HELIOS, THE LINAC INJECTOR OF SOLEIL: INSTALLATION AND FIRST RESULTS

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Abstract

HELIOS is the **H**undred MeV **E**lectron **L**inac **I**njector **O**f **S**OLEIL [1] the new French SR facility. The Linac is constructed by THALES as a "turn key" equipment on the basis of SOLEIL APD design. The Linac injector is composed of a triode gun (90kV, 500mA), a prebuncher (10kV, 200W), a buncher (SW, 15MeV, 5MW) focalised by a shielded solenoid and two accelerating sections (TW, 2π/3, 45MeV, 12MW) feeded by two klystrons (35MW). The major Linac components have been previously tested at THALES factory and the on-site installation has begun since October 2004. After a brief description of the building construction and the Linac installation, the tests of the different components and operating modes will be detailed. The commissioning with beam was planned in March. But, the official clearance to start the Linac tests arrived in the first week of April. Therefore, the commissioning will take place in June.

BUILDING DESCRIPTION

The beginning of the SOLEIL project construction started at summer 2003. Linac buildings are composed of three principal parts: the tunnel with the accelerating structures, the RF hall with the two klystrons and the control room where the beam characteristics are acquired.

The Linac zone construction began in December 2003. The tunnel was finished in March 2004. The annex accommodation like the RF hall was finished in May 2004. However, to be operational, all the utilities must be in place. Indeed, the operation of a Linac requires specific utilities: electrical power of 150kVA, two demineralised hydraulic networks (21°C and 30°C) and compressed air. These utilities are located in RF hall and during the installation, they will be brought in the tunnel. After the validation of the utilities in September 2004, the tunnel and auxiliary rooms were ready to receive the accelerator. Then, the installation of the Linac started in October 2004.

LINAC INSTALLATION

Respectively to the THALES schedule, the Linac installation lasted three months.

First, the hydraulic system was built with the own Linac cooling station and the network to the tunnel. During October 2004, the beam line - gun, buncher and the two accelerating sections - was installed in the tunnel allowing their alignment and connection to the hydraulic networks.

At the beginning of November, when the Linac alignment has been done, the RF network assembly could start. The two modulators and their klystrons were installed in the RF hall with the all auxiliary power supplies for the beam steering and focusing. Finally, the RF network has been installed and completed in December 2004.

In January 2005, THALES team checked all the auxiliary subsystems and finished the Linac installation with the command control software.

LINAC DESCRIPTION

The design of the Linac injector of SOLEIL has been presented in a previous conference [2]. This description is a sum-up of the Linac characteristics like it was made and installed in the tunnel (Fig. 1). Along its 15m, the Linac is composed of an electrons source (the gun) and different accelerating structures (prebuncher, buncher and

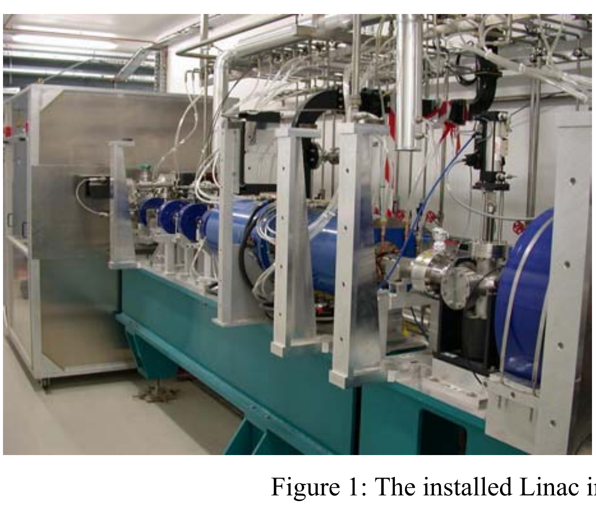


Figure 1: The installed Linac inside the SOLEIL building's tunnel.

0-7803-8859-3/05/$20.00

accelerating sections). The RF power is provided by klystrons with their modulators situated in the RF hall.

Four shielded lenses, a solenoid over the buncher and a Glaser lens ensure the beam focusing to the first section.

Gun and Cleaner

The 90kV triode gun uses the thermoionic emission to produce electrons beam. To provide high reliability, the entire gun can be replaced. This is the utility of two vacuum valves between the gun and the prebuncher. For the cathode lifetime, the gun vacuum is particularly important. Two 65l/s ion pumps keep the pressure better than 10^{-9}mbar, so we can expect several years of lifetime.

The repetition rate is typically 3Hz for the booster injection and possibly 10Hz for Linac tests.

The EGUN code was used to study the gun electrodes shape and to minimize the emittance [3]. This analysis was done for an electron beam current between 120 and 450mA. The grid effect was neglected. The simulation result for 450mA, the outcoming beam has a 2.9mm radius and 6mrad divergence.

For different injections, the gun has two working mode. These modes are explained with the characteristics of current and charge at the Linac output:

- *Long Pulse Mode (LPM)*

The gun produces a pulses train of 1.4ns at 352MHz during 300ns. The macro pulse average current is 30mA and the total charge is 8nC. Preliminary measurements were made before the installation (Fig. 2).

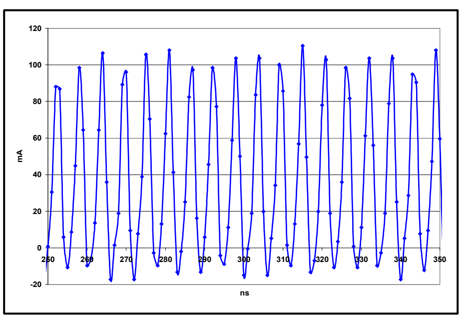

Figure 2: The pulses train middle of the LPM mode.

- *Short Pulse Mode (SPM)*

For this mode, the gun can yield one to four pulses of 2ns FWHM. The average pulse current is 250mA with a charge of 0.5nC. The figure 3 shows the first SPM pulse measured.

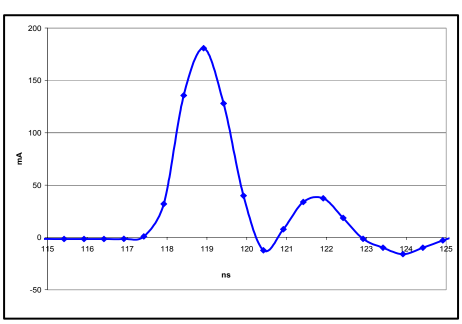

Figure 3: The first pulse of the SPM mode.

The cleaner, just after the gun, is used to filter the beam during the single pulse mode. It is a fast electric deflector which avoids parasitic beam current from the gun between short pulses. It allows a path window of 2ns eliminating the dark current and cutting the beam pulse wings. This 90keV dark current is deflected in front of a circular collimator by a 700V DC.

Prebuncher Cavity and Buncher

A prebuncher cavity in the TM010 mode (3GHz) produces a velocity modulation with ±10kV for 200W input power with an operating frequency 2998.300 MHz at 37.5°C.

A one meter long and 43 cells (22 for accelerating and $\pi/2$ mode) standing wave buncher increases the energy up to 15MeV for a 5MW RF power with the same operating frequency at the same temperature.

Figure 4

Figure 5

Figures 4 and 5: The prebuncher (4) and the buncher (5).

All the cavities for the prebuncher and the buncher were diamond mechanized and RF tested in stabilised temperature room. Shunt impedance, quality factor, SWR, field pattern was measured before brazing in air and after brazing in vacuum. The buncher is pumped out by a 100 l/s ion pumps mounted on waveguide to maintain a pressure lower than 10^{-8}mbar.

Accelerating Sections

This accelerating structure consists of two identical travelling wave sections of 4.5m long, working in the $2\pi/3$ mode. These two sections (three with a spare section) come from the LIL (Linac Injector of LEP) at CERN. So they have already seen RF power. A section allows an energy gain up to 60MeV for 15MW of input power. The operating frequency is 2998.3MHz at 35°C.

The first measurement on these sections showed good RF characteristics and very low activation.

In the middle of the sections, a residual pressure of 10^{-8}mbar is guaranteed by two 100 l/s ion pumps located on the input and the output waveguides.

Modulator and Klystrons

To improve the reliability of operation the Linac has modularity of two, i.e. two accelerating sections and two RF power sources: two klystrons TH 2100 (THALES) 35MW. The first one is feeding the buncher (5MW) and the first section (12MW), it is running at about 25MW. The second one is feeding only the second section (12MW) runs at 20MW. As we see each klystron is underemployed and this is an aspect of reliability. The

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two modulators have been tested up to 280kV, 300A, and their klystrons have reached 35MW on a dummy load.

Figure 6: A klystron with the oil tank and the focusing in the RF hall before installing the lead protection.

Hydraulic System

The hydraulic system assumes two different functions: the cooling for elements with strong dissipation of power (klystrons, magnetic elements, power supplies, RF load) and the temperature regulation to provide the required temperature of the RF structures (prebuncher, buncher and sections). A specific system, installed inside the RF hall, provides water temperature stabilisation to better than ±0.1°C in the range of 33 to 39°C.

There are three stabilised fluid network, the first is for the prebuncher and the buncher and the two others are respectively for each section.

Modes of Operation

- *Full injection*

The Linac runs at 3 Hz during 2 minutes, 3 or 4 times per day. The warm-up begins 15 minutes before.

- *Toping-up*

The Linac launches one single shot every 2 minutes all the time. All the power supplies are continually running except the accelerating high frequency field and the gun which are triggered together at right time.

- *Rescue*

In case of klystron or modulator failure, a switch system on waveguide network always permits to feed the Linac RF structure (buncher and first section) with the other klystron. The remaining klystron will have to supply its maximum power (35MW) and the modulator also (80MW). Finally the Linac yields a 70MeV electrons beam. This energy is sufficient to be injected into the booster. This arrangement allows the replacement of the faulty klystron while the Linac is running.

Beam Qualities

The main beam specifications at the Linac output are an energy spread < ±1.5% and a normalised emittance <200π mm.mrad. According to the two different running modes, simulations were done with different beam currents [3]. With these simulations, we can see different emittance estimation. For example, the figure 7 shows an emittance representation for a Linac output beam of 250mA and 2ns. This emittance is in the xx' plan and the value is 0.27π mm.mrad.

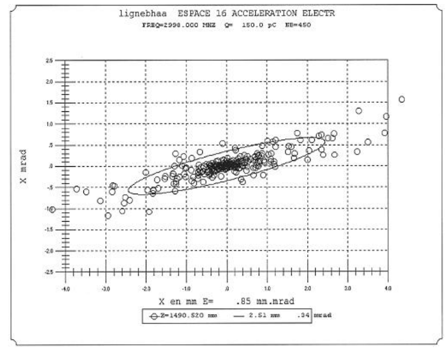

Figure 7: Emittance at the Linac end for 250mA.

LINAC CONTROL

The system will be delivered with its own local control system, using LabVIEW applications. This local control use computers inside the RF hall to watch the different elements: fluids, modulators, vacuum… Every local computer is connected to the supervisor situated in the Linac control room. This supervisor is linked to a Linac computer inside the SOLEIL general control room. In the future this local control system will be linked to the TANGO control system of SOLEIL.

LINAC TESTS

At the end of January the Linac was ready to be tested according to the planning. From this stage, two months were necessary for the last tests and the commissioning.

Unfortunately, the official clearance of the nuclear survey authority to put the RF power on the general installation arrived in the first week of April. With this clearance, the first test can begin.

However, it was impossible to get a first accelerated electrons beam before this conference.

ACKNOWLEDGMENTS

The authors would like to thank the members of the THALES team for their contributions especially A. Bonaccorsi for the Linac installation and A. Sacharidis for the command control system. Many thanks to the HELIOS group members for their technical assistance especially J-P. Baete and J. Salvia.

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