THE RF SYSTEM OF THE FRASCATI LISA 1 MeV INJECTOR

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Abstract

A room temperature 1 MeV injector, under construction at Frascati INFN Laboratories, will produce the electron beam to be accelerated by the Superconducting Linac LISA. This paper presents the characteristics of the RF system of the injector. The structure of the low power electronics and the first measurements are reported.

Introduction

The Superconducting (SC) Linac LISA, in construction at Frascati, will be a test-bench accelerator developed to implement a high efficiency FEL in the infrared region and to investigate some peculiar aspects of the physics and technology of the future linear SC colliders like low emittance electron beam generation, beam recirculation, beam break-up and the problem of the beam energy recovery.

An injector stage will accelerate the electron beam to 1.1 MeV and four SC cavities [1], working at 500 MHz at an average accelerating gradient of 5 MV/m, will then increase the particle energy up to 25 MeV (49 with one recirculation) for FEL operation.

The injector operates at room temperature and accelerates the electrons emitted, with an initial energy of 100 keV, by a thermoionic gun consisting of a triode with the grid driven in pulsed mode to produce 1 msec macropulses beam at a repetition rate of 10 Hz.

A RF complex, consisting of a double chopper (50 MHz and 500 MHz) in combination with a collimator, modulates each macropulse producing a train of 0.3 nsec (≈ 6 cm long) microbunches, 20 nsec apart.

A RF prebuncher, also resonating at 500 MHz in TM010 mode, then further reduces the length of the bunches to about 3-4 mm before traveling through a high energy capture section. This is a β-graded, π/2 mode, accelerating section [2] working at the fifth harmonics of the main radiofrequency, which increases the particle energy up to 1.1 MeV.

The installation of a deflecting 2.5 GHz RF cavity, which is a part of a system for the measurement of the bunch length is also planned.

A block diagram of the whole system is presented in fig.1. The preliminary phasing of the various RF channels is made with motor driven "trombone" delay lines. The electronics and the injector itself will be located in separated halls and connected with about 40 m long links. To decrease the average dissipated RF power, the whole RF system of LISA injector will operate in pulsed mode (≈3 msec pulses) at a repetition frequency of 10 Hz. The resonators will be in vacuum at about 10^{-8} Torr.

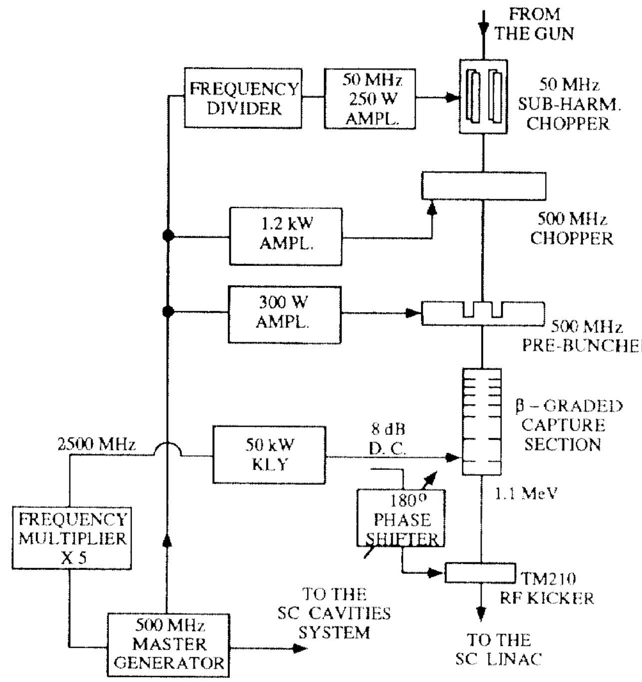

FIG. 1 - Layout of the Injector RF System.

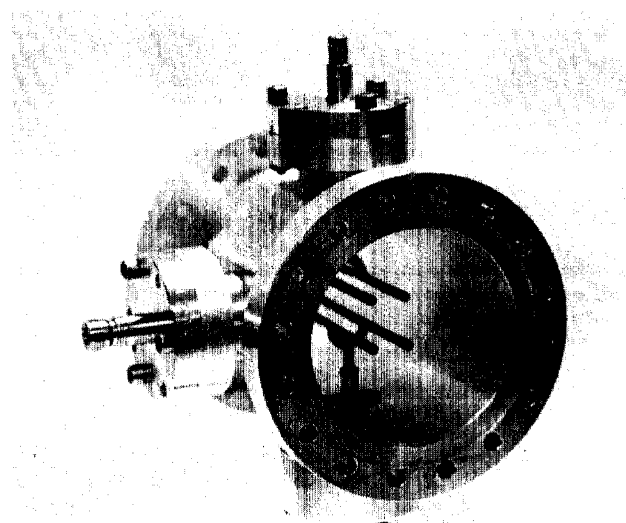

Fig. 2 - The 50 MHz Sub-Harmonic chopper.

The Injector RF System

The beam emitted by the gun is preliminarily deflected by a sub-harmonic (50 MHz) of the main RF frequency, to decrease the average macropulse current and reduce the requirements for the machine radiation shielding. The duty cycle in the macropulse remains sufficient for the FEL performance.

The Sub-Harmonic (SH) chopper consists of two pairs of 10 cm long OFHC copper rods, installed inside the injector vacuum chamber, parallel to the beam axis. The structure is shown in fig.2. One pair will be biased to about 2 kV positive DC, while the other one will be driven at 50 MHz, and represents a capacitive load for the RF source. This configuration produces an electric field orthogonal to the beam path and gives an angular modulation to the beam direction at a frequency of 50 MHz [3].

The 50 MHz signal is generated by prescaling the main 500 MHz radiofrequency and drives a solid state 250 W amplifier. This is connected to one pair of rods by means of a 1-5/8" coaxial line resonating with the capacitive load (≈ 16 pF) of the SH-chopper and compensated with a variable capacitor. The circuit is schematically shown in fig.3.

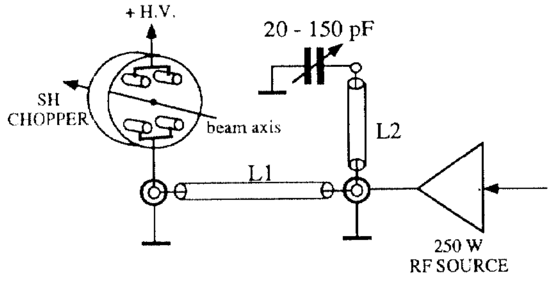

FIG. 3 - Schematic Layout of the 50 MHz Sub-Harmonic Chopper.

The lengths L1, L2 are respectively 138 and 75 cm and the variable capacitance is about 80 pF for the best circuit tuning. The standing wave ratio at the power generator output is better than 1.1. To obtain the required deflecting field of $1.5 \cdot 10^5$ V/m [4], the RF amplifier supplies about 87 W to compensate the RF losses in L1 and L2. Feedback controls provide the field amplitude and phase stability.

The 500 MHz chopper consists of a rectangular Aluminum cavity resonating at 500 MHz in the TM210 mode and providing a vertically deflecting magnetic field. The phase of the RF field is adjusted so that the particles traveling through the cavity in correspondence of its peak value, pass in the collimator hole. The maximum field required for the needed beam deflection is 10 Gauss. A set of magnetic lenses then transports the beam to the collimator [3].

Other significant parameters of the chopper are the followings :

Max. Deflecting Magnetic Field	10 Gauss
Max. RF Input Power	1250 W
Outer dimensions (in cm)	70 x 60 x 10

A TV transmitter, using the TH347 tetrode tube as final stage, provides up to 1.3 kW in pulsed operation. The power generator is linked to the cavity, located about 40 meters away in the accelerator hall, with 50 Ω, 1-5/8" low losses coaxial cable. The cavity RF input is made by a 7/8" ceramic feed-through holding an antenna coupled to the RF electric field with a factor K= 1, since the beam loading is practically negligible.

The beam specifications for a good FEL operation, require the development of efficient field amplitude and phase controls that are shown in bold in fig.4. The Bode Diagrams of the feedback transfer functions are shown in fig.5.

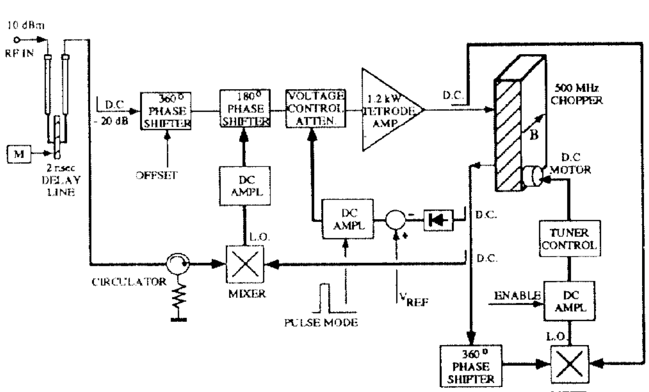

FIG. 4 - Schematic Block Diagram of the 500 MHz Chopper System.

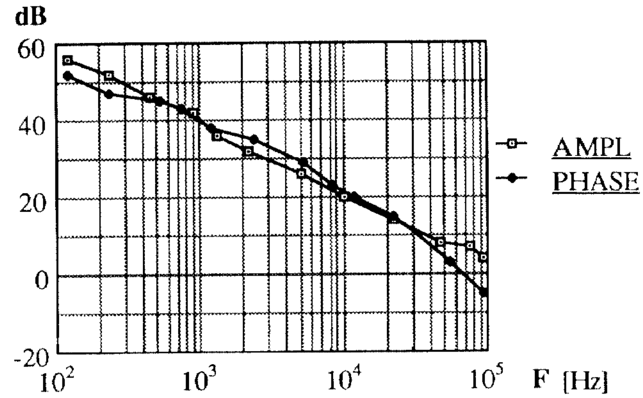

Fig.5 - Bode Diagrams of the Feedback Transfer Functions for the 500 MHz chopper.

An automatic tuning system has also been developed because the cavity temperature is not stabilized by cooling, for mechanical simplicity. The tuner is a 5 cm-diameter Aluminum cylinder which penetrates the cavity in a magnetic field region and is driven by a D.C. motor.

The 500 MHz prebuncher consists of a cylindrical, reentrant Aluminum TM010-like resonator producing a longitudinal RF electric field which gives the particles an energy dispersion needed to reduce the bunch length to about 4 mm before the capture section [3]. The picture in fig.6 shows the resonator before the installation. The cavity has the following characteristics:

Resonant Frequency	500 MHz
Cavity Q_0	14,000
[r / Q]	110 Ohm
Max. Long. Electric Field	20 kV_p
Max. RF Input Power	260 W
Length	10 cm
Diameter	70 cm

The power source is a TV transmitter using the tetrode tube TH338 capable to supply 300 W RF pulsed power. The electrical layout of the prebuncher chain is mostly the same as for the chopper. Also in this case, particular care was given to the control feedbacks. The RF input is made with N-type feed-through and the generator is connected with a low loss, 1-5/8", 50 Ω coaxial cable. The cavity is not cooled and, like for the chopper, the frequency detuning is automatically compensated with a motorized plunger.

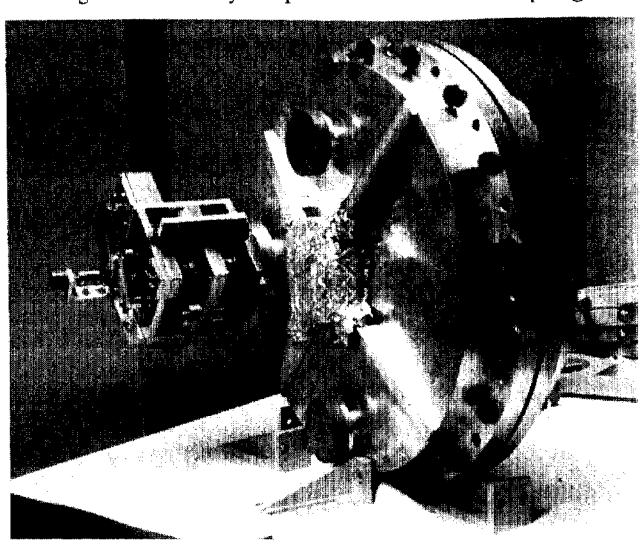

Fig.6 - The 500 MHz Prebuncher Cavity.

The particles are then accelerated to 1.1 MeV by means of a 2.5 GHz capture section whose detailed description and power tests performed in Frascati Laboratories are reported in another paper [2].

The 2.5 GHz signal is coherent with the 500 MHz source and is generated [5] with a step recovery diode frequency multiplier. The circuit, shown in fig.7, produces a frequency-comb, from which, the fifth harmonics of the main reference source is filtered out. The microwave signal can be increased up to 30 dBm with a variable gain solid state amplifier channel. The RF power required by the capture section for accelerating the particles to 1.1 MeV is about 20 kW, including the beam power and the waveguide losses. A directional coupler, installed at the klystron output, provides the RF signal to the amplitude and phase controls since there are no field probes inside the capture section.

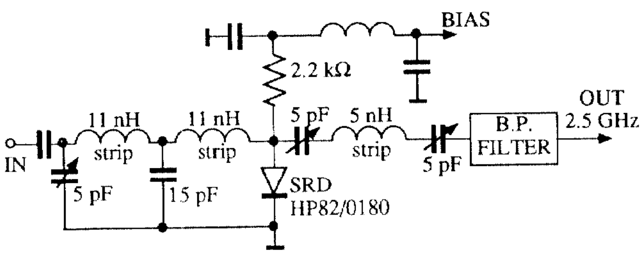

FIG. 7 - Circuit of the Step Recovery Diode Frequency Multiplier.

An 8 dB directional coupler will spill a fraction of the klystron power from the waveguide, for feeding an Aluminum TM210 deflecting cavity. This resonator will be used in a system for the measurement of the bunch length at the injector output. The whole complex is described in details elsewhere [6]. Besides the cavity, the RF section will mainly consist of a 180° delay line to adjust the phase of the cavity fields and of a 4 dB variable attenuator to vary the cavity input power from 1.5 to 3 kW to obtain the needed deflecting magnetic field of about 35 Gauss for a gap length of 5 cm. The cavity will be slot-coupled with the waveguide and water cooled at 38°C. Fig. 8 shows a prototype under measurements.

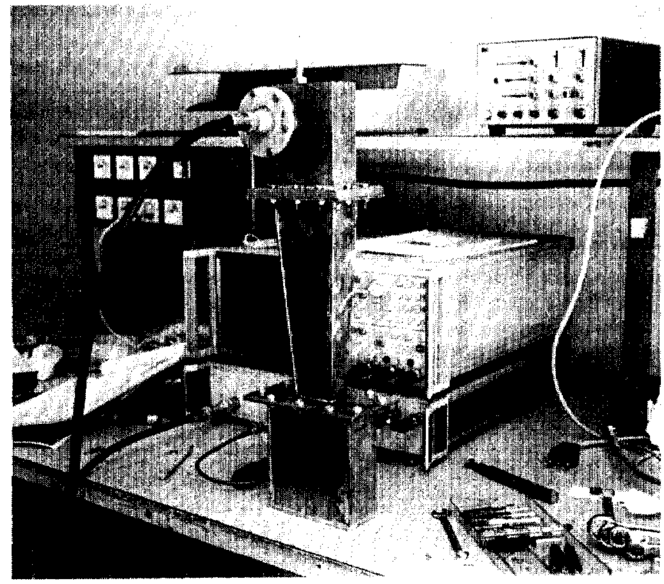

Fig.8 - RF test of a prototype of the deflecting cavity for the bunch length measurement.

Conclusions

The RF system of the Frascati LISA injector has been designed and the various parts successfully tested.

The injector will be installed starting from next autumn.

The whole system will be computer interfaced and remotely controlled by means of a control system [7] based on Macintosh II computers.

Acknowledgements

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