COMMISSIONING OF THE ALTO 50 MEV ELECTRON LINAC

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Abstract

The ALTO 50 MeV electron linac is dedicated to the production of neutron-rich radioactive nuclei using the photo-fission process and the optimisation of the target-ion source system for SPIRAL 2 and EURISOL projects. The accelerator consists of a 3 MeV injector (old test station of LAL, Laboratoire de l'Accélérateur Linéaire d'Orsay), LIL (Linac Injector of LEP) accelerating structure, RF power plant, beam line, control system and diagnostics. Specified and measured beam parameters will be compared to show the performances of the photo-fission process and eventually other applications.

INTRODUCTION

The production of neutron-rich nuclei through fission is currently of prime research interest for the future radioactive beam facilities. In a recent experiment, we have demonstrated the technical feasibility and interest of fission-fragment production induced by gamma [1]. This has stimulated us to build a new experimental area at Orsay, equipped with an electron linac close to the Tandem, which is already used for generating fission induced by fast neutrons. The main components of the electron accelerator were recovered from decommissioned LEP injector (CERN) and LAL test station. Irradiating a uranium carbide target (^{238}UCx) at high temperature with a 10 µA electron beam at 50 MeV allows a delivering of a large variety of neutron-rich isotope beams and to dispose of a test bench for R&D of accelerators and target-ion source set for SPIRAL-2 and EURISOL. Expected productions at ALTO using 50 MeV incident electron beam with 10 µA averaged current correspond to 10^{11} – 4×10^{11} fissions/s. This represents a factor of 100 in comparison with PARRNe [2]. For example, the $^{132}Sn^{+}$ intensity will reach 3 10^{7}-10^{8} ions/s after separation. ALTO with its integrated equipment will give opportunities to test on-line and off-line the target-ion source prototypes developed [3] for SPIRAL-2 and EURISOL.

ALTO DESCRIPTION

The required characteristics of the linac [4] for photo-fission are the following:

RF frequency: 2998.55 MHz
Repetition rate: 100 Hz
Output averaged current: 10 µA
Output energy: 50 MeV

The RF System

The RF system is based on the use of a THALES klystron (TH2100) and a modulator from LAL. The 3 GHz klystron delivers a 4.5 µs RF pulse and provides a peak power of 35 MW.

The accelerating section works in the 2π/3 TW mode with quasi-constant field gradient. This section (LIL accelerating structure given by the CERN) provides an energy gain of 46 MeV for only 9 MW input RF power. The RF distribution allows to deliver the suitable power for a klystron power of 30 MW (fig 1).

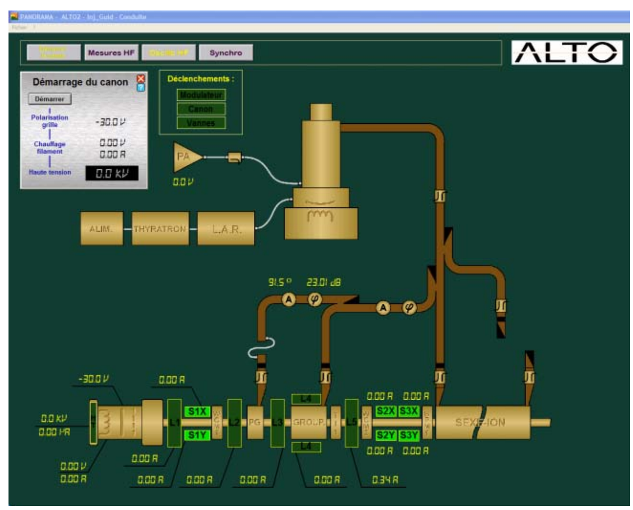

Figure 1: scheme of the RF system

The filling time of the section is 1.35 µs and the energy dispersion is 8 % for a current pulse of 50 mA.

The buncher is a triperiodic structure working in standing wave mode at 3 GHz. An appropriate time allows to reduce the energy spread in the buncher.

The pre-buncher allows to improve the time structure of the beam in the buncher. Simple calculations (confirmed by simulation) give optimal bunching for a power of 1 kW in the cavity.

A classical triode thermionic gun operating between 80 kV and 90 kV produces variable pulses (0.2 µs to 3 µs). The peak current is typically 3A but the cathode is under heated for exiting only 60 mA in order to minimize the current fluctuation during the pulse.

To minimize the beam loading in the accelerating section, we choose to function at maximum pulse length. With 3 μs pulse at 100 Hz the beam loading is 4 MeV of 50 MeV. But the first tests were done with only 100 nA current (awaiting for the administrative authorizations for higher current intensity). We have also reduced the repetition frequency at 10 Hz and operate with 250 ns pulse duration.

Transmission between gun and entrance section is 77 % (81% theorical), and transmission in the section is 96 %.

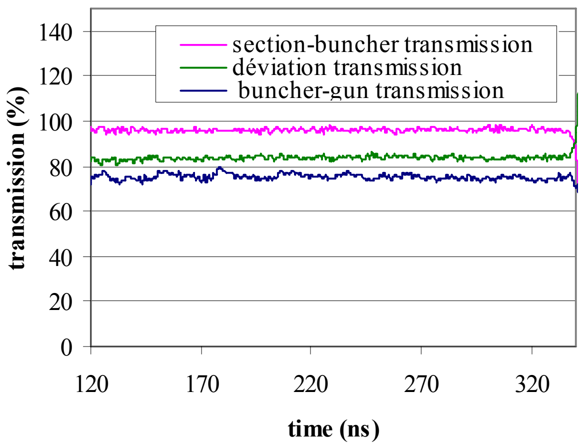

Figure 2: Transmission during the current pulse

The bad transmission in the deviation is a defect of magnetic field created by an ionic pump close to the line which will be moved soon.

The Beam Line

The designed beam line consists of two 65° dipole magnets (R=0.4m) and six magnetic quadrupoles (fig. 4).

The first quadrupole doublet is put behind the accelerating section and allows the control of the beam envelope at the entrance of the first dipole. To achieve the achromaticity of the deviation, two quadrupoles are put between the two dipoles and between quadrupoles a tuned slit allows to measure the energy dispersion (fig 3).

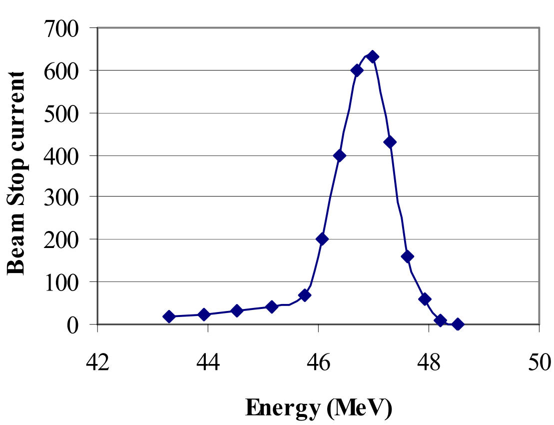

Figure 3: energy dispersion measurement

The beam dimension is adjusted on the PARRNe target using the last quadrupole doublet.

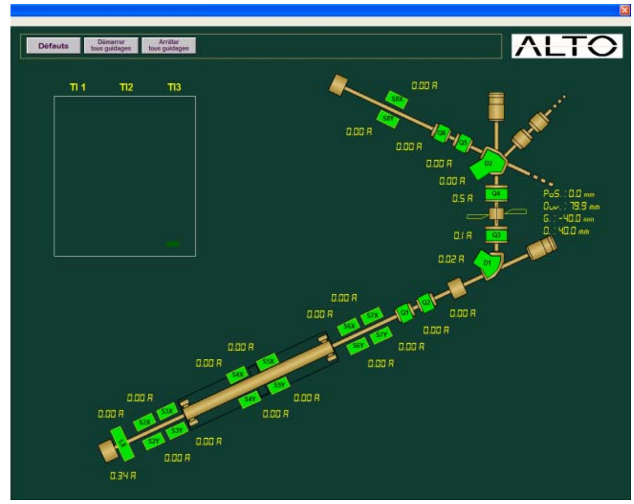

Figure 4: Beam line

The Diagnostics

There are three types of current diagnostics, the two WCM (Wall Current Monitor) are resistive monitors, the three current transformers (TI) and two beam stop (BS) with faraday cage and magnet in order to capture secondary electrons.

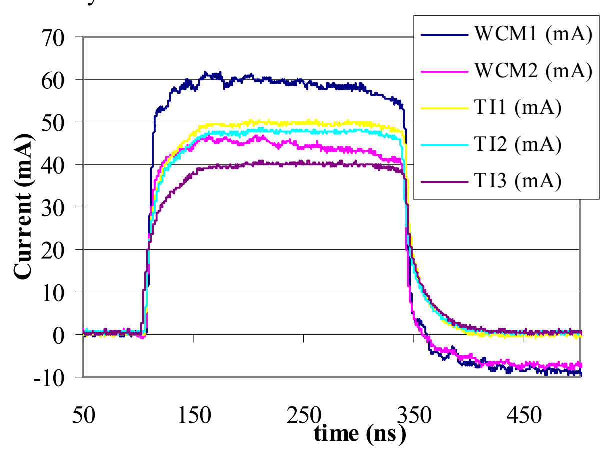

Figure 5: Current diagnostics

The three beam position monitors (BPM) have been taken from the Linac Injector of LEP/CERN. These BPM are the magnetic monitors. We also use a system composed of a CCD and a screen in order to visualize the beam "on line".

The Control & Command

Alto supervision is done with the PanoramaV8® software. It assumes the acquisition and the Human Machine Interface (HMI) but also the storage history of the machine parameter, alarm and receipt functionalities. This software is running on industrial XP-PCs (3Ghz, 2Go).

Acquisition servers (two) are working in redundancy.

They are located close to the accelerator. HMI is located in the main control room of the building. A 6-knob box, is used alternatively with a mouse and a keyboard to tune the process. General overview of the C&C is given on the figure 6 and some of the HMI screens on figure 1 and 4.

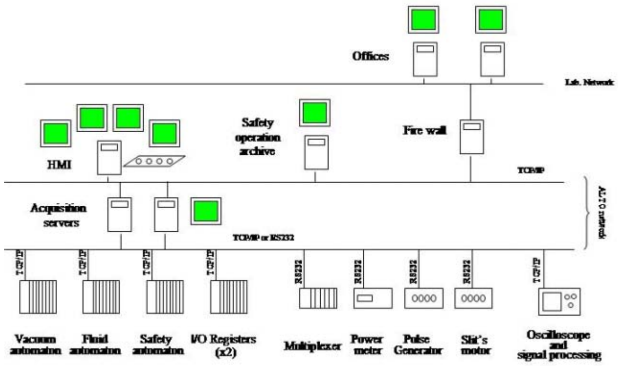

Figure 6: C&C overview

The Security

The system of safety was carried out on the basis of AFNOR NF M62-105 standard, related to particle accelerators of installations. This system is elaborated around an automat of Safty Integrity Level 3 according to IEC 61.508 standard approved for safety. All automat entries are doubled and exits as well as their states are self-checking.

The Target-Ion Source System

To produce neutron-rich nuclei by photo-fission, a thick target containing 72 g of uranium in a standard form of UCx is used. The properties of such a target is described in [2]. The target is heated up to about 2000 °C inside a 20 cm long Ta oven in the middle of which a transfer tube allows the neutron-rich nuclei produced to effuse to the ion source. The first ion source used is an ISOLDE standard plasma source at high temperature.

Figure 7: The target ion source system

The Vacuum

The vacuum system is composed of six 240 l/s sputter ion pumps. At the entrance of the RF cavities, the section is pumped by two 70 l/s sputter ion pumps. The linac is maintained at a residual pressure lower than 10^{-7} mbar.
The whole vacuum system is controlled by a Siemens automat.

CONCLUSIONS AND PERSPECTIVES

The first experiment of photo-fission took place at the end of June 2006 with a current beam of 100 nA. As soon as we receive the safety authorization, a new experiment will be performed with an average current of 10 µA.

Furthermore, ALTO will experimental applications in other fields such as biology, biochemistry, industry etc...

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Figure 8: The ALTO Team

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REFERENCES

[1] S. Essabaa *et al*, Nucl. Instrum. and Meth. B204 (2003) 780.

[2] C. Lau *et al*, Nucl. Instr. and Meth. B204 (2003) 246.

[3] C. Lau *et al,* Rev. Sci. Instrum. 77(2006) 03A706.

[4] M'garech ,thesis in french, Utilisation de faisceaux d'électrons pour la production des noyaux radioactifs par photo-fission (2004) (IPNO-T-04-0)