A 200 MeV Recirculating LINAC as an Injector for the LNLS UVX Electron Storage Ring

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Abstract

The design of an isochronous recirculating system to double the injection energy (from 100 to 200 MeV) of the LNLS UVX electron storage ring is described. The system is composed of a gun-to-LINAC transport line, four 3-meter long SLAC-type traveling wave sections, which accelerate the beam to 100 MeV, and an isochronous recirculating line which reinjects the beam into the LINAC where it is accelerated to 200 MeV. The optics of the recirculating line is studied in detail, with special attention to the correction of high order aberrations. Preliminary experimental results on the gun-to-LINAC transport line are reported.

1. INTRODUCTION

LNLS is building a synchrotron radiation source[1] composed of a 1.15 GeV electron storage ring and a 100 MeV injector LINAC. The choice of a low-energy injection system for this machine was mainly dictated by cost and time constraints, although the addition of a booster synchrotron was kept as a possible future upgrade of the facility. This choice however has its drawbacks, as attested by the difficulties observed in the accumulation process at injection energy[2] as well as during ramping to full energy[3]. Indeed, there seems to be evidence that even small changes in the injection energy (in the 100-200 MeV range) have a large impact on injection efficiency.

In this work, we present a design study of a recirculating line proposed to increase the injection energy of the UVX storage ring. This was considered a cost effective solution to the injection problem in comparison with other possibilities such as the use of pulse compression techniques (SLED) or the addition of more RF power, particularly because the technology to produce the additional hardware (i.e., the recirculation magnets) is readily available at LNLS.

2. THE RECIRCULATING LINE

Fig.(1) shows the lay-out of the proposed injector. A conventional Pierce-type electrostatic gun produces 80 keV, 100 ns long electron beam pulses that are transported by means of iron-core solenoidal magnetic lenses and a 30° rectangular bending magnet up to a velocity modulation pre-buncher that precedes the first SLAC-type traveling wave accelerating structure. The four consecutive structures are fed each with 12.5 MW of RF power at 2856 MHz from two klystrons. At the end of the first pass, the 100 MeV beam is bent upwards and taken back to the entrance of the linear accelerator by means of bending magnets. Focusing is provided by quadrupole magnets and correction of high-order aberrations is accomplished with sextupole magnets.

The recirculating LINAC is designed to satisfy two basic requirements: first, the recirculation optics must be isochronous in order to avoid bunch lengthening and consequent increase in energy spread (the energy acceptance of the UVX storage ring is ±2%); second, the geometry of the line must conform to the *existing* LINAC tunnel. The second constraint turned out to be a major source of design difficulties, since use of symmetrical magnet configurations (which could guarantee the minimization of second order effects on the transverse beam optics)[4] was not possible.

A design that satisfies these highly restrictive constraints is achieved by using four 90° bends, combined into two 180° turns which are reflection-symmetric. The dispersion function started by the first dipole is focused to negative values on the second dipole so that the path length for the complete line is independent of energy to first order (isochronicity condition). The quadrupoles Q3 and Q4 in fig. 1 are fixed by this condition to rather high values ($K \approx 25\ m^{-2}$). This fact demands for strong beam focusing outside the 180° turns as well. The dipole radius of 40 cm is about the maximum we can have to fit the recirculating line into the tunnel. This requires a field of 1 Tesla for a 120 MeV beam. In our case second order effects are important and contribute significantly to the beam size. To minimize these effects, sextupoles are placed in the straight section between the 180° turns. Figure 2 shows the first order beam size calculation as compared to the optimized second order calculation. An increase up to a factor of 2 can be observed. The optics design and optimization were performed with the program Transport[5].

An estimate of the transmission efficiency in the second pass is carried out by analyzing the beam size at the

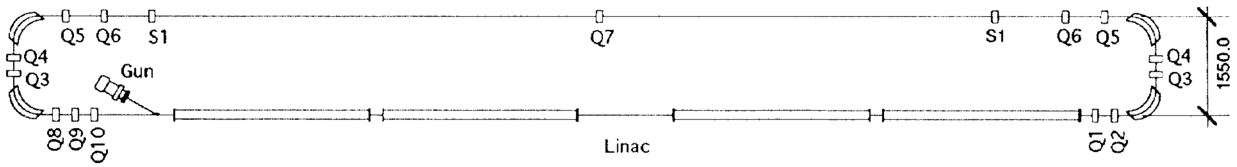

Figure 1: Lay-out of the proposed recirculating line.

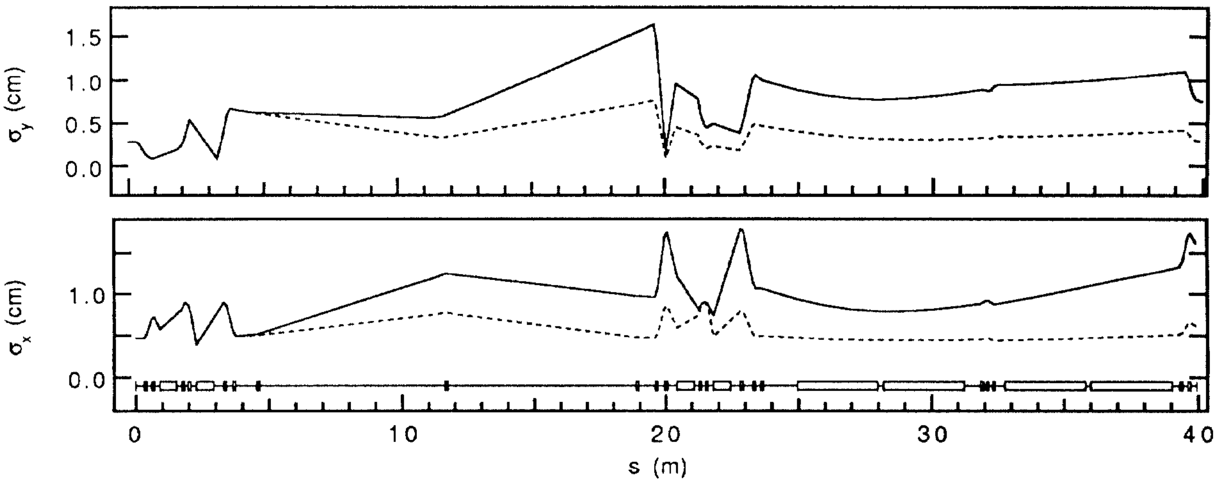

Figure 2: Beam sizes in the bending (bottom) and non-bending (top) planes determined by first order (dashed) and second order (solid) calculations. We assume an initial 120 MeV beam with 2 mm.mrad r.m.s. emittance.

acceptance-limiting point of the recirculating LINAC (in this case, at the smallest iris of the fourth accelerating structure). We consider two initial beam distributions in phase space, gaussian and uniform. In each case, various initial r.m.s. emittances for a 120 MeV beam are considered. The results are shown in figure 3. We expect the beam emittance to be close to 0.7 mm.mrad., scaled from the measured value at 50 MeV[6] in a similar linear accelerator set-up. The transmission for the second pass is thus expected to be about 60% for a gaussian beam.

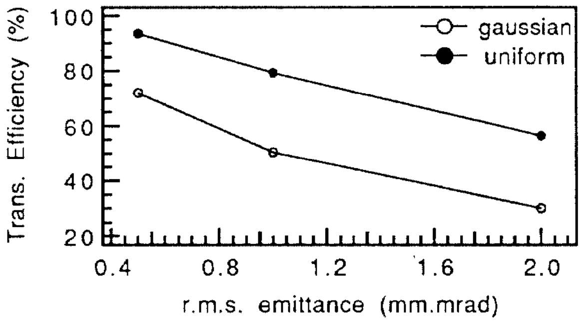

Figure 3: Transmission efficiency for the second pass in the recirculating LINAC.

Orbit correction in the bending plane is performed by an independent adjustment of the magnetic field in the 90° dipoles. In the non-bending plane, orbit correctors are located inside the quadrupoles adjacent to the entrance and exit of the 180° turns. There are position monitors at the middle of the 180° turns, at the center of the straight section between the turns and at the end of the line, i.e. just before re-entering the first accelerating structure. The beam orbit can be kept within ±1 mm displacement for mean-square alignment errors of 0.2 mm and maximum corrector strengths of 3.5 mrad.

3. PRELIMINARY RESULTS

Measurements of the transmission efficiency in the low energy (80 keV) gun-to-LINAC line have been carried out. This line includes a 30° dipole which injects the beam from the gun into the recirculating LINAC. Beam focusing in this region is provided by three solenoidal magnetic lenses. The experimental results show that there is no appreciable current loss in this injection process.

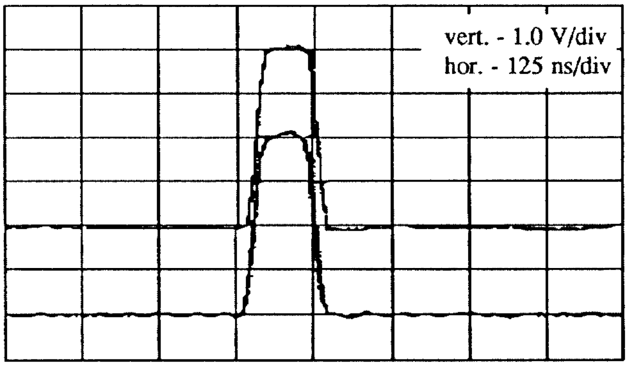

Fig. 4: Current pulses measured at the gun exit and next to the LINAC entrance. The pulses have the same magnitude (I=1.4 A).

4. REFERENCES

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