THE 100 MEV PREINJECTOR FOR THE TRIESTE SYNCHROTRON

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Abstract: A 100 MeV electron linac, used as a preinjector for a 2 Gev Booster synchrotron, is described here. Three operating modes are possible: a single bunch mode with one Booster RF-bucket (500 MHz) filled, a multibunch mode with 5 to 150 buckets filled and a Free Electron Laser mode which provides a long pulse beam with energy ranging from 30 to 75 MeV. The linac includes a triode gun, subharmonic chopper/prebuncher cavities, followed by a S-band buncher and two accelerating structures. Specifications on the beam current, emittance and energy spread require a special care in the the choice of the operating parameters. This project is a step in the design of compact injectors for light sources, as those GE CGR MeV is developping for ESRF (Grenoble - France) or for HELIOS, a synchrotron light source dedicated to microlithography (Oxford Instr. - UK and IBM - USA).

INTRODUCTION

ELETTRA, which will be built by Sincrotrone Trieste [1], will serve as a synchrotron light facility. It will consist of a storage ring as the main part with 2 GeV maximum energy and a combination of a 100 MeV electron linac and a 2 GeV Booster Synchrotron for full energy injection without ramping the storage ring.

This injection scheme has been chosen for the sake of simplicity and reliability, which are extremely important for a user facility, and the high requirements for orbit stability and orbit reproductibility.

This paper is dedicated to the description and design of the 100 MeV linac preinjector.

OPERATION MODES

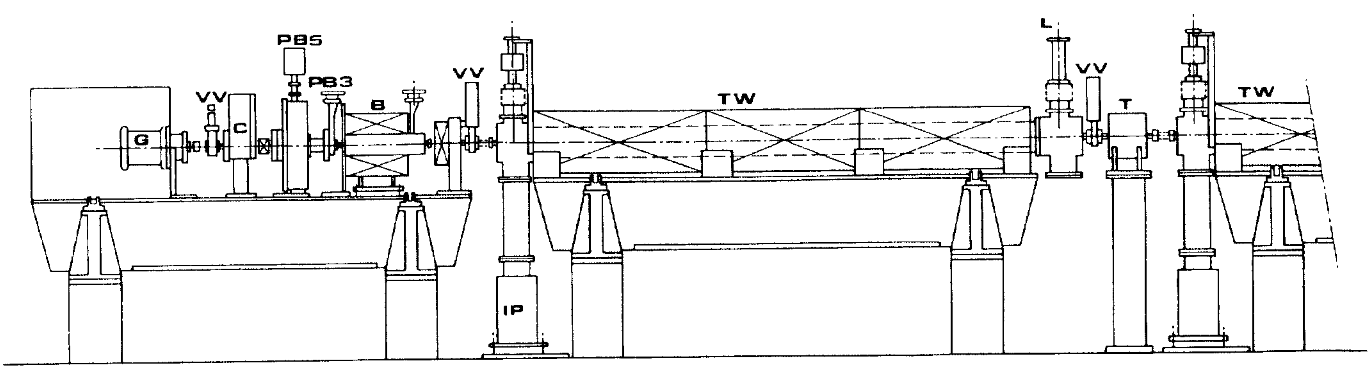
The linac will work at a fundamental frequency of 2997.924 MHz and the synchrotron at the sixth subharmonic of this, i.e. 499.654 MHz. The RF master oscillator of the linac will be also the source for the booster and the storage ring RF systems.

The linac is designed to work according to 3 operation modes : (see Table 1)
. single bunch mode
. multibunch mode
. FEL mode

For the single bunch mode, the requirement is mainly to provide , on the one hand, a minimum of 0.16 nC in 1 ns (i.e. half of the subharmonic bucket) at a repetition rate of 10 Hz, and on the other hand, a ratio of charge between the filled bucket and the adjacent ones exceeding one thousand.

An appropriate way to realize this performance consists in using an association of a chopper and a prebuncher at the subharmonic frequency (500 MHz). With a chopping, letting open a phase window of 90° in a subharmonic period , the current transmission through the chopper-prebuncher system and the buncher at the fundamental, is estimated to be between 10% and 12.5%. With an electron gun delivering 800 mA to 1 A in 2 ns, it is possible to obtain a bucket filled with 0.16 nC to 0.25 nC.

The advantage of this system is that it can also provide one single bunch at the fundamental frequency.



C : 500 MHz Chopper
IP : Ionic Pump
PB3 : 3 GHz Prebuncher
T : Triplet
VV : Vacuum Valve
G : 100 kV Gun
L : RF Load
PB5 : 500 MHz Prebuncher
TW : Traveling-wave section

Fig. 1. The Trieste preinjector beam line

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MODE SINGLE-BUNCH	
Energy	100 MeV
Beam pulse width	<= 1 ns
Fine struct. of the pulse	<= 3 contiguous S-band bunches
Charge per pulse	>= 0.16 nC
Charge ratio bet. filled bucket and neighbouring empty buckets	>= 1000
Emittance (80 %)	<= 1 π. mm.mrd (200 π.mm.mrd.$\beta\gamma$)
Energy spread	< +/- 0.5 %
Repetition frequency	10 Hz
MULTI-BUNCH MODE	
Energy	100 MeV
Beam pulse width	10 to 300 ns
Charge at 300 ns	> 3 nC
Emittance (80 %)	<= 1 π. mm.mrd (200 π.mm.mrd. $\beta\gamma$)
Energy spread	<= +/- 0.5 %
Repetition rate	10 Hz
FREE ELECTRON LASER MODE	
Energy (variable)	30 to 75 MeV
Beam pulse width	>= 10 µs
Bucket repetition rate	31.25 and 20.833 MHz
Charge per bucket	>= 0.15 nC
Central bunch length	<= 10 ps
Normalized emittance(80%)	200 π.mm.mrd.$\beta\gamma$
Energy spread at 75 MeV	<= +/- 0.5 %
Repetition rate	10 Hz

Table 1. Operation modes / performances

The choice of the chopping phase window is a compromise between the maximum current required from the gun and the minimum pulse full width (100% of current). In order not to fill the adjacent buckets, with a phase window of 90° and 800 mA in a 2 ns pulse (FWHM), the pulse full width needs to be less than 3.5 ns.

With a 180° window, for example, the pulse full width must be shorter than 3 ns, but the required current is reduced to the half (400 mA in a 2 ns pulse FWHM).

The specified emittance is less than 1 π .mm.mrd at 100 MeV (i.e. 200 π .mm.mrd.$\beta\gamma$ normalized). With a gun emittance estimated at 50 to 75 pi.mm.mrd at 100 keV, an emittance growth due to the chopping and different bunchings as large as 4 to 6 times could be acceptable.

For the multi-bunch mode, the beam pulse required is from 10 to 300 ns, i.e. including 5 to 150 filled buckets. The chopper is no more indispensable. With a beam loss due to prebunching and bunching, estimated to be 75%, only 80 mA out of the gun, is necessary to deliver 20 mA , i.e. 6 nC in 300 ns.

The constraints on emittance and energy spread are the same in the multibunch mode as in the single bunch mode.

In the FEL mode, the required beam pulse should be larger than 10 µs, with one bucket filled every 32 ns (16 periods of the booster) or every 48 ns (24 periods of the booster).

The requirement on the amount of charge per bucket is the same as in single bunch mode (0.15 nC), but here the chopper is no more indispensable. The energy has however to be variable between 30 to 75 MeV.

Without the chopper, the bucket will be constituted of three successive 3 Ghz bunches. The central bunch duration should be about 10 ps at half width (i.e. 10° at 3 GHz). The required normalized emittance remains the same.

GENERAL DESCRIPTION OF THE LINAC (fig. 1)

The gun will be a grounded grid type triode which derives from a Pierce gun diode geometry such to get a low voltage grid control. It will deliver a 2 ns to 10 µs pulse width at a 10 Hz repetition rate.

The injection voltage is 100 kV and the peak gun current exceeds 1 A in a 2 ns pulse. In the FEL mode, a 2 ns pulse with a repetition rate of 31.25 MHz or 20.83 MHz will be applied to the grid.

The gun is followed by a subharmonic assembly including :

(i) a chopper, a rectangular cavity operating in the TM110 mode, associated with bias deflecting coils and a collimator for selection of the phase window [2].
The chopping principle used here, consists in transversally deflecting the beam at the RF frequency. Then the scanning beam is cut with the collimator. Taking into account the focusing system and the nominal beam current, the power required to feed the cavity is estimated at about 500 W for a 80 mA beam current, and at 2 kW for 800 mA.

(ii) a 500 MHz prebuncher , a simple pill-box cavity, which is inserted between the chopper and the collimator [3].

With a 800 mA beam current out of the gun, dynamics studies show that an RF voltage of 40 kV in the cavity is a good choice to minimize the phase extension at the output of the system .

The subharmonic system is followed by a 3 GHz prebuncher in order to improve the beam quality and the acceptance of the 3 GHz buncher. This latter is of the biperiodic standing-wave type (0.4 m length).

The accelerating field shape is especially designed to insure RF focusing and small emittance [4]. The output energy will be about 4 MeV.

Two traveling-wave structures of 3.2 m length each, raise the electron energy to the required level.
For a maximum of 18 MW at each main accelerating structure input, the expected energy gain is 2 * 48 MeV, for a 20 mA accelerated beam.

In this condition the maximum peak field on the iris will be about 40 MV/m (twice the peak field on-axis). The main design guidelines , for example the choice of the c/vg law, are to insure a good compromise between the acceleration efficiency and the sensitivity of the structure to temperature variation.

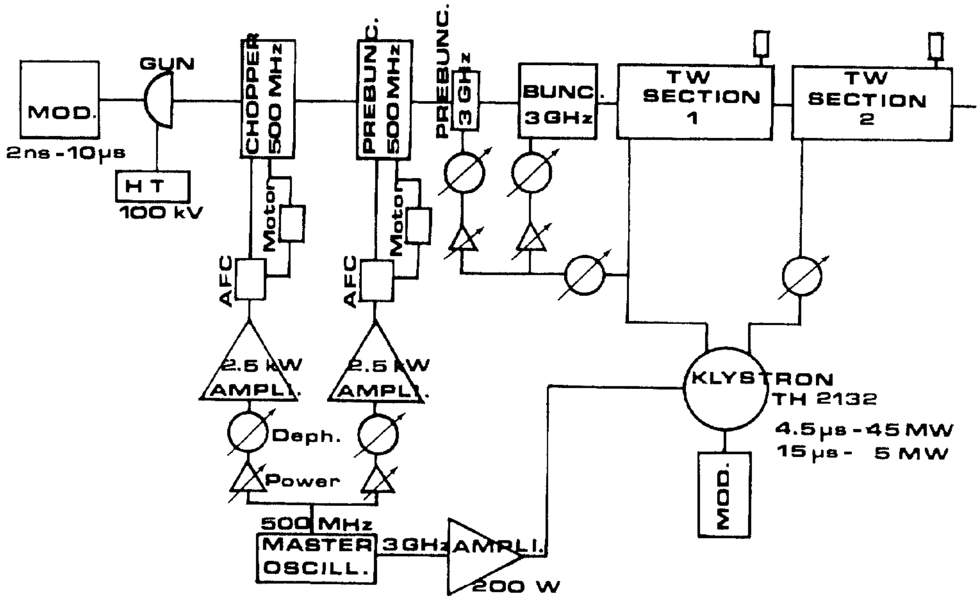

Fig. 2. Synoptic diagram and RF system

The synoptic diagram of the linac is shown in fig 2.

The klystron used to power the buncher, and the two accelerating sections will be the TH 2132 from Thomson CSF, a new klystron with two outputs . It is guarantied to deliver at least 45 MW peak for 4.5 μs RF pulse and 25 MW for 15 μs RF pulse. These values exceed what is required for the injection modes as well as for the FEL mode.

A derivation will permit obtaining 2 MW to feed the 3 Ghz prebuncher and buncher. The subharmonic assembly will need about two times 2.5 kW .

CONCLUSION

From the description given above one can single out the following points of interest:

1) The single bunch mode has a high selectivity in time. It uses a chopper system similar to the one already tested at lower current and described in [2].

2) The emittance growth is kept moderate as the injection system uses an RF focusing buncher.

3) The beam line is very compact. It uses high accelerating fields thanks to the experience gained on the HELIOS instrument described in [3].

4) The expected low energy spread is achievable, thanks to the chopper phase selection and the use of two accelerating units. These ones allow for fine back and forth adjustment of the beam to RF wave positions.

5) The cost is kept reasonably low as one RF modulator drives one klystron with two separate windows.

REFERENCES

[1] - The Sincrotrone Trieste Machine Group presented by A. Wrulich "The Trieste Synchrotron light source ELETTRA", 1rt European Part. Acc. Conf. (EPAC), Roma, June 1988

[2] - C.Bourat, B.Aune, M.Jablonka, J.M.Joly "A 600 MHz chopper system for an electron linac" , 1rt European Part. Acc. Conf. (EPAC), Roma, June 1988

[3] - D.Tronc, D.T. Tran, G.Meyrand, A. Setty " Electron injector designs for light source" 1rt European Part. Acc. Conf. (EPAC), Roma, June 1988

[4] - D.Tronc, A.Setty " Electrons RF auto-focusing and capture in bunchers" Linear Acc. Conf., CEBAF, October 1988