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EXCEPTIONAL TECHNOLOGY FOR THE LASER MEGAJOULE FACILITY

Par by thierry lucas - Publié le 09 avril 2015 | L'Usine Nouvelle n° 3418_HSFRANG

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One of four halls housing the laser amplifier chains.

Some 250 industrial partners have contributed to the innovative technology and production methods for making this facility's components.

On 29 January 1996, the French President, Jacques Chirac, announced the end of French nuclear tests. On 23 October 2014, the French Prime Minister, Manuel Valls, opened the Laser Megajoule (LMJ) facility in Le Barp (Gironde). The LMJ will recreate reactions occurring in nuclear weapons and, together with numerical simulation, will replace tests as a means of ensuring the reliability of France's nuclear deterrent. Almost two decades' worth of R&D, which extended the boundaries of optical, electronic, mechanical, etc. technology, was carried out between these two dates. Innovative manufacturing

methods were developed by the project's industrial partners. Factories were specially set up to manufacture LMJ components in optimum conditions. From the initial laser impulse to the millimetre-sized target on which a nuclear fusion reaction is triggered, practically everything had to be invented.

A PURE SOURCE

Laser beams triggering nuclear fusion begin with... a source. In other words, a small laser producing very low-energy impulses (1 billionth of a joule) with extremely controlled properties. This laser has a very precise wavelength (1 053 nm) and all its properties (beam shape, impulse duration, etc.) are established and calculated in anticipation of beam distortion along amplifier chains. This ensures that the intended performance is achieved on the target. "The laser source is fitted with a diagnostic system, which guarantees a beam's properties before an impulse passes through an amplifier chain, thus avoiding any risk of damage," explains Patrice Le Boudec, CEO of Idil, which supplied the LMJ's four laser sources. These sources generate 176 beams, which are immediately pre-amplified using a module supplied by Quantel. Idil, an SME employing 28 people, found it a challenge to integrate into the LMJ industrial project. It had to ensure its laser sources interacted with monitoring and control software supplied by Codra (over a million variables will be monitored), and provide follow-up and documentation in a project run according to aeronautics-industry standards. But it was worth it: the LMJ represents 15% of Idil's business and the expertise acquired has opened the door to major scientific instrument projects, such as the European X-Ray Free-Electron Laser (European XFEL), an X-ray laser facility under construction near Hamburg.

ENERGY AMPLIFIED 20,000-FOLD

It takes three essential ingredients to amplify the 176 laser beams generating energy needed for experiments: gigantic size, advanced technology, and cleanliness. Each laser chain (22 chains of eight beams each are planned) passes four times through an amplification 'tunnel' (amplifier) manufactured by Cilas. This ensures that as much energy as possible is generated. Each 'tunnel' contains a series of neodymium-doped laser glass slabs illuminated by flash lamps. Powerful electronic systems supplied by Thales are used to control these lamps in a fraction of a millisecond. The LMJ's 3,000 laser glass slabs were manufactured in a specialist factory in the USA that was involved in a similar American project: the National Ignition Facility (NIF). Although there is nothing standard about laser beam-lines, it is worth dwelling on two components at least, which ensure the quality of laser beams generated by amplification.

A mirror supplied by Alsyom (Alcen Group) is positioned at one end of the 'tunnels'. This enables laser beams to circulate and corrects wavefront deformations.

It is an adaptive mirror, which deforms using micro-actuators designed by ISP System. "We began drawing up a catalogue during preliminary studies for the LMJ and now deliver products for big lasers throughout the world," says a delighted Paul Sauvageot. He is the CEO of ISP System, a Hautes-Pyrénées-based SME that has also supplied most of the LMJ's precision actuators. Another sophisticated component – the Pockels cell – is positioned next to the mirror. "It's a safety system," sums up Franck Poirier, CEO of Sodern the Airbus subsidiary that manufactures these cells. A Pockels cell is a sort of 'switch' – operating at nanosecond speed – that turns off part of a wave when it is likely to damage optical components. Its key component is a large

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the first cell, which gives some idea of its complexity.

Cleanliness is easy to understand: it applies to everything.

And always for the same reason: the slightest speck of dust is dangerous for the facility. This obviously applies to the laser halls, which have a controlled atmosphere. Their air is renewed nine times an hour and the temperature is regulated to within 0.5 °C. But this obsession with cleanliness starts much earlier. In Cilas's specially built factory next to the LMJ facility, all amplifier components, – the 'tunnel's' metal structure that is the size of a bus – from the laser glass slabs to the tiniest screw or washer, are machine-washed before entering the assembly clean rooms. At the neighbouring Alsym factory, which manufactures large mechanical structures to support components, post-washing integration is done in a 4,000 m²-clean room. Both sites share a clean vehicle for deliveries to their only client. This 'clean room-on-wheels' keeps everything dirt-free up to installation in the LMJ halls.

176 LASER BEAMS FOCUSED ON 1 MM

This is the distribution phase. The 176 amplified laser beams are transported and redirected around the spherical experiment chamber. This is done by sets of mirrors (currently manufactured in the USA), which are supported by extremely stable mechanical structures impervious to any vibrations that might disturb laser chain alignment. It was built by Seiv (Alcen Group), which has since supplied mirror supports for the Romanian ELI super laser.

"The LMJ has enabled us to become an exporter," says Patrice Daste, CEO of Seiv. The motorized optical-component positioning systems – which can move two-tonne weights to within a micron – were manufactured by CNIM. There are two final stages before lasers enter the experiment chamber. First, the laser frequency is converted from infrared to ultraviolet, which interacts better with the target. This is done using a KDP crystal manufactured by Saint-Gobain. Secondly, the lasers are focused, which reduces beams measuring 40 cm across to less than a millimetre when they reach the target.

FUSION EXAMINED IN MINUTE DETAIL

The laser beams converge towards an experiment chamber with a diameter of 10 meters that resembles a time-travel machine. This spherical chamber, and the experiment hall housing it, both contain a great deal of technology. Although the hall is 38 meters high, it is packed. According to Bernard Ponsot, CNIM's director of major projects and the experiment hall's project manager, it is "like a submarine".

This is no randomly chosen image since CNIM, a defense supplier, has worked on submarine missile launch systems. It also expresses the complexity of this facility and of integrating its 10,000 components supplied by 25 partners. Specially designed handling robots were even developed to handle several-tonne loads in this very tight space.

The spherical experiment chamber, manufactured by Cegelec, is located in the middle of the hall. Its wall consists of aluminium (10 cm-thick) and boron-doped concrete (20 cm-thick), which absorbs neutrons. During experiments, a target is positioned in the middle of the chamber. This is a microbead containing a deuterium/tritium mixture, which is placed inside a container with a diameter of two millimeters. The experiment chamber contains an array of mechanical and optical systems to position the target and align the lasers. It also contains observation and measuring instruments for use during experiments. Bertin, a CNIM subsidiary, supplied the target positioning system.

Its telescopic arms are several meters long and accurate to within ten microns. The French Atomic Energy and Alternative Energies Commission, Military Applications Division (CEA - DAM) is responsible for the targets. Dozens of targets, which vary according to the experiments conducted, are planned. They are manufactured at the CEA's Valduc Center (Côte-d'Or), which specializes in nuclear materials.

At cruising power, the LMJ is large enough to carry out 50-200 experiments a year (i.e. a maximum of one a day). This complies with the specifications drawn up by the army. Nevertheless, some space will be made at the PETAL facility; a high-power (several petawatts) laser beam installed in one of the LMJ halls that share its experiment chamber. PETAL's ultrashort impulses, which are 100 times more powerful than LMJ cells, are for scientific research. This facility is due to start up at the end of 2015.

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This is how many large optical components are required for the Laser Megajoule (LMJ) facility's first fit. Not every optical components manufacturer knows how to make square lenses measuring 40 cm across! The LMJ, and its counterpart National Ignition Facility in the USA, have been an incentive for a few specialists to develop technology. Thales Seso has designed mass polishing equipment to make at least 2,000 of these large optical components. The slightest surface blemish caused by powerful laser beams can damage a component, and it may even have to be changed. Thales shares this market with two American manufacturers. In addition, a Seiv workshop near the LMJ uses a sol-gel process developed at the CEA to add an anti-reflective coating to thousands of optical components.

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