THE INJECTION SYSTEM FOR THE LNLS SYNCHROTRON LIGHT SOURCE: THE LINEAR ACCELERATOR

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Abstract

The conceptual design of the injection LINAC of the Brazilian National Laboratory for Synchrotron Light (LNLS) is described.

Introduction

The injection system of the Brazilian National Laboratory for Synchrotron Light (LNLS) (1,2) will consist of the following accelerators:

- A linear accelerator for electrons up to about 100 MeV.
- A synchrotron booster from about 100 MeV up to 3 GeV.

This injection system will provide electrons to fill a 1 to 3 GeV X-Ray storage ring (SR) designed for low emittance (high brillance). In a first stage the LINAC will be used to inject a 1 GeV VUV synchrotron/storage ring.The principal goals of the injection system are:

- to provide a beam to the storage ring at its nominal operating energy of 2 GeV and,
- to provide a stored current of 100 mA, with the desired beam quality, in a short filling time (about 5 minutes) compared to the stored beam lifetime (about 10 hours).

In this report we present a proposal for the pre-injector, the linear accelerator of the LNLS Synchrotron Light Source.

A. General Description

The design of the LNLS LINAC is based primarily on the Stanford Two-Mile Linear Accelerator (3) for reliability reasons.

The basic parameters of the LINAC are shown in Table I.

The frequency, mode and type of structure are chosen to be the same as those of the Stanford accelerator. The current and repetition rate are estimated for single-turn injection of 100mA into the storage ring in a reasonably short time (5 min.).

The desired LINAC output emittance is estimated to assure injection of four standard deviations of the beam into the booster (1).

The lay-out of the LINAC is shown in figure 1.

An electrostatic gun provides 80 keV electrons which will be further accelerated to 100 MeV in four three-meter long accelerating sections. A preliminary study (4) shows that the required beam current and energy dispersion at the end of the LINAC can be reached with just a pre-buncher,without using a buncher. Focussing of the beam is accomplished by three magnetic lenses and a solenoid in the low energy region and by triplets between the accelerating structures in the high energy region.

Table I - Basic parameters of the LNLS LINAC.

1. Frequency: 2856.0 MHz
2. Mode: $2\pi/3$
3. Repetition rate: 0.5 to 30 Hz
4. Type of structure: traveling wave disk-loaded structure.
5. Output energy: 100 MeV.
6. Energy dispersion: < 2%
7. LINAC macropulse current: 200 mA.
8. Output emittance: < $8.3 \times 10^{-3} m_o c$ cm or 4.2×10^{-7} rad.m at 100 MeV
9. Pulse lenght: 100 - 200 ns

B. Accelerating Structures

Each accelerating structure is composed of 84 elementary disk-loaded cells. To reduce the number of different cells (but still have almost constant gradient) the structure is divided into six constant impedance landings, with 10 identical cells per landing, except the first and the last ones which consist of 12 cells. From one landing to the next the iris diameter varies by 875 μm. To smooth this iris variation there are four transition cells between landings which reduces the step to 175 μm. This is the same type of structure used for the LEP Injection LINAC (5).

The geometrical parameters of the accelerating cells are shown in figure 2. The iris diameter (2a) was calculated to give a maximum longitudinal gradient on axis of 15 MV/m which is considered a conservative value as far as RF sparking is concerned, while the cavity diameter (2b) was calculated by tuning the cavity to the operating frequency (2856 Mhz) with the SUPERFISH (6) code. Figure 3 shows the accelerating gradient along one structure.

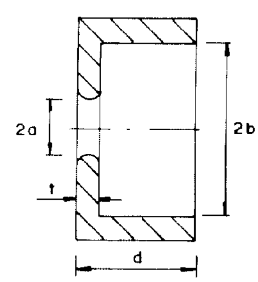

Figure 2 - Geometrical parameters of the accelerating cell.

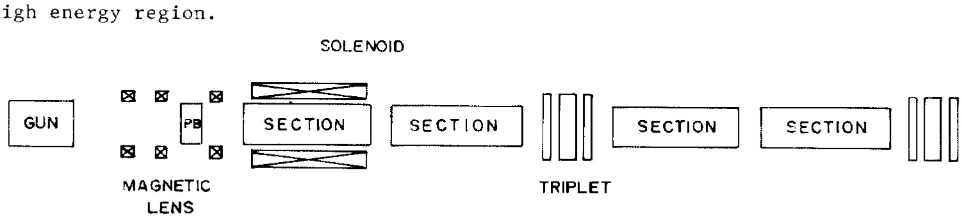

Figure 1 - Lay-out of the LINAC

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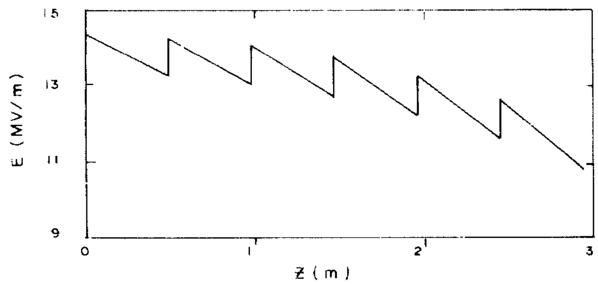

Figure 3 - Accelerating gradient along one structure

The main parameters of each accelerating section are given in Table II.

Table II -Characteristics of the accelerating sections

Total length		2.939 m
Number of cavities		84
Number of cavity types		26
Iris diameter	maximum	23.000 mm
	minimum	18.625 mm
Cavity diameter	maximum	82.586 mm
	minimum	81.674 mm
# of const. impedance sections		6
Elementary iris diameter step		175 μm
c/v_g	maximun	144.3
	minimun	75.2
Quality Factor	maximun	13841
	minimun	13804
Shunt Impedance	maximun	64.7 MΩ/m
	minimun	56.3 MΩ/m
Filling time		1.04 μs

C. The Gun

The requirements for the LNLS LINAC injection gun are set by the desired beam characteristics at the output of the LINAC. The electron gun must, therefore, be able to provide pulses of length 100-200 nsec at a repetition rate of 0.5-30 Hz. These pulsing properties and the availability of commercial cathode-grid assemblies led us to choose a triode gun with a controlling grid. The required gun current is calculated considering a 20% transmission efficiency along the LINAC, so that we must have 1.0 A at the output of the Gun in order to extract 200 mA at the output of the LINAC. The Gun energy is chosen to be 80 keV, according to the available high voltage power supply. The desired gun emittance is determined according to the desired LINAC output emittance, the acceptance of the LINAC accelerating sections and the emittance growth caused by the pre-buncher and first accelerating section. The gun characteristics are summarized in Table III.

Table III - Gun characteristics.

Type: Modified Pierce Triode with control grid
Energy: 80 keV
Current: 1 A
Emittance: < 1.5×10^{-5} rad.m
Pulse length: 100 - 200 ns
Repetition rate: 0.5 to 1 Hz

Beam optics simulation is performed using the SLACGUN code written by W.B. Herrmansfeldt [7] and modified by M. Sedlacek with the aim of optimizing the shape and position of the anode and focussing electrode to get the best possible gun emittance.

Apart from the geometrical optimization, we analyse the stability of gun emittance against anode voltage variations. We observe that 10% variation in anode voltage will cause a variation of 3% in emittance.

The final optimized emittance is 3.06×10^{-6} mrad.

In figure 4 we show the electron trajectories given by Herrmansfeldt's program.

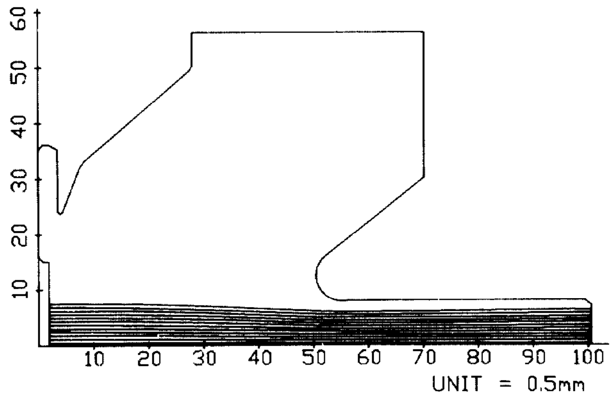

Figure 4 - Electron trajectories.

D. Particle Dynamics

The pre-buncher bunching effect was primarily studied with the program LISA [8], which calculates longitudinal motion of electrons without taking into account transverse displacements or space-charge effects. Pre-buncher voltage and drift length are V_{PB}= 6.1 kV and D = 32.96 cm.

Focussing of the beam (to counteract the effects of space-charge forces and transverse RF forces) is done by three magnetic lenses. In the first accelerating structure the electron beam is focussed by an axial magnetic field produced by a solenoid. An ensemble of 500 particles with uniformly distributed transverse displacements and momenta is tracked from the gun's output to the end of the first section using the program PARMELA [9], which includes space-charge effects in the calculations.

After the first accelerating structure, the behaviour of the beam is studied with the program TRANSPORT [10] . A triplet between structures S2 and S3 ensures focussing of the beam in both transverse planes.

The results given by PARMELA and TRANSPORT have to be corrected to include the beam-loading effect. A study of this effect shows that the beam-loading energy spread can be minimized, in our case, by delaying the RF turn-on time [4].

Figure 5 represents the transverse envelopes (one standard deviation).

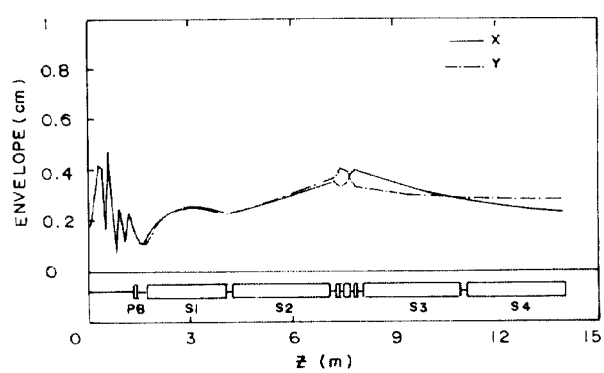

Figure 5 - Beam envelope.

Acknowledgments

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