OPERATION OF THE ELETTRA INJECTION LINAC IN THE FEL MODE

G. D'Auria, C. J. Bocchetta, M. Plesko, C. Rossi, L. Tosi, R. P. Walker, A. Wrulich

Sincrotrone Trieste, Padriciano 99, 34012 Trieste, Italy

The new FERMI project of an FEL in the infrared will make use of the ELETTRA full energy injection linac. The first part of the Linac was provided with the proper characteristics and an experimental hall to host the FEL was foreseen already from the beginning. The diagnostic measurements on the Linac in the FEL mode are discussed and the performance is presented.

I. INTRODUCTION

The Elettra injector is a linear accelerator composed of a 100 MeV preinjector with a traditional design [1] followed by seven high gradient, backward travelling wave structures equipped with a SLED system[2].

In 1992 the preinjector was successfully commissioned in the injection modes (single bunch and multibunch mode) [3] and since September 1993 the full Linac has been running to inject a 1.0 GeV electron beam into the Storage Ring with an increasing reliability.

At present the injector is used to fill the storage ring once per day and for the rest of the time the Linac would be available to drive an FEL facility extending the light spectrum of ELETTRA, as it was formerly planned. The design characteristics of the preinjector have been chosen to drive also an infrared FEL facility.

Up to now, due to hardware constraints, the switching of the preinjector from injection to FEL operation takes a long time. A single Gun modulator which may support both injection and FEL modes is under design to solve the problem and should be operational by the end of the year.

II. THE MACHINE SET UP

In the FEL mode configuration, the preinjector is capable to accelerate an electron beam to an energy varying from 20 to 75 MeV with a macropulse repetition rate of 10 Hz. The maximum expected pulse width is 10 μs with a micropulse repetition rate variable from 20.83 to 31.25 MHz (32-48 ns in 2 ns steps). During the first initial tests the micropulse repetition frequency has been fixed to 25 MHz (40 ns) and a macropulse width of 5 μs could be reached.

The RF source used is the TH 2132 klystron equipped with two separate RF outputs which feed the two accelerating sections and the bunching section.

The RF peak power has been selected in order to have a beam energy of 30 MeV at the exit of the preinjector to investigate the beam energy spread in the low energy region.

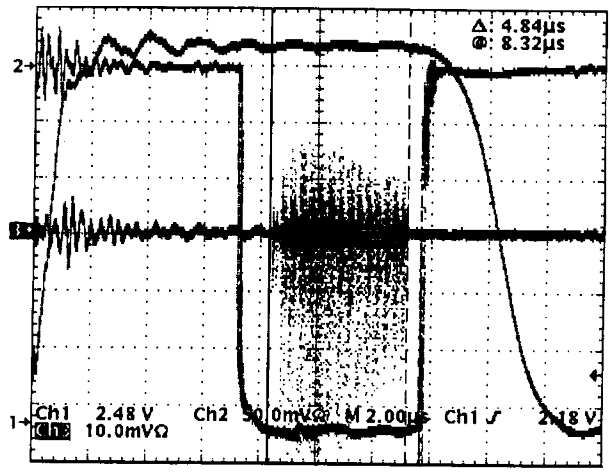

Figure 1: Klystron anodic current (trace 1), RF pulse (trace 2) and beam pulse at Linac output (trace 3).

We have operated the RF generator at roughly 10 MW output peak power. Figure 1 illustrates the klystron anodic current pulse (trace1), the RF pulse detected on one arm (trace 2) and the complete beam pulse at the Linac output (trace 3).

The Gun is a thermionic gridded Pierce type (ϕ 1 cm) which operates at 87 kV and is driven with a burst of micropulses, shorter than 2 ns each. In this first stage we were not allowed to continuously regulate the emitted current due to a fixed grid polarization.

A sample of a 2 μs beam burst is shown in figure 2.

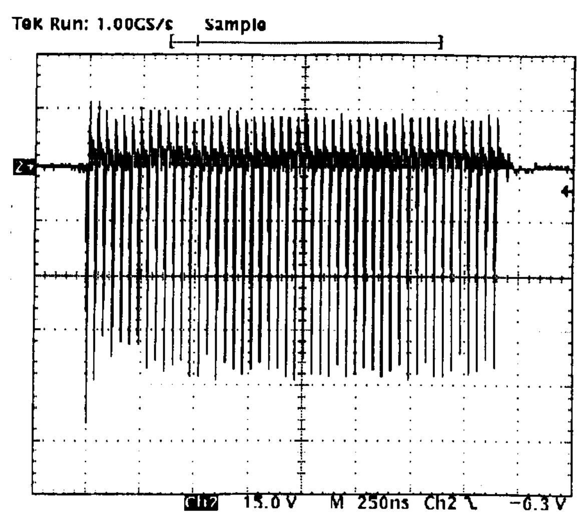

Figure 2: Beam burst from the Gun

Figure 3 shows a detailed image of the beam structure at the exit of the Linac.

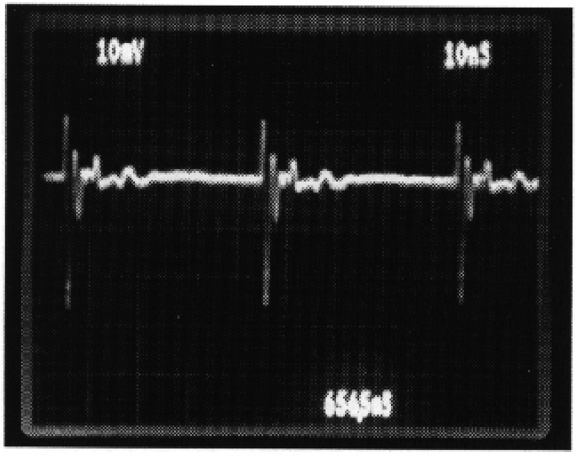

Figure 3: 40 ns structure of the 30 MeV beam

III. TRANSVERSE EMITTANCE AND ENERGY SPREAD MEASUREMENTS

Measurements of the geometrical emittance (defined for 80% of the electrons) and of the energy spread have been performed for the Linac under FEL mode operating conditions. The specifications [4] and the relative measured values are reported in Table 1. Measurements were performed at an energy of 30 MeV for a beam delivering a current of 30 mA in a 5 µs long macropulse measured on a toroid at the exit of the preinjector. Two diagnostic lines, shown in figure 4, were used each of which is terminated with a fluorescent screen [5]. FS1, situated downstream after three bipolar quadrupoles individually powered, is used for the transverse emittance measurement, whereas FS2 placed after a non-normal entry 45 degree bending magnet is used to determine the beam energy and its spread. In order to aid the measurement, two programs based on the high level software philosophy adopted at ELETTRA [6] were prepared. Theoretical details of the adopted measurement methods go beyond the scope of this paper and may be found extensively described in ref. [4].

Parameters	Specified	Measured
Energy	20 to 75 MeV	30 MeV
Charge in bucket	≥ 0.15 nC	-
Central bunch length	≤ 10 ps	-
Emittances at 30 MeV	3.17 π mm mrad 2.85 π mm mrad	3.38 π mm mrad -
Energy spread at 30 MeV	≤ ±0.75%	≤ ±0.60%

Table1: FEL mode Linac beam characteristics.

Both methods are essentially based on measuring the beam width on the fluorescent screens. The resolution error of the destructive monitors is 0.3 mm rms and the error resulting from the method used in finding the width [7] is ±0.2 mm. Given the fairly large amount of beam current in each macropulse, the screens had the tendency of saturating, even though the doping had been kept low [5]. Many measurements with different diagphram settings had to be performed, especially for the emittance, before satisfactory results could be found.

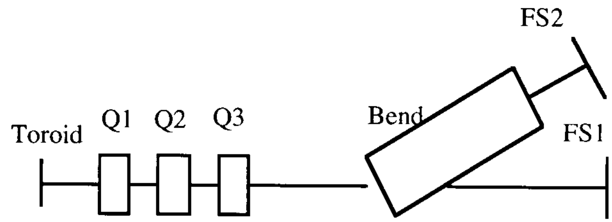

Figure 4: Schematic layout of the diagnostic lines

Regarding the transverse emittance measurement, the technique adopted is based on measuring the transverse dimensions of the beam on FS1 around a minimum as a function of the strength of the last quadrupole in the triplet. A least square fit is then performed to extract the emittance and subsequently the Courant-Snyder parameters for the given emittance at the entrance of the quadrupole. Associated with each measurement there are systematic errors, which can be minimized [4] by a long drift (1.82 m) between the screen and the upstream quadrupole and the proper choice of an optics which gives a small beam size at the entrance of the quadrupole. The two above conditions resulted in a large minimum spot at the screen. Before being measured on the screen, the beam has to traverse a titanium foil, which introduces a systematic error σ_S (0.4 mm for 30 MeV) due to scattering [8]. Since the minimum beam size is more than $1.5\sigma_S$, this error was subtracted from the measured data. Special care was taken to ensure that the beam was passing through the magnetic centers of the three quadrupoles and in the center of the upstream accelerating sections. While the former guaranteed the elimination of spurious dispersion which would give an effective beam size increase, the latter avoided skew effects due to the non-linearities of the accelerating fields which would couple the transverse beam motions. In the design of the optics, care was taken that the beam was always seen entirely on the screen in both planes and that the minimum spot on the screen would occur far from a zero quadrupole strength to avoid undesirable power supply ripple effects. The square of the measured beam size (units in mm^2) together with the fit are shown in figure 5 as a function of the quadrupole current. The measurement was performed with the designed optics and for each current five measurements of the beam width were averaged. The fit yielded a tranverse emittance of ε=3.38±0.09 π mm mrad and β=0.509±0.02 m and α=0.027±0.04 as the Courant-Snyder parameters at the entrance of the diagnostic lines. The expected values for the latter obtained via simulations [9] was estimated to be β=0.71 m and α=-0.54.

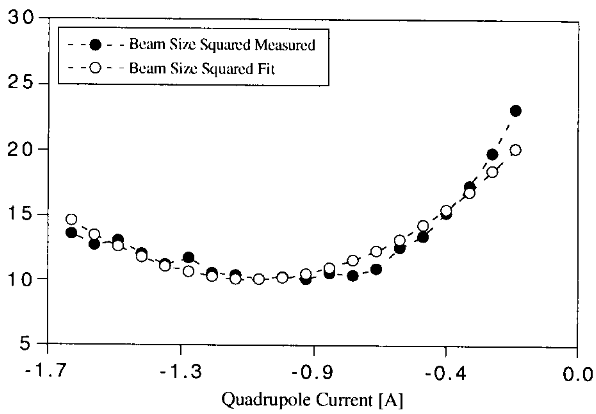

Figure 5: The square of the measured beam size in mm^2 together with the fit as a function of quadrupole current for the transverse emittance measurement.

Regarding the energy spread measurements, the diagnostic line has a dispersion of 1.0 m at the fluorescent screen location. Thus the beam size at FS2 is dominated by the dispersion. Performing an average over ten measurements the energy spread resulted to be ±0.6% assuming a zero emittance beam. Evaluation of the actual natural beam size was found to bring a negligeable contribution to the measurement. It must be pointed out that the image seen on the screen showed a nucleus with a long low energy tail. A very crude method was adopted to estimate that the measured energy spread refered mostly to the nucleus. However at the present date it is not possible to give a precise estimation of how much of the 30 mA macropulse beam measured at the toroid at the entrance of the diagnostic lines was actually in the nucleus.

IV. CONCLUSIONS

The first results obtained during these preliminary tests encourage an FEL operation based on the Trieste preinjector. Several hardware problems have to be solved as soon as possible. A single Gun modulator which can support both the injection and FEL modes is required to simplify the machine operation and to reduce the switching time.

V. REFERENCES

[1] C. Bourat et al., The 100 MeV Preinjector for the Trieste Synchrotron (IEEE Particle Accelerator Conference Proceedings, Chicago, USA, March 1989).

[2] D. Tronc et al., The Elettra 1.5 GeV Electron Injector (IEEE Particle Accelerator Conference Proceedings, San Francisco, USA, May 1991).

[3] C.J. Bocchetta et al., First Measurements of the Elettra 100 MeV Pre-Injector (Linear Accelerator Conference Proceedings, Ottawa, Canada, August 1992).

[4] C.J. Bocchetta, A Diagnostic Line for the Commissioning of the 100 MeV Linac. (Sincrotrone Trieste Technical Note, ST/M-TN-91/16, August 1991).

[5] G.R. Aiello, The ELETTRA Fluorescent Screens. (Sincrotrone Trieste Technical Note, ST/M-TN-91/12, March 1991).

[6] M. Plesko, A Complete Data Structure for the High Level Software of ELETTRA. (European Particle Accelerator Conference Proceedings, London, Great Britain, July 1994).

[7] P. Sereni, Degree Thesis. (University of Trieste, Italy, 1991).

[8] G.R. Aiello et al., Assessment of the Material and Thickness of the Metallic Window in the Housing of the Fluorescent Screen Monitor. (Sincrotrone Trieste Technical Note, ST/M-TN-91/13, March 1991).

[9] J. Gonichon, Beam Dynamics Simulation in the 100 MeV Linac Preinjector for ELETTRA. (Sincrotrone Trieste Internal Report, ST/M-91/9, July 1991).

ACKNOWLEDGEMENTS

The authors are grateful to all the Linac technical staff and in particular to A. Milocco who followed the setup of the gun modulator. Furthermore, the authors wish to acknowledge M. Ferianis, R. Visintini and D. Zangrando for the setup of the diagnostic lines and for useful discussions.