPU)

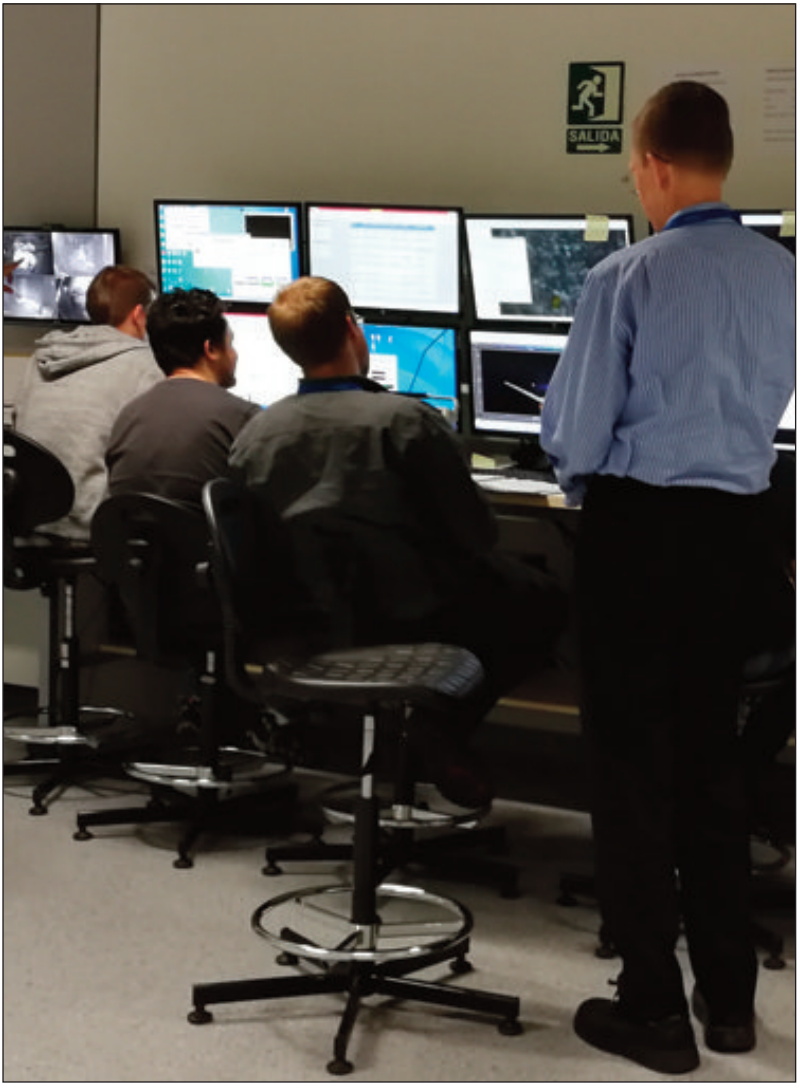
Dates: 10 to 19 December

Objective: The CLPU has a liquid jet vacuum system that generates a millimetric extremely thin sheet of water at very high pressure. The decision to undertake this strategic action was based on the fact that this system had never been tested on the petawatt and its use will be required for one of the competitive campaigns planned for 2020.

VEGA operational data:

Days of high energy use of VEGA-3 (percentage in relation to days offered)	1 (12.5%)
Total shots	6
Average energy	20,85 J post-compression (570 TW)
Average hours high energy use of system/day	0 h 3 minutes

Results: Tests were successful and yielded highly valuable data on the distinguishing characteristics between a conventional solid target and the flat liquid target used when subjected to petawatt-laser irradiation.



RESEARCH

As a user-oriented centre, the CLPU must always remain at the forefront of technology and innovation. Only in this way can it provide researchers with comprehensive and strategic services for international scientific development. In line with this, the CLPU is committed to four well defined lines of work:

- **Technological development of VEGA:** its guidelines, as mentioned in the section devoted to the system's uniqueness, are mainly focused on offering total synchronization both among its phases and between the complementary equipment and VEGA. It is a strategic line that seeks to optimize the uniqueness and versatility of the Centre's main system.
- **VEGA applications:** in this case, as shown by the competitive access campaigns, the field of laser-induced plasma physics takes centre stage. The high repetition rate provided by VEGA, one of the three petawatt systems in the world that is capable of firing at one shot per second, gives it an added value by increasing the statistics of its results. The complexity involved in fields like diagnostics or targetry is one of the CLPU's primary objectives, both in particle acceleration and radiation experiments, and in others linked to warm dense matter and the effects associated with laboratory astrophysics. In short, plasma physics, nuclear physics, materials science, astrophysics and medical physics are priority fields at the Centre inasmuch as they are so too among the international scientific community. A large part of the knowledge acquired through the campaigns is being devoted to obtaining secondary ionizing radiation sources, which include: proton sources (between 1-20 MeV) for the TNSA; LWFA-accelerated electron sources (around hundreds of MeV); generation of betatron radiation; and X-ray Bremsstrahlung sources.
- **Metrology:** as noted when addressing the unique system, the CLPU has a sophisticated metrology bench in the laser area for the permanent analysis and control of the different beam parameters. Expectations are to complement it with a new system in the test area, another added value for our users' experiments. The project started in 2019.

- **Non-unique sources:** associated with the ULAMP system, since the CEP is already complementary to VEGA, this laboratory bridges the gap between conventional systems and unique systems such as VEGA. Besides, the gigawatt system and all its additional scientific equipment and personnel provide a suitable environment to test novel ideas that may bring new scientific groups closer to the femtosecond world.

Publications

Pasley, J.; Andrianaki, G.; Baroutsos, A. Volpe, L. et al., Innovative Education and Training in high power laser plasmas (PoweLaPs) of plasma physics, high power laser-matter interactions and high energy density physics-theory and experiments, High Power Laser Science and Engineering, vol. 7, e23.

Barbato, F.; Batani, D.; Mancelli, D. Volpe, L. et al., Propagation-based imaging phase-contrast enhanced imaging setup for single shot acquisition using laser-generated X-ray sources, Journal of Instrumentation, vol. 14, 03, C03005.

Antonelli, L.; Barbato, F.; Mancelli, D. et al., X-Ray phase-contrast imaging for laser-induced shock waves, EPL–Europhysics Letter, vol. 125 (3). 35002.

Volpe, L.; Fedosejevs, R.; Gatti, G. et al., Generation of high energy laser-driven electron and proton sources with the 200 TW system VEGA 2 at the Centro de Láseres Pulsados, High Power Laser Science and Engineering, vol. 7, e25. *

Curcio, A. and Volpe, L., A quasi-static model for hot-electron interaction with self-generated magnetic fields, Plasma Physics and Controlled Fusion, vol. 61, 5, 055013.

Zeraouli, G.; Gatti, G.; Longman, A. et al., Development of an adjustable Kirkpatrick-Baez microscope for laser driven X-ray sources, Review of Scientific Instruments, vol. 90, 063704. *

Malko, S.; Vaisseau, X.; Perez, F.; Batani, D.; Curcio, A.; Ehret, M.; Honrubia, J.; Jakubska, K.; Morace, A.; Santos, J.J. And Volpe, L., Enhanced relativistic-electron beam collimation using two consecutive laser pulses, Scientific Reports, vol.9, nº 1, 14061.

He, C.A.; Longman, A.; Pérez-Hernández, J.A., de Marco, M.; Salgado, C.; Zeraouli, G.; Gatti, G.; Roso, L.; Fedosejevs, R. and Hill III, W.T., Towards an in situ, full-power gauge of the focal-volume intensity of petawatt-class lasers, Optics Express, vol.27, nº21, 30020. *

Amini, K.; Biegert, J.; Calegari, F.; Chacón, A.; Ciappina, M.F.; Dauphin, A.; Efimov, D.K.; Figueira de Morisson, C.; Giergiel, K.; Gniewek, P.; Landsman, A.S.; Lesiuk, M.; Mandrysz, M.; Maxwell, A.S.; Moszyński, R.; Ortmann, L.; Pérez-Hernández, J.A.; Picón, A.; Pisanty, Prauzner-Bechcicki, J.; Sacha, K.; Suárez, N.; Zaïr, A.; Zakrzewski, J. and Lewenstein, M., Symphony on Strong Field Approximation, Reports on Progress in Physics, 82, 116001.

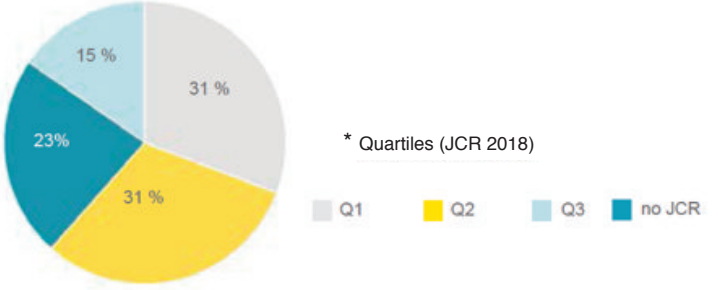
Huault, M.; Ospina, V.; Pérez-Hernández, J.A.; Apiñániz, J.I.; de Luis, D.; Malko, S.; Mendez, C.; Salgado, C.; Vaisseau, X.; Zeraouli, G.; Fedosejevs, R. and Maffini, A. A 2D scintillator-based proton detector for high repetition rate experiments, High Power Laser Science and Engineering, vol.7, e60. *

De Marco, M.; Volpe, L.; Gatti, G.; Liszi, M.; Drotar, I.; Kamperidis, C. and Nelissen, K., Propagation of laser-driven electromagnetic pulses in laser target area, EMC Europe 2019 Proceedings

Shahzad, M.; Reid, L.R., Spesyvtsev, R.; et al., Characterisation of a laser plasma accelerator x-ray source size using a Kirkpatrick-Baez microscope, SPIE Optics+Optoelectronics [11036] Bellingham *

Méndez, C.; Varela, O.; García, E. et al.,VEGA laser facility beamlines management for pump-probe experiments, Proceedings of SPIE (AOP 2019, Lisboa (Portugal), AOP2019_112071Z

With an asterisk (*) the publications related to experimental campaigns carried out at the CLPU



Projects

applied research

Entity	Title	IP	Duration	CLPU role
MINECO	*PALMA*	Luis Roso/ Giancarlo Gatti	30/12/16 - 29/12/20	Leader
MinCIU	*Technical Support Staff (PTA 2017)*	José Manuel Álvarez	10/12/18 - 09/12/21	Leader
MinCIU	*Youth Guarantee 2018*	José Manuel Álvarez	01/09/19 - 31/08/21	Leader

r & d networks

Entity	Title	IP	Duration	CLPU role
UE/H2020	*Laserlab Europe IV*	Luis Roso	01/12/15 - 30/11/19	Partner
MINECO	*RedLUR*	Luis Roso	01/07/17 - 15/11/19	Coordinator
UE/H2020	*Laserlab Europe V*	Luis Roso	01/12/19 - 30/11/23	Partner
UE/H2020	*IMPULSE. Integrated management and reliable operation for user-based laser scientific excellence*	Luca Volpe	01/12/19 - 30/05/23	Partner

Laser Accelerated Particles for Medical Applications (PALMA)

MINECO / R&D projects – Research challenges 2016 *48 months*

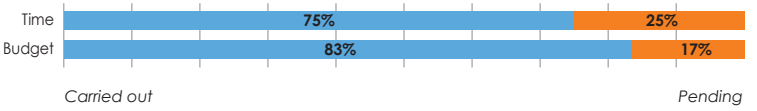
Aim:

Development of radiation sources that may allow biomedical scientists to measure and characterize the influence of ultrafast radiotherapy as compared to traditional radiotherapy. For this purpose, an X-ray betatron source, a TNSA proton source and a preliminary phase neutron source will be developed. Direct adjustments for applications in other sectors such as materials science will also be made.

Actions:

During 2019, several experimental campaigns have been carried out, contributing to the development of secondary sources of radiation. Likewise, progress has been made in the development of new targets. Specifically, tests of the working of the ultrathin water sheet system have been conducted using VEGA-3. The system consists of two liquid microjets whose collision generates a water sheet. On the other hand, in order to enhance its performance and improve the vacuum level in the laser's essential components, a liquid nitrogen cold system that collects much of this vapor and enhances the equipment's performance as regards operating time has been designed and installed. A gas mixer has also been improved for experiments with gaseous targets at high pressures. This year has also been one of significant progress in the generated particle (essentially electrons and neutrons) characterization and detection systems. The existing dipolar systems used for the characterization of the energy spectra of the generated beams have also been improved. Automatic measurement of single pulse duration has been carried out for the first time, which allows one-to-one correlation between each shot and its residual *chirp*.

Implementation:



Radiological protection plan in the CLPU's authorized radioactive faciliy

MinCIU / Promotion of employment for young people & youth guarantee 2018 *24 months*

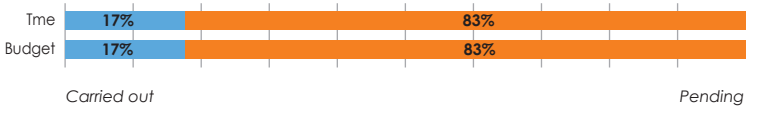
Aim:

The purpose of this project is to develop and implement the Centre's radiological monitoring plan to ensure the correct operation of the CLPU as a radioactive facility. In this regard, one of its main goals is the technical monitoring of the equipment and devices that make up the radiological protection system, performing thermoluminescence dosimetry and registering any activated materials there may be.

Actions:

The primary goal of the projects presented in this call is the recruitment, training and specialization of young researchers. Recruitment for this applied research project took place in September 2019, devoting the first months to their becoming familiar with the operation of the detectors that make up the Centre's radiological monitoring network. Among their tasks were routine registration of the facility's radiation levels on a daily and weekly basis, yearly check of some of such detectors (taking charge of the consequent sending and receiving of equipment for its compulsory calibration at the CIEMAT and the operation and supervision of the IRA 3254, performing radioprotection operator tasks throughout the two experimental campaigns that took place in the last quarter of the year. Alongside this, a study on the use of passive dosimetry for the characterization of pulsed radiation fields generated by VEGA has been launched and in-house training courses have been delivered.

Implementation:

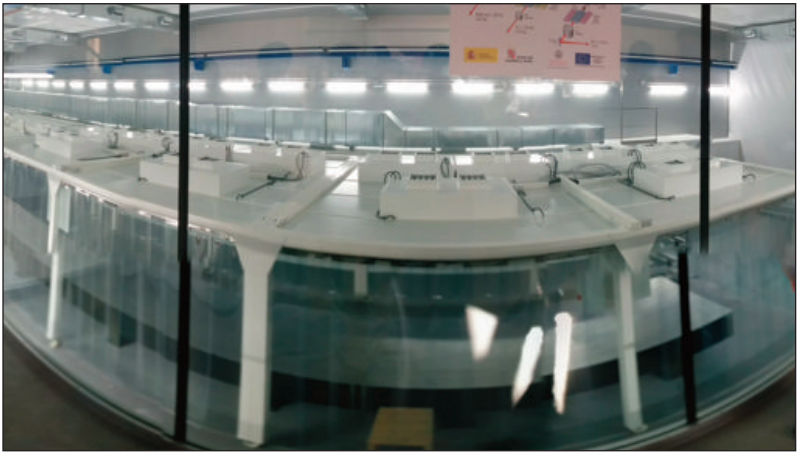


Analysis and optimization of radiological protection of the CLPU and other similar facilities

MinCIU / Technical support staff 2017 *36 months*

Aim:

This project is aimed at the tuning and operation of the high-purity germanium detector and the development of additional measures for the optimization of the radiological protection of the Centre. This includes Montecarlo simulations, tuning and operation of the thermoluminescence dosimetry Harshaw 4500 workstation, systematic measurement of dosimetric characterization during the experimental campaigns, drawing up of protocols to establish a national and international standard for radiological protection, and contribution to the development of new techniques and measurement systems according to the fields generated in the facility.



Actions:

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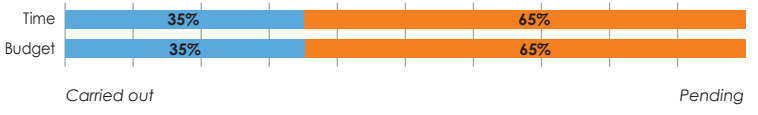
campaigns, drawing up of protocols to establish a national and international standard for radiological protection, and contribution to the development of new techniques and measurement systems according to the fields generated in the facility.

Implementation:



Spanish network of ultrafast lasers (RedLUR)

MINECO / Excellence networks 2016 *24 months*

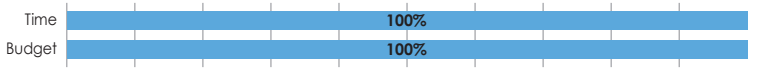
Aim:

On occasion of the CONSOLIDER – SAUUL project, Spain became the venue for a gathering of a scientific community and a generation of young researchers who share an interest in ultrafast ultra-intense lasers. Upon this basis, the Ultrafast Laser Specialized Group, GELUR, was born, its consolidation, continuance and promotion being the main goals of the RedLUR. The project suggests an action that revolves around two axes: the holding of an on-site yearly meeting of the scientific-technological community and the distance maintenance and expansion of a scientific platform.

Actions:

During this year of the project, the web platform developed at *http://www.ultrafast.es* was maintained and updated, gathering the activities undertaken by the GELUR laser laboratories and uploading two new publications: 'Libro Blanco Ultrafast' and the catalogue of services, a living document aimed at bringing to the fore the knowledge and equipment that these national laser laboratories make available to scientific and industrial communities. Likewise, the third edition of Ultrafast Science & Technology Spain, a significant meeting that consolidates the scientific collaboration of this excellence network, was organized and held, this time in Madrid.

Implementation:



Totally carried out

Laserlab Europe IV

UE / H2020 - INFRAIA 2014-2015 *48 months*

Aims:

Laserlab-Europe is a consortium made up of European laser-technology research organizations whose goal is to consolidate a network for the promotion of scientific-technical research in this area.

Actions:

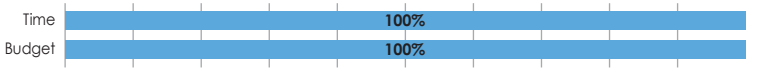
The CLPU has participated in this action though several work packages (WP):

WP4. Scientific and technological exchange through the organization of the NEILS (network activity on the extreme intensity laser systems).

WP9. The CLPU has led the task of fostering relationships with centres and institutes from other worldwide regions.

Likewise, the Spanish Centre for Pulsed Lasers has taken part in two joint research activities (JRA): Innovative Laser Technologies (ILT), specifically in the Thin-disc and volume laser based mid-IR resources section; and Laser-driven high-energy photon and particle sources towards Industrial and Societal Applications (LEPP), in the implementation of the Development and applications on compact light sources for imaging; radiotherapy and imaging applications of laser based proton beams and Advanced instrumentation and targets for applications of laser-driven high energy photon and particles sources tasks.

Implementation:



Totally carried out

Laserlab Europe V

UE / H2020 - INFRAIA 2018-2020 *48 months*

Aim:

The pan-European consortium consolidates its standing once again with a fifth edition whose main goals are the coordinated promotion of the use of advanced lasers and laser technologies for research and innovation, providing services to an interdisciplinary user community (academia and industry), increasing the European specialized human resources base and enhancing such human and technical resources through the exchange of technology and know-how among laser experts and operators across Europe.

Actions:

For the first time after the full running of the unique equipment of the Centre, VEGA, the system is offered to Laserlab users.

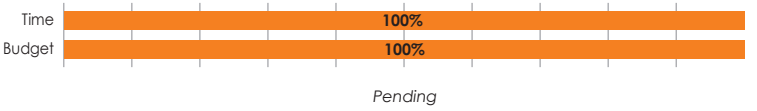
Likewise, as in other editions, the CLPU takes part in this action through several work packages (still beginning, since the project was launched in December 2019):

WP3. Scientific and technological exchange. Together with the German GSI facility, the Centre leads the task of establishing specific networks related to extremely high-intensity laser systems.

WP11. Specific package for transnational access to the CPLU.

WP33. Participation of the CLPU in the Joint Research Activity (JRA) on primary and secondary sources and workstations for application.

Implementation:



Integrated management and reliable operation for used-based laser scientific excellence (IMPULSE)

UE / H2020 - INFRADEV 2019 *42 months*

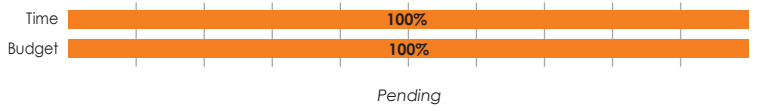
Aim:

This project, supported by a significant funding contribution of the European Union, will provide the resources and experience of the main European laser facilities to accelerate the transition of Extreme Light Infrastructure (ELI) centres to the running phase and improve sustainability. By developing best practices as a group to support user experience, the project's consortium will mitigate the risk of operating state-of-the-art, high-power and high repetition rate lasers. The technologies that most contribute to such risk will be developed and ELI will rise as a global platform for high-power laser development, fostering innovation in the field.

Actions:

Approval of the project and kick-off meetings for its coordination and launching.

Implementation:



Other results

Roso, L.; Pérez-Hernández, J.A.; Gatti, G. et al., Possibility of an in situ gauge for PW relativistic intensities, SPIE Optics and Optoelectronics, Prague (Czech Rep.) [Guest presentation]

Malko, S.; Cayzac, W.; Ospina, V. et al., Ion stopping power measurements in coupled and degenerate plasma, International Conference in High Energy Density, Oxford (United Kingdom) [Presentation]

Méndez, C.; Varela, O.; García, E. et al., VEGA laser facility beamlines management for pump-probe experiments, AOP 2019, Lisbon (Portugal) [Presentation]

Méndez, C. Varela, O.; Hernández, I. et al., VEGA Petawatt laser facility: current system capabilities and near future beamlines management, CLEO Europe-EQEC 2019, Munich (Germany) [Poster]

Méndez, C. García, E.; Varea, O. et al., VEGA Petawatt laser: influence of large Ti:Sapphire crystal quality in final energy distribution, CLEO Europe-EQEC 2019, Munich (Germany) [Poster]

Pisarczyk, T.; Gus'kov S. Yu; Batani, D. et al., Investigation of spontaneous magnetic fields, electron and ion emissions in laser-produced plasma in experiments at PALS, EPS Conference, Milan (Italy) [Poster]

Claps, G.; Cordella, F.; Pacella, D. et al., Gamma rays detection in laser produced plasmas with Silicon C-MOS imager by means of trace analysis, 3rd European Conference on Plasma Diagnostic (ECPD), Lisbon (Portugal) [Poster]

Claps, G.; Cordella, F.; Pacella, D. et al., Soft X-ray measurement with a gas detector coupled to microchips in la-ser plasma experiments at VEGA-2, 3rd European Conference on Plasma Diagnostic (ECPD), Lisbon (Portugal) [Poster]

De Marco, M.; Nelissen, K.; Ospina, V. et al., First characterization of EMP generated during VEGA-2 laser pulse interaction with Al foil target, 3rd European Conference on Plasma Diagnostic (ECPD), Lisbon (Portugal) [Poster]

Malko, S.; Salgado, C.; Fedosejevs, R. et al., Characterization of the pre-plasma formation for high intensity laser solid target experiment, 3rd European Conference on Plasma Diagnostic (ECPD), Lisbon (Portugal) [Poster]

Revet, G.; Ehret, M.; Santos, J.J. et al., Particle energy deposition in CR-39 detectors: track's diameter/length couple analysis method, 3rd European Conference on Plasma Diagnostic (ECPD), Lisbon (Portugal) [Poster]

Zeraouli, G.; Gatti, G.; Longman, A. et al., Development of an adjustable Kirkpatrick-Baez microscope for laser driven X-ray sources at CLPU, 3rd European Conference on Plasma Diagnostic (ECPD), Lisbon (Portugal) [Poster]

Volpe, L., Targetry for High Power High Repetition rate Experiments 'The CLPU strategy', TARG4, Milan (Italy) [Presentation]

De Marco, M.; Gatti, G.; Salgado, C. et al., Characterization of micrometer flat liquid foil for high repetition rate laser-plasma experiment @ the CLPU, TARG4, Milan (Italy)

Cristoforetti, G.; Antonelli, L.; Mancelli, D. et al., Half-integer harmonics: a powerful tool for investigating stimulated Raman Scaterring and Two Plasmon Decay in shock ignition irradiation regime, IFSA2019, Osaka (Japan) [Presentation]

Salgado, C.; Ehret, M.; Opsina, V. et al., Near-critical plasmas from supersonic gas-jets for enhanced ion accel-eration by ultraintense laser interaction, TARG4, Milan (Italy) [Presentation]

Salgado, C.; Ehret, M.; Opsina, V. et al., Near-critical plasmas from supersonic gas-jets for enhanced ion accel-eration by ultraintense laser interaction, IFSA2019, Osaka (Japan) [Presentation]

Malko, S.; Cayzac, W.; Ospina, V. et al.,, Experimental approach for ion stopping power measurements in a warm dense plasma at high repetition rate, IFSA2019, Osaka (Japan) [Presentation]

Fedosejevs, R.; Longman, A.; Salgado, C. et al., MeV Electron and Betatron Production from wakefield interactions using orbital angular momentum laser pulses, 9th Frontiers of Plasma Physics and Technology, Negombo (Sri Lanka) [Presentation]

Rico, M.; Jubera, M.; San Blas, A., et al., Improvements on characterization of the threshold and productivity in femtosecond laser ablation of bone, CLEO Europe 2019, Munich (Germany) [Poster]

Ehret, M.; Apiñaniz, J.I.; Bagnoud, V.; et al., Picosecond Laser-Driven Transient electromagnetic Fields for High Energy-Density Beam Tailoring, 25º Congrès Général de la Société Française de Physique, Nantes (France) [Poster]

Malko, S.; Cayzac, W.; Ospina, V.; et al., Ion stopping power measurements in plasma, 9th Omega Laser Facility User Group Workshop, Rochester (USA) [Poster]

Roso, L. Radioprotección en Instalaciones Científico-Técnicas Singulares, 6º Congreso SEFM–SEPR, Burgos (Spain) [Presentation]

Soria, A; Álvarez, J.M. and Gutiérrez-Neira, C.., Estudio de la activación en la cámara de interacción de una in-stalación láser, 6º Congreso SEFM–SEPR, Burgos (Spain) [Poster]

Roso, L., Petawatt Lasers and Their potential applications in biomedicine, International School on Light Sciences and Technologies (ISLiST), Santander (Spain) [Guest presentation]

Méndez, C., VEGA laser facility: current system capabilities and near future improvements, XXXVII Reunión Bienal de la RSEF, Zaragoza (Spain) [Presentation]

Méndez, C., VEGA laser facility: current system capabilities and near future improvements, XXXVII Reunión Bienal de la RSEF, Zaragoza (Spain) [Poster]

De Marco, M. et al., Propagation of laser-driven electromagnetic pulses in laser target area, Electromagnetic Compatibility Conference, Barcelona (Spain) [Presentation]

He, C.Z.; Longman, A.; Pérez-Hernández, J.A.; de Marco, M.; Salgado, C.; Zeraouli, G.; Gatti, G.; Roso, L.; Fedosejevs, R., and Hill, WT. Towards an in situ, full-power gauge of the focal-volume intensity, Laserlab Europe User's Meeting, Coimbra (Portugal) [Presentation]

Méndez, C. VEGA laser fiacility: characterization and beamlines management, USTS2019, Madrid (Spain) [Guest presentation]

Rico, M. Florián, C., Jubera, M. et Roso, L., Femtosecond laser drilling of metals with axicon lens & filamentation USTS2019, Madrid (Spain) [Poster]

Rico, M.; Colomer, B.; Ortiz, R.. et Roso, L., LASERONUAV - Development of laser microdiode in 2.1 um as countermeasure for RPAs, USTS2019, Madrid (Spain) [Poster]

Zaldo, C.; Rico, M.; Serrano, MD. et Cascales C., Ultrafast non-linear absorption excitation of Tb.Eu-based nano-thermometers, USTS2019, Madrid (Spain) [Poster]

Volpe, L., Advances on the VEGA system @ CLPU. the first commissioning experiment; the first call for uses access, HFLP– High Field Laser-Plasma Interaction, Satellite Meeting of the EPS 2019, Milan (Italy) [Presentation]

Volpe, L., Laser-Plasma Physics and Particle Acceleration at the Centro de Láseres Pulsados, 11th NLTE Code Comparison, Gran Canaria (Spain) [Guest presentation]

Gatti, G., Progress in CLPU Experimental Activities, Plasma Physics by Laser Application (PPLA), Pisa (Italy) [Presentation]

Volpe, L., Proton detector based on scintillator for HRR at Dresden, JRA Laserlab Meeting, Florence (Italy) [Presentation]

Gatti, G., Laser Particle Accelerators, Innovation in Radiation Therapy, Villamayor (Spain) [Presentation]

Roso, L., Applications of laser-driven accelerators, Innovation in Radiation Therapy, Villamayor (Spain) [Presentation]

Longman, A.; He, C.Z.; Pérez-Hernández, J.A. et al., Experimental determination of peak laser intensity via relativistic Thomson scattering, 61st Annual Meeting of the APS Division of Plasma Physics, Fort Lauderdale (USA) [Presentation]

Malko, S.; Cayzac, W.; Osppina, V. et al., Stopping power measurements of ions in a moderately coupled and degenerate plasma, 61st Annual Meeting of the APS Division of Plasma Physics, Fort Lauderdale (USA) [Presentation]

He, C.Z.; Hill III, W. T.; Longman, A. et al., Relativistic Thomson scattering: a tool for pulse diagnostics and exploring inner shell dynamic, 50th Annual Meeting of the APS Division of Atomic, Molecular and Optical Physics, DAMOP 2019, Milwaukee (USA), [Presentation]

Hill III, W.T.; He, C.Z.; Roso L. et al., First experimental steps towards an in situ gauge for direct measurements of relativistic intensities, CLEO San José (USA) [Presentation]

Pacella, D.; Claps, G.; Cordella, F., Innovative X and Gamma rays detection with silicon and gas detectors coupled to microchip electronics for laser produced plasmas, 3rd European Conference on Plasma Diagnostics, Lisbon (Portugal) [Poster]

Antonelli, L.; Barbato, F.; Mancelli, D. et al., Phase-enhanced X-ray radiography for dense plasma studies, 3rd European Conference on Plasma Diagnostics, Lisbon (Portugal) [Presentation]

Turianska, O.; Raffestin, D.; Batani, D., Bremsstrahlung Canon for the characterization of hot electrons generated in high intensity laser-plasma interactions, 3rd European Conference on Plasma Diagnostics, Lisbon (Portugal) [Poster]

Roso, L., CPA lasers: the ultrafast ultraintense scientific revolution, Reunión hispano-lusa IBER2019, Évora (Portugal) [Guest presentation]

Roso, L., Posibilidades de los láseres pulsados, Foro 2E+I Fuerza 35, Toledo (Spain) [Presentation]

Pérez-Hernández, J.A., Volpe, L., Fedosejevs, R. et al., Generation of high energy laser-driven electron and proton sources with the 200 TW system VEGA-2 at the Centro de Láseres Pulsados, USTS2019, Madrid (Spain) [Presentation]

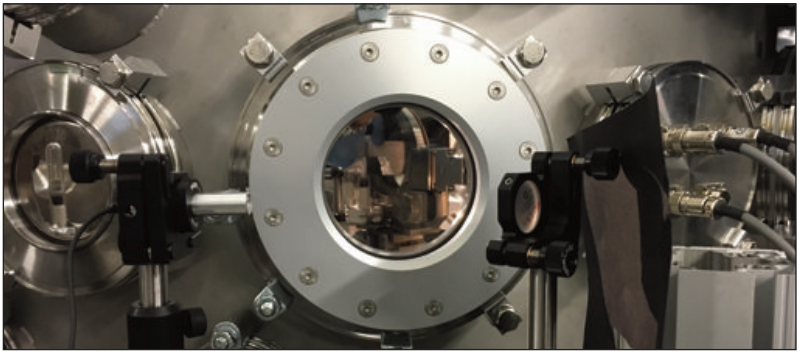
Volpe, L., Impact of staff exchange for infrastructure development, Laserlab Europe Conference, Florencia (Italy) [Presentation]

Volpe, L., Ultra-high dose rate radiation research at CLPU, Innovation in Radiation Therapy, Villamayor (Spain) [Presentation]

Lundh, O. et al., Electron acceleration in merging laser wakefields, 4th European Advanced Accelerator Concepts Workshop (EAAC), Isola d'Elba (Italy) [Presentation]

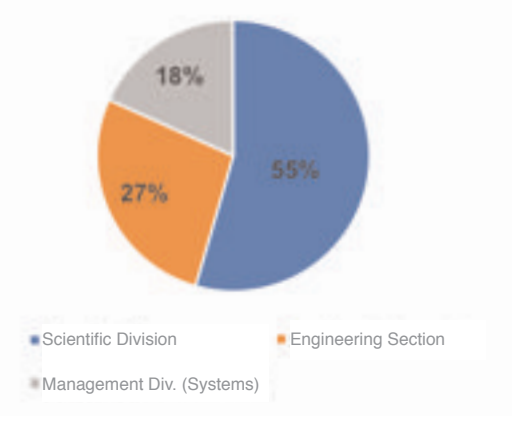
Training

- **Laser-Plasma Physics Summer School (LaPlaSS):** in 2019, the second edition of this specialized event that is driven by the Chair of the Spanish Centre for Pulsed Lasers, of the University of Salamanca was held. On this occasion, training was focused on the analysis of experimental methods in laser-driven plasma physics. It was taken by around twenty students from European and American Institutions and included the participation of more than ten guest teachers from a number of European laser research facilities. Further information on the edition can be found at https://www.clpu.es/es/LaPlaSS_2019. This school is held in late September and its first two editions were supported by the Laserlab Europe pan-European project.



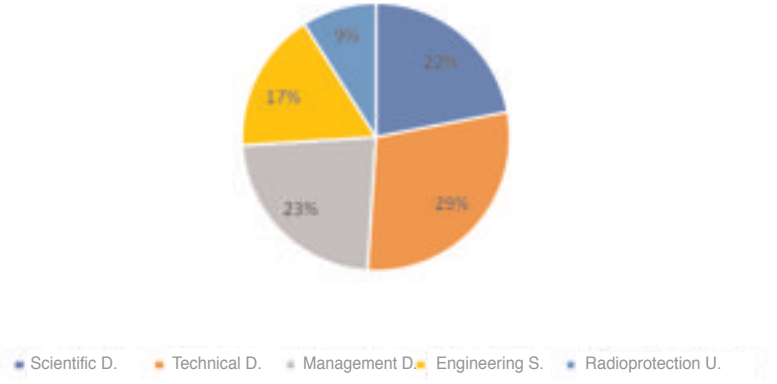
- **Bordeaux Summer School:** under the title Short pulse lasers and applications, the University of Bordeaux held its summer school with the participation as guest speaker of the director of the CLPU Chair in laser-driven plasma physics at the University of Salamanca, Luca Volpe, who delivered a lecture entitled *'Laser-Plasma Physics application for Warm Dense Matter and ICF'*.
- **PowerLaPs Training School:** this is a specialized event linked to the PowerLaPs European project. It includes the participation of the University of Salamanca represented by the CLPU Chair. Alongside its director, Luca Volpe, several members of the facility's scientific division participated as guest speakers.

- **Master's Degree in Physics and Laser Technology:** during academic years 2018-2019 and 2019-2020, the Spanish Centre for Pulsed Lasers has participated and is participating in the training delivered in this master's degree, which is promoted by the University of Salamanca and includes the participation of the University of Valladolid. Aimed at training laser-specialist scientists, it consists of 60 ECTS taught throughout one academic year. Although its approach is strongly practical, it also includes a significant training component on the theoretical foundations of applied optics. Further information can be found at *http://laser.usal.es/posgrado/*
- **Lifelong Training Courses:** the Chair of the USAL 'Spanish Centre for Pulsed Lasers', through its director Luca Volpe, conducted the Laser Plasma Physics and Diagnostic Methods specific training course in academic year 2019. At the end of the year, once the following academic year had begun, information on three new specialization courses to be held in 2020 was issued. Further information can be found at *https://www.clpu.es/usal_clpu_2020*
- **University of Experience (for older adults):** the facility's director, Luis Roso, Chair of Optics at the University of Salamanca, teaches physics as part of the Experience curricula of the University of Salamanca. He delivered lectures in academic year 2018-2019 and is doing so now in academic year 2019-2020.
- **Internships at the CLPU:** in 2019, the Spanish Centre for Pulsed Lasers hosted 9 curricular and extracurricular internships, held by 7 students from the University of Salamanca and 2 from training cycles from different secondary education schools of Castile and Leon:



- **In-house training:** in 2019, the CLPU's specialized staff took a total of 50 courses to enhance and upgrade their training at the professional level. Eleven of these courses were taken at the same time by staff from different divisions. Taking this into account, the total number of training hours in 2019 has been 2,920, the average per worker being 67.90.

Courses percentage by Division / Section / Unit



INNOVATION AND DEVELOPMENT

Projects

technological development

Entity	Title	IP	Duration	CLPU role
EDA	*Study on critical critical components for military lasers (...)*	Luis Roso	21/11/17 - 31/03/19	Partner
MinisDEF	*SIGILAR*	Luis Roso	01/12/19 - 31/10/21	Coordinator
MINECO	*ULTRALASER*	Luis Roso	01/09/15 - 31/01/19	Partner
MinCIU	*Multi-shot with HRR experimental campaigns*	José A. Pérez	01/01/18 - 31/12/20	Leader
MinCIU	*Youth Guarantee*	Giancarlo Gatti	01/10/19 - 30/09/21	Leader
MinCIU	*Youth Guarantee*	Cruz Méndez	01/09/19 - 30/08/21	Leader

Study on critical components for military lasers and advantages and use of wide area sensor technologies on UAV

AED / Call of the European Defence Agency *15 months*

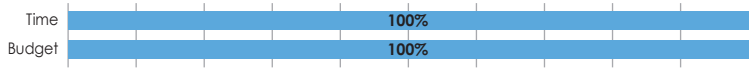
Aim:

This project, driven by AERTEC Solutions in collaboration with the Spanish Centre for Pulsed Lasers is aimed at the miniature development of a countermeasure system prototype that includes a near infrared laser emitting unit that can be used onboard in unmanned aerial vehicles of the European Defence Agency, the sponsor of the project.

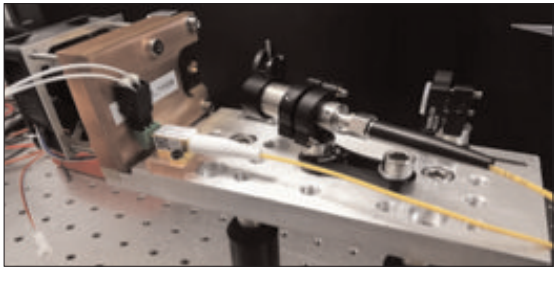
Actions:

The experimental part of the project was completed at the beginning of the second quarter of 2019, and the corresponding reports were submitted at the end of April. Subsequently, approval was obtained for the publishing of certain details at specific events. Specifically, material was prepared for OPTRO 2020, held in January 2020.

Implementation:



Totally carried out



Prototype based on optically pumped microdiodes during the TRL5 phase.

High-power pulsed laser guided system in the military field (SIGILAR)

MinDEF / COINCIDENTE Program *24 months*

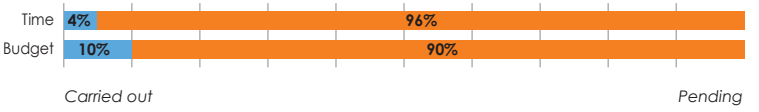
Aim:

The Spanish Centre for Pulsed Lasers is in charge of the management of this program whose main purpose is the development of a pulsed laser guided system prototype that can be implemented on a shoring prototype and subsequent analysis of the scalability of the technology designed.

Actions:

Launched in November 2019, the first steps have been focused on project management, preparing kick-off and coordination meetings with the company subcontracted for the development of the shoring technology. The first deliverable has been sent and work on the project's first packages is in progress.

Implementation:



Development of low-cost ultrashort pulse lasers with advanced functions for application in new industrial sectors - ULTRALASER

MINECO / Collaboration challenges 2015 *41 months*

Aim:

The main goal of this collaborative project was to obtain a family of low-cost ultrashort pulse lasers for new applications in emerging industrial sectors. The two parameters that should define these systems are advanced functions and great versatility.

Actions:

This project was completed in January 2019, when the final reports were drawn up and a final telematic meeting was held with the participation of the action's coordinator and the rest of the partners, who agreed to continue collaborations based on what had already been achieved in the project.

Implementation:

Totally carried out

Multi-shot with high repetition rate experimental campaigns

MinCIU / Support for scientific-technical infrastructures and equipment 2018

36 months

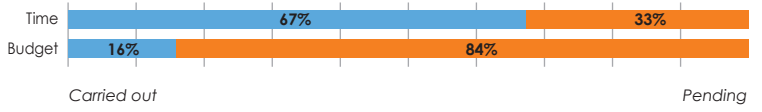
Aim:

Their main goal is to adapt the Centre's test area to be able to make full use of the potential of the VEGA petawatt in a way that is effective, relevant and safe for both users and CLPU staff.

Actions:

This year's actions have focused on the launch of the call for tenders following an open procedure of the shot-to-shot detection elements and of the multicast chamber and video-recorder; the signing of a contract for a new vacuum chamber for experimentation; making the necessary boreholes in the concrete block to strengthen radiological protection; purchase and installation of a new vacuum chamber; and signing of the contract for a gate valve for the vacuum system.

Implementation:



Synchronization of beam outputs of VEGA-3 petawatt laser system

MinCIU / Promotion of employment for young people and implementation of youth guarantee 2018

24 months

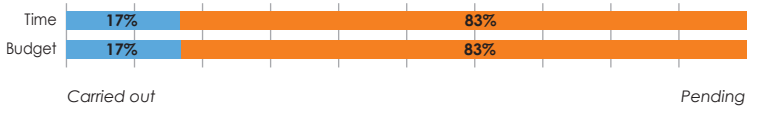
Aim:

This project includes a study of the different optical-electronic subsystems of the VEGA unique system and their levels and modes of synchronization (slow, average, fast); the study, design and implementation of loop systems to succeed in stabilization of the laser's parameters (time, position, energy…); and the analysis of the electromagnetic noise generated by high intensity lasers, alongside the study of feasible and effective mitigation measures.

Actions:

The call where the project is framed is aimed at specialized training of young scientists and engineers, so that recruitment is always the first step. Subsequent actions included the use of Labview to develop a Tektronik oscilloscope for remote data visualization and storing and the programming of another software for motor control of a solid target for high repetition rate. At the same time, the knowledge required to draft user manuals and protocols for the control programs developed was acquired.

Implementation:



Technological development for the optimization and further development of the VEGA petawatt laser system

MinCIU / Promotion of employment for young people and implementation of youth guarantee 2018

24 months

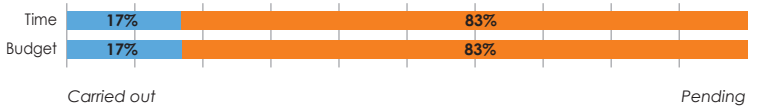
Aims:

The project is focused on the technological development of a series of detectors to improve the VEGA system, including implementation and/or improvements of already existing prototypes.

Actions:

In 2019, work was carried out to develop an automatic flood detection system in the technical corridor where VEGA's power supply unit is located, and a system to detect VEGA's operational status was activated and connected to the database of the current signaling prototype. To detect the condition of the front-end, the signal received by a photodiode is synchronized with the database located in the central server, while, for the different parts of VEGA, a programmable logic controller analysis and an automation study to be able to synchronize its reading and the operation of different shutters were started.

Implementation:



New collaborations

University of Córdoba	Confidentiality Agreement for PPA-PADR-RA-2018	10/01/2019
Escribano Mechanical & Engineering	Confidentiality Agreement	29/01/2019
Valle del Jerte Secondary Education School	Education Centre Agreement – Training Companies Work Centres	4/02/2019
Keyland	Confidentiality Agreement	25/03/2019
Natural Machines Inc.	Confidentiality Agreement	20/05/2019
CIEMAT	Framework agreement for the development of joint projects	3/06/2019
State Research Agency (AEI)	Agreement for the authorization of CLPU scientists and technicians to assess, manage and monitor certain scientific and technical research projects and actions funded by the Agency	16/12/2019

Platforms

INEUSTAR: Private non-profit association whose purpose is to contribute to the advancement of science and technology and to the strengthening of innovation. Its work philosophy is to foster effective networking partnerships among companies, research centres, universities and support organizations and institutions.

FOTÓNICA 21: Spanish technology platform whose main purpose is to efficiently boost photonic technology in the process of industrial innovation and its applications, mainly in four key sectors: information and communication technology, industrial manufacturing processes, life sciences, and lighting and display.

PEPRI: promoted by the Spanish Society for Radiological Protection (SEPR) and by the Nuclear Safety Centre (CSN) in 2014, PEPRI is the national platform for research and development in the area of radiological safety. It is a forum created to foster idea-sharing, the search for synergies and the management of effective plans in this area and at all levels of administration.

DISSEMINATION

Projects

dissemination

Entity	Title	IP	Duration	CLPU role
FECYT	The black chamber	Jon I. Apiñániz	01/01/18 - 31/03/19	Leader

The black chamber

MEIC / Support for the fostering of scientific, technological and innovation culture 2017

15 months

Aim:

The goal is to explain light from a scientific point of view to children with visual disabilities by means of a cross-curricular interactive workshop.

Actions:

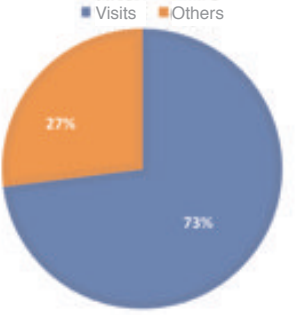
The workshops were developed towards the end of 2018 and both the economic and technical justifications of the project were submitted in the year of this report.

Implementation:

Totally carried out

Activities

One of the strategic lines of this unique scientific and technical infrastructure is the dissemination not only of specialized-level results but also of training contents for the fostering of scientific vocations. In this regard, a total of 38 events have been held, most of which were visits aimed at promoting the Centre and its activities.



The design and production of brochures, participation in the *Pint of Science* dissemination event and the 'Black Chamber' workshop adapted to students with autism spectrum disorders of the special education centre La Cañada in Salamanca, accounted for 27% of other dissemination activities.

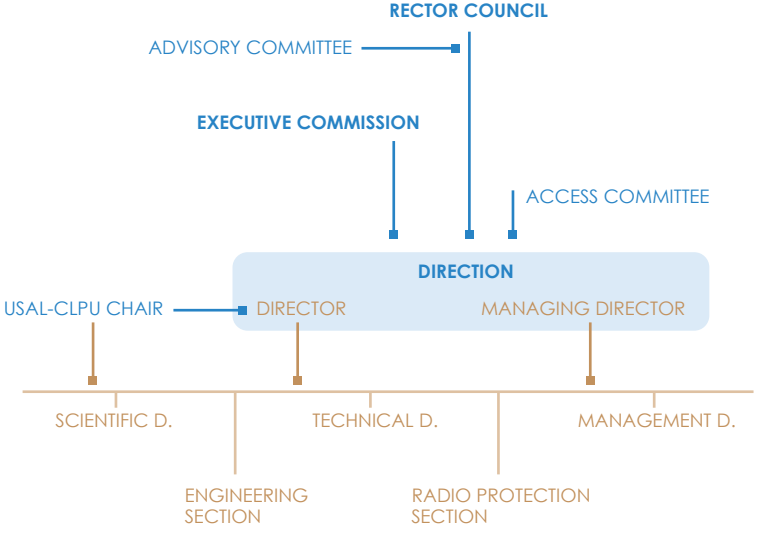
Likewise, as every year, the CLPU participated in the Science Week of Castile and León. For this occasion it designed a new activity aimed at students from third year of childhood education to third year of primary education: **The Colour Cave**, a staged story where concepts such as reflection or how rainbows are formed are explained through the curious adventure of a beam of light that enters a cavern: *At a time unknown, in the corner of a very dark cave, a beam of light learned about itself…*

Finally, we cannot fail to mention the contribution of the Centre's director, Luis Roso, to the *Anales de Química* journal which, on occasion of the 100th anniversary of the periodic table, published a special issue. His article can be found under the title 'Z=115, Mc. en este preciso instante, lo más probable es que no haya ningún átomo de moscovio en la Tierra', in *Anales de Química*, vol.15, no. 2.

INSTITUCIONAL INFORMATION

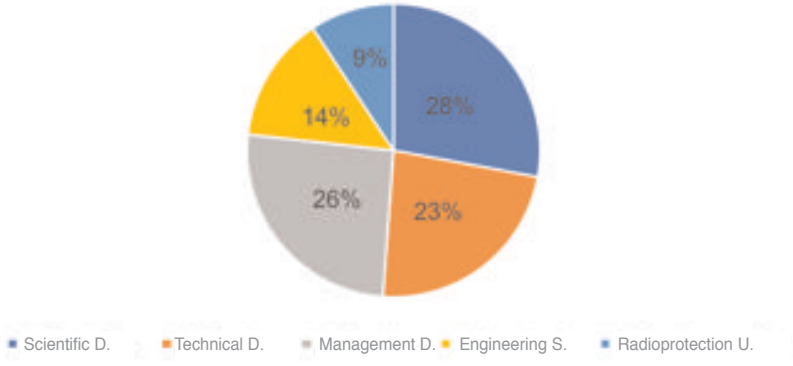
Center Structure

The Spanish Centre for Pulsed Lasers is a public consortium attached to the General State Administration. The Ministry of Science and Innovation makes up 50% of it; the Regional Government of Castile and León 45%; and the University of Salamanca 5%. This is why the members of its governing board, rector council and executive committee are high representatives of the aforementioned entities. Further information is available at *https://www.clpu.es/quienes-somos/organigrama*

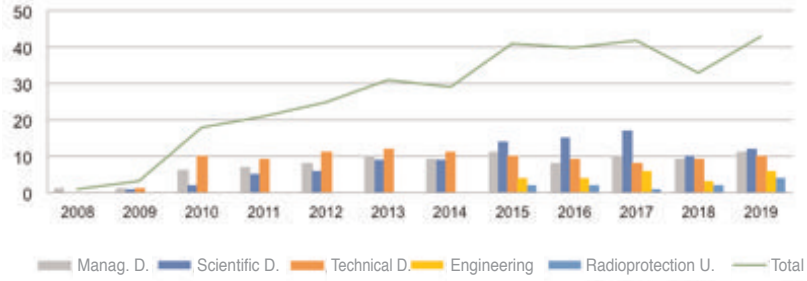


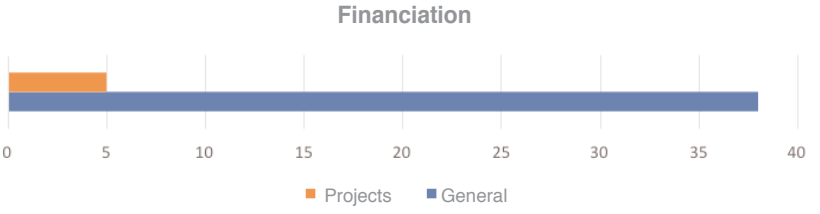
Human Resources

Areas splitting



Staff evolution

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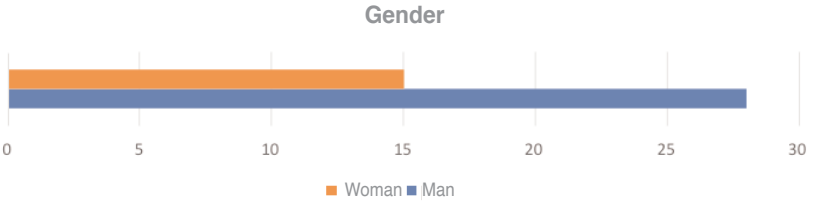
Projects
General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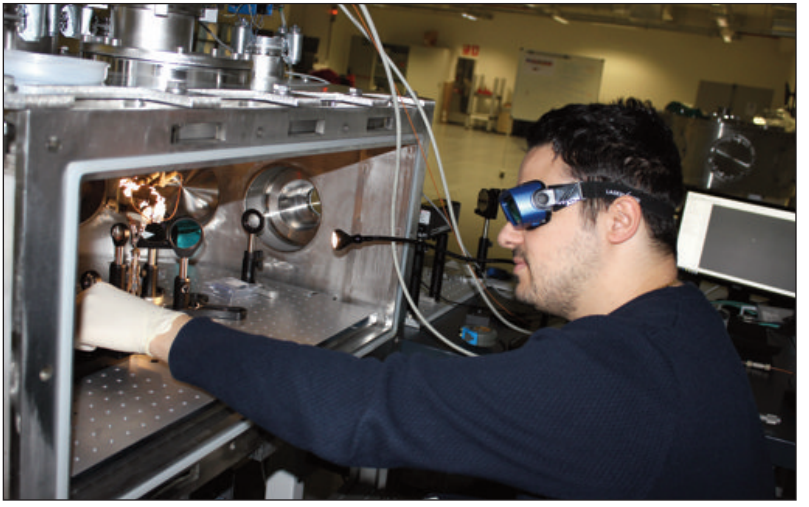
Man



External financiation

applied research

Laser accelerated particles for medical applications (PALMA)	242.000,00 €
Technical support staff (PTA 2017)	39.000,00 €
Promotion of employment for young people and youth guarantee	39.200,00 €

r&d networks

Laserlab Europe IV	66.250,00 €
Spanish network of ultrafast lasers (RedLUR)	41.500,00 €
Laserlab Europe V	207.150,00 €
Integrated management and reliable operation for used-based laser scientific excellence (IMPULSE)	499.721,00 €

technological development

Study on critical components for military lasers and advantages and use of wide area sensor technologies on UAV	67.000,00 €
High-power pulsed laser guided system in the military field (SIGILAR)	450.000,00 €
Development of low-cost ultrashort pulse lasers with advanced functions for application in new industrial sectors (ULTRALASER)	318.666,20 €
Multi-shot with high repetition rate experimental campaigns	477.680,00 €
Promotion of employment for young people and youth guarantee	39.200,00 €
Promotion of employment for young people and youth guarantee	39.200,00 €

dissemination

Tha Black Chamber	12.000,00 €