N.I.L., the New Injector for the Orsay Linac

M.A.Tordeux, D.Betaille, M.Bol, R.Chaput, M.Corlier, R.Corne, D.Fraticelli, M.Gagnat, F.Marteau, J.Michaut, D.Minssen, P.Lebasque, J.Lesrel, A.Pichot, C.Prevost, B.Sobieranski.
LURE, Centre Universitaire Paris-Sud, F - 91 405 Orsay Cedex, France

Abstract

Two electron sources are now available at the Orsay Linac (the injector for the Super-ACO and DCI storage rings). The new source, called N.I.L., provides intense short pulses allowing 'single bunch' injection into the Super-ACO, and generation of intense positron beams. Description and results of the new injector are presented ; we will insist on the original aspects of the gun modulator and on the large momentum acceptance achromatic transport line.

1 . INTRODUCTION

The construction of the Super-ACO has created the need for a short pulsed gun, which would allow the transfer of a single bunch into a single bucket of the 100 MHz cavity of the ring. Up until now, injection has been achieved using a long pulse (25 ns) provided by the previous diode gun, and injection duration for the 2 bunch mode was badly affected.

On the other hand, as we couldn't stop the machine for a few months, we had to build the new source without stopping the existing gun. Consequently, the New Injector runs parallel to the first one (Fig. 1). Due to the strong space-charge forces generated by the high current (15 A), the electrons have to be accelerated up to 20 MeV, before being bent to the main Linac through a transport line.

2 . THE GUN AND ITS PULSE MODULATOR

2.1 Electron gun

The electron gun is a triode gun built by CGR MeV with a spherical dispenser cathode (diameter 35 mm, R = 40 mm), and a J.R.Pierce optic (Table 1).

Table 1
Gun and Modulator parameters

Beam Parameters :	Repetition rate		25 Hz
	Peak current		15 A
	Pulse length		5 ns
	Total jitter		1,5 ns
Electron Gun	Type		triode
	High Voltage		- 100 kV
Pulse Forming Network (PFN)	Characteristic impedance		20 Ω
	Thyratron :	type	CX 1599
		dI/dt	100 kA/µs
	forward max. voltage		12,5 kV
	Trigger pulse (before doubler) :		
		voltage	250 V
		rise time	1 ns
	Jitter		200 ps

2.2 Basic concepts of the Modulator

The cathod-grid distance (1 mm), as well as the high current required force the pulse magnitude up to several kV. To accomodate these pulses and to keep open the option of injecting long pulses (25 ns) into the Super-ACO in multibunch mode, and into the DCI, two coupled pulse forming networks (PFN) were built.

The short PFN is a triaxial structure (copper and air) set in the gun axis. This Blumlein-type assembly allows

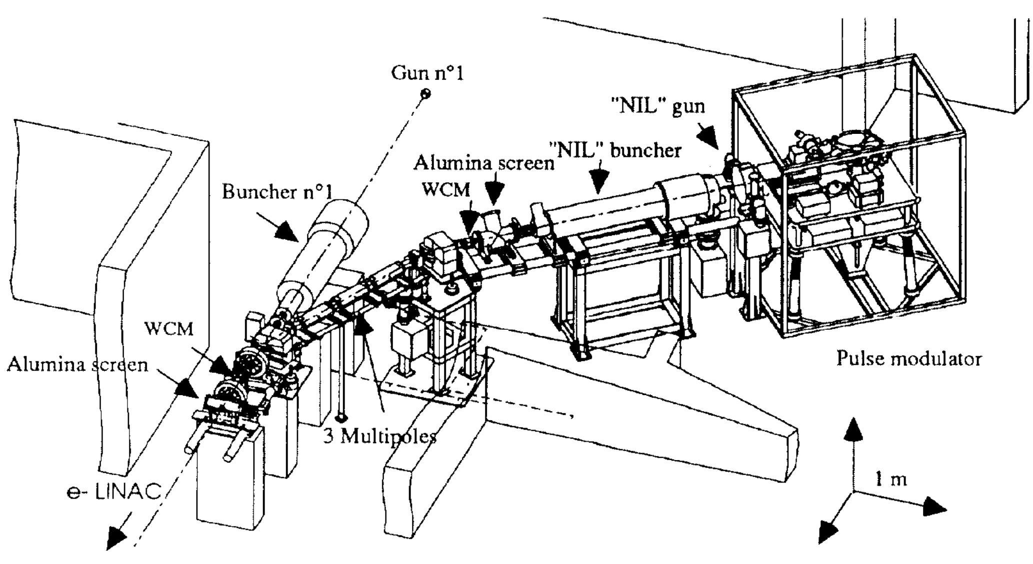


Figure 1 : Two electron sources for the Orsay Linac

pulses in the gun, of the same amplitude as the PFN charging voltage. The long PFN is a two meter long 50 Ω coaxial cable with open circuit end. It is connected to the gun by a T shaped coaxial structure situated on the far end of the short PFN. In this scheme, the amplitude of the long pulse in the gun is only the third of the PFN voltage.

A large number of power supplies and control circuits operating at 100 kV is installed inside the Faraday cage. Initial problems associated with electrical break down and electromagnetic disturbances have now been brought under control.

2.3 Technological options

After having carried out a characterisation study into the various types of switches available, a thyratron switch of high dI/dt, very small jitter and capable of withstanding voltages over 10 kV was chosen [1] (Table 1).

To minimize total jitter, trigger speed electronics were studied. Particular attention was given to the electronics required for trigger pulse of the thyratrons grid. They consist of a Marx circuit amplifier, with four transistor stages in avalanche mode, followed by a voltage doubling transformer [2].

Optical fibers ensure the communication to equipment at 100 kV, i.e. the slow control with serial link, the speed securities and the triggering (developement of speed optoelectronic emetters and receptors).

The control- system is divided into 3 levels : control-room of the accelerator, gun area (100 kV supply, vacuum, radiations and electrical securities, synchronization), and modulator deck (supplies, thyratrons, amplifiers and speed securities control). Implementation was successful.

3 . BEAM ACHIEVEMENT

3.1 Transverse focusing and longitudinal bunching

The bunching system was designed to accelerate more intense electron beams. The use of the *Parmela* code [3] permitted us to minimize the effect of debunching due to any space-charge forces. A prebuncher S-band cavity was placed as close as possible to the electron gun, whilst leaving enough space for the three solenoides which produce a Brillouin type focusing field [4]. The 3 GHz bunching and accelerating section follows at a minimum distance required by the dynamics (Table 2).

Table 2

Bunching system design values

Single copper cavity TM_{010} :		
	maximum field	14. MV/m
	available input power	63. kW
	cavity size	14.85 mm
Buncher TW	maximum field	13. MV/m
	available input power	20 MW
	length	2 m
	cavity size	20 to 25 mm
Focusing magnetic field		1 500 G

3.2 Principle of the 20 MeV transport line

The transport line has to transmit the electron beam into the second accelerating structure used by both injectors. The two parameters which determine the deviation design are the energy spread of the electrons due to beam loading inside the buncher and the microbunch time structure.

The line is composed of two 25° bending magnets, between which are three quadrupoles ensuring first order achromaticity. However due to the very large currents generated it was necessary to introduce three sextupoles into the beam line at the maximum dispersion points. By adding the fields it was possible to minimize the effect of the chromatic aberrations (T_{166} and T_{336} terms of the second order transfer matrix) which would otherwise cause the transverse dimensions at the line exit to be prohibitively large as shown in fig. 2. With sextupoles, the energy acceptance of the system is ± 12.5 %, inside a 90 mm diameter chamber.

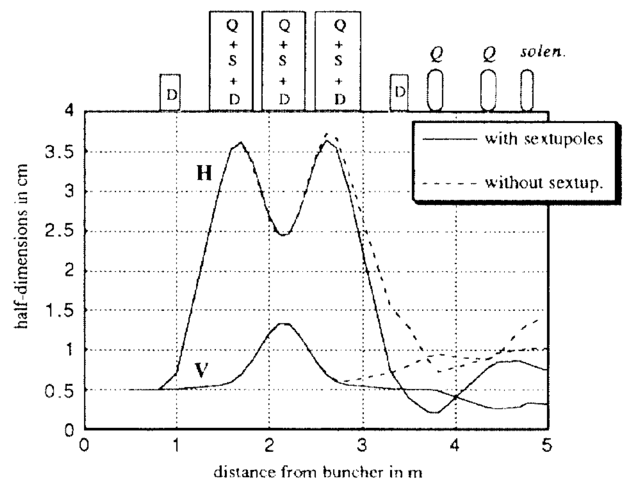


Figure 2 : Transport calculations at 20 MeV

As the electron microbunch lengthening only depends, in the achromatic transport case, on energy spread and bending magnets, the deflection angle was minimized so that the maximum difference between path lengths remains under one microbunch length. As a result the transport is **quasi-isochronous** (0,45° @ 3 GHz / %).

3.3 Printed circuits

As the angle between the two injectors was too small to allow the insertion of classical lenses, printed circuit magnets were developed [5] [6]. Four circuits rolled according to the dimensions of the vacuum chamber, are isolated from each other by a thin layer of Araldit. They provide the second order multipolar field required to achieve achromatic transport.

Table 3

Printed circuits measured parameters

	Units	Quad1	Quad2	Sextu.	Dip
Mean radius of the circuit	mm	51.7	53.2	54.7	56.2
Number of turn per pole	-	2x14	2x14	2x9	2x28
Nominal current	A	18	18	9	2.5
Tension per circuit	V	34	34.4	12	4.7
Measured magnetic length	mm	319		314	
n-value	-	1		2	0
k-value	T/m^^n	0.603		2.42	
Lmag x k	T.m^^(1-n)	0.193		0.759	7.7E-4
dk/k variation in ± 21mm	%	0.7		1.2	2

It was difficult to mechanically optimize the relative position of any one circuit with respect to any another and as a result the transverse homogeneity of the fields produced was bad (Table 3). It was however possible to compensate for this by using the principle of induction superposition which enables one to correct each n-order default with the fundamental field of the same order magnet. The overall effect on the field integral was good [7].

A double µmetal layer closes up the magnetic circuit, and ensures a negligible remanent field (10^{-2} G). As the multipoles nearly cover the total length of the transport line, they provide efficient shielding against external magnetic fields.

Indirect cooling of the circuits proved delicate. *Modulef* code simulations of the heating problems [8] show the necessity to control precisely the copper thickness during the chemical etching, as well as the Araldit thickness. A future project will consider water jet cutting.

4. DIAGNOSTICS AND CONTROL-SYSTEM

The anode current is measured using an electrode capacitive monitor. Two WCM type intensity monitors, each with an alumina screen (doped with 0,2 % chrome) give the transmission rate of the transport line (Fig. 1).

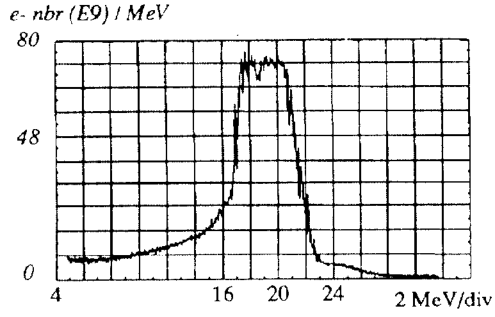
The general control-system is composed of VME cards.

5 . COMMISSIONING

5.1 Energy spectrum

The energy and energy spread were measured using the first dipole of the transport. At the dipole exit, electrons go through a 2 % resolution tungsten slit, and charge a Faraday cup yielding d.c. readings. The magnet and monitor are controlled by a P.C. At the same time, the transverse density of the high current beam is measured at the buncher exit.

We found two optimized RF field values in the prebuncher (85 and 165 kV). Figure 3 shows the energy spread at 85 kV : 65 % of the electrons are contained in 25 % of the dispersion, corresponding to 80 % of the electrons in a 8.1 mm diameter.



Total charge at buncher exit = 79 nC
Maximum charge in 25 % energy spread = 51,5 nC

Figure 3 : spectral density at high charge

5.2 Transmission in the Linac

The transmission rate of the 20 MeV transport line is 50 % between the buncher exit and the Linac. The beam profil observed on the second alumina screen shows the sextupolar effect (30 % of the electrons would be lost without sextupolar field). Good focusing was achieved using the calculated values of the multipolar fields. The limited transmission rate can be explained by the mean energy (16 MeV) which is lower than the nominal one.

Transmission in the electron linac was found to be good (90 %), after elimination of serious instabilities. These were generated by dark current (grid emission at 100 kV) loading of the first alumina screen when it was in its out of the beam position.

6 . RESULTS AND FUTURE

The New Injector now performs the 2 bunch mode injection in Super-ACO in less than 4 minutes (positron stored current 200 mA), that is to say a notable gain on the injection duration. The positrons are injected in a single bucket without splashing the adjacent buckets. Thus the use of RF knock-out to kill the adjacent bunches is avoided ; frequent use of which had been required due to problems associated with the phase instabilities of the small adjacent bunches which made particle storage difficult.

This improvement would make it easier to place a second RF cavity operating at 500 MHz on the ring : the use of such a second cavity was initially proposed in the ring project [9], and its implementation would be of special interest to FEL users (gain increasing, spectral range extension, and short bunch).

Finally, an optical transition radiation diagnostic, enabling the measurement and optimization of the emittance of the New Injector beam, is to be installed on the Linac.

7 . ACKNOWLEDGEMENTS

The authors are very much indebted to the Linac groups, STE, SETT and HMM services, technical drawing office and the safety group for their support.

8 . REFERENCES

[1] A. Damany, " Le modulateur du nouveau canon NIL", LURE internal report, NIL 91/04
[2] D. Lagrange, "Déclenchement " et "NIL - tiroirs électroniques", LURE, internal report, NIL 90/02, 07, 10
[3] We use a version of the original PARMELA code which has undergone some revision . See B. Mouton LAL/SERA 93-455 September 1993
[4] M.A. Tordeux, F. Marteau, "Etude du système de focalisation du N.I.L.", MATn°98/91, LURE Linac internal report
[5] J.C. Schnuriger, "Creation des champs magnétiques utilisés pour la focalisation forte à l'aide de bobines sans fer", Le journal de la physique et le radium, suppN°2, Tome 22, février, p 68
[6] A. Nakach, "Multipolar Magnetic Elements for Weak Field and Correctors", EPAC 90 p 1131
[7] M. Barthès-Corlier et al, "Mesures magnétiques des multipôles du NIL", LURE, internal report to be published
[8] M.A. Tordeux, "Etude thermique des multipôles du NIL", LURE Linac, internal report to be published
[9] M.P. Level, "Système RF 500 MHz", Super-ACO/90-19