OPERATION OF THE 100 MeV PRE-INJECTOR LINAC OF ELETTRA IN THE FEL MODE

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ABSTRACT

FERMI [1, 2] is a free electron laser in the infrared wavelength range which is going to be constructed at Sincrotrone Trieste. A first test set up is presently being installed. The device is driven by the 100 MeV part of the linear accelerator which is used as the preinjector for the ELETTRA injector Linac [3, 4]. To meet the strict requirements for a user dedicated FEL facility and to guarantee a wide flexibility in utilization, some relevant improvements on the linac are in preparation and under test. The modifications performed on the linac are reported and the operation of the linac in the FEL mode is described.

1 INTRODUCTION

One year ago we started the first tests on the FEL mode operation at the Trieste Linac preinjector (100 MeV Linear Accelerator). Those tests demonstrated that it has the capability to deliver an electron beam burst 5 µsec long at the test energy of 30 MeV. The beam characteristics were partially measured and it was demonstrated that they stay within the required specifications [5]. We mentioned in the conclusions [5] that the main hardware constraints for the continuation of the tests came from the Gun Modulator architecture, which didn't allow a fast switching between FEL and injection modes. Now we have developed the prototype of a new Gun modulator which integrates the FEL and injection modes.

For reader's convenience, the FEL beam parameters are resumed in table 1:

Beam Energy	20 ÷ 75……. MeV
Energy Spread @ 75 MeV	± 0.3………. %
Macropulse repetition rate	10………….. Hz
Macropulse length max.	10………….. µsec
Micropulse repetition rate	20.8 ÷ 31.2.. MHz
Micropulse length FWHM	10………….. psec
Charge per micropulse	0.4…………. nC
Peak Current	37.5………… A
Normalized Emittance rms	62.5………… mm mrad

Table 1: Linac beam parameters in the FEL operation mode.

2 THE GUN MODULATOR

Up to now, in order to operate the preinjector in FEL mode it has been necessary to replace the injection Gun Modulator with the FEL Gun Modulator; the switching procedure was a lengthy procedure which required more than one hour.

The new modulator unifies the single bunch and FEL modes on an especially designed single PCB. The pulse train required for the FEL operating mode has been obtained by means of two 2N2369 transistors operating in avalanche mode. The two transistors are alternately fired on the Gun cathode with the microbunch repetition rate ranging up to 32 MHz.

Considering the first tests, even if the beam stability seemed to be acceptable, more accurate measurements will be performed to evaluate the micropulse train jitter and the current amplitude stability.

The selection of the micropulse repetition rate and the macropulse width is remotely made by means of a fiber optic link with the control room.

The Trieste Gun is a standard plane thermionic Pierce gun using a conventional Thomson triode as emitter, the TH 306. To interdict the emission the grid is negatively biased at about -14 V @ 85 KV anodic voltage; a positive pulsed voltage is given to the cathode to extract the electron beam at about 85 KeV.

A more detailed description of the Gun modulator and its performances will be presented at the next Linear Accelerator Conference to be held in August at CERN [6], since the prototype needs to be refined and deeply tested. Here the preliminary results obtained will be presented together with the first beam outcomes.

3 THE BEAM MEASUREMENTS

The new GUN Modulator prototype has been operated on the Linac on May 16th for the first time. We injected in the multibunch mode a 250 mA electron current in the storage ring, using a 70 ns beam pulse and delivering about 10 mA peak current/pulse. We tested the capability of delivering several tens of mA peak current, by taking the grid voltage close to the minimum interdiction level.

At the end of May we made the first measurements in the FEL and single bunch modes. For the single bunch operation no particular problem was found, just some minor adjustements are needed on the modulator to clean up some little spurious signals sometimes observed.

We operated the machine in FEL mode with a micropulse repetition rate ranging from few MHz up to 32 MHz. The current measured at the Linac exit was higher than 100 mA. The beam quality parameters, compared with the previous 1995 measurements, are reported in table 2.

Parameters	March 1995	May 1996
Energy	30 MeV	30 MeV
Current	30 mA	> 100 mA
Horizontal emittance at 30 MeV	3.38 π mm mrad	4.22 π mm mrad
Energy spread at 30 MeV	≤ ± 0.6%	≤ ± 0.51%

Table 2: FEL mode Linac beam characteristics. Comparison between the present and the new Gun Modulator.

Figure 1 shows a typical electron bunch at the 3 GHz buncher exit. A TEK SCD5000 digitizer has been used.

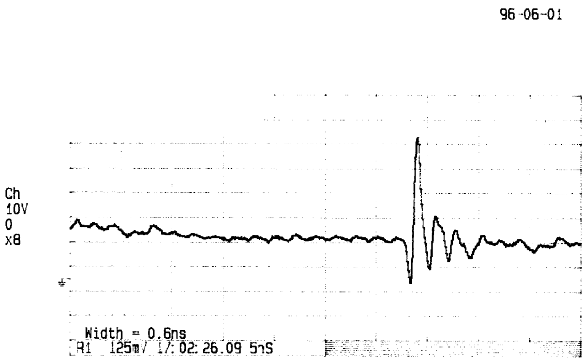

Fig.1: Single beam pulse in the 25 MHz train at the output of the 3 GHz pre-buncher.

The current amplitude was stable within 10% of its maximum in the train of pulses. At 30 MeV the energy spread was measured to be better than ± 0.51% in good agreement with the previous measurements [5]. Due to the short time available for the FEL measurements it was not possible to completely optimize the beam parameters. The method of the three quadrupoles has been used [5]. We are confident that improvements can be achieved in the beam quality parameters with a more careful optimization in the Linac.

4 THE LINAC UPGRADING PROGRAM FOR FEL OPERATION

The present results on the Linac FEL operation can be considered encouraging in order to start an upgrading program which adapts the Linac hardware to the needs of a FEL injector required for the FERMI project.

A big limitation comes from the present PFN (pulse forming network) which delivers a useful pulse length of 6 ÷ 8 µsec maximum, while the anodic current pulse is 14 µsec wide at 50 % of its maximum; since the klystron specification allow 195 ÷ 200 A as maximum anodic current amplitude with this pulse width, the maximum expected beam energy is 40 ÷ 50 MeV.

In order to reach the target of a 10 µsec beam pulse and a beam energy close to 70 MeV, it seems to be mandatory to substitute the present PFN by a new one which can provide a flatter plateau for the klystron anodic current pulse. The specifications for such a PFN are being assigned and it will certainly be the first hardware modification for FEL operation.

As regards the Gun modulator, further improvements are now under consideration to try to increase the output current of the machine. More than 0.4 nC per bunch are expected adding a wide band RF amplifier capable of delivering up to 70 ÷ 100 Volt pulses at the cathode. We hope to collect the first results with the RF amplifier before the end of August.

Furthermore the beam diagnostic line has to be improved adding a toroid and a moving slit system to measure the useful beam current for the FEL operation.

The goal of a higher operating energy, from 70 to 100 MeV, requires an additional modulator for the preinjector plant. Till now only one Thomson TH 2132 klystron, operating at 15 ÷ 18 MW peak power, is used to power the two accelerating sections and the bunching structures of the preinjector, i.e. the RF power coming from the generator is distributed following the scheme reported in fig.2.

The upgrading project includes the development and the installation of a supplementary RF plant so that with the first RF generator the bunching sections and the first accelerating section are feeded, while the second accelerating section will take the power from the supplementary plant.

The power and wavelength stability of the FEL are deeply affected by the stability of the Linac beam; furthermore a fast change of the operating conditions, switching between ELETTRA injection modes and FEL mode, requires to maintain optimum beam parameters with minimum manual adjustments. The 3 GHz bunching system, consisting of a single cavity prebuncher and a standing wave buncher, takes the RF power from a coupler placed on one klystron arm. While the phase regulation of the bunching system is independent, the phase shifter of the RF Driver amplifier, which acts on the accelerating sections phase, affects also the bunching phase. As a consequence each time the energy level is varied or the beam loading is changed, the long and tedious procedure of phasing has to be repeated. A phase feedback loop around the bunching system and the klystron RF driver seems to be the appropriate solution, which could improve the phase stability and speed up the switching between different working conditions. The phase and power changes on the bunching system will drive the automatic phase control to keep the operating conditions at optimum level.

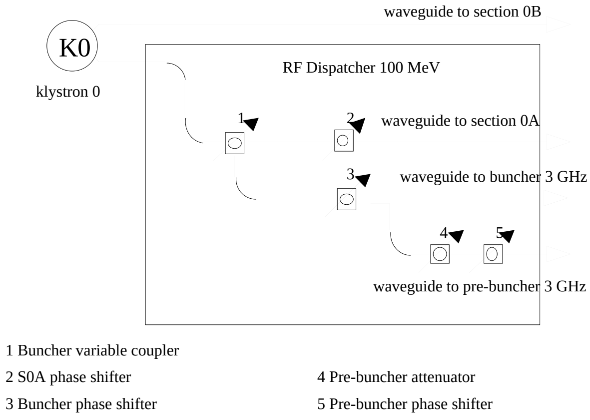

Figure 2: The present 100 MeV RF distribution.

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