COMMISSIONING HIGHLIGHTS OF THE PULSE STRETCHER RING EROS

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Abstract

This paper presents the project EROS. After describing the principle of the pulse stretcher and some of its design features, the paper gives a short history of the project. Some highlights of the commissioning period are illustrated and the paper ends with current achievement data and future plans.

1. Project Specifications

The electron linear accelerator of the Saskatchewan Accelerator Laboratory has the characteristics listed in Table 1.

Energy range	50 – 300 MeV
Rep. rate	360 Hz
Peak current	200 mA
Pulse length	0.2 – 1.0 µs
Energy spread	1 %
	0.1 % with ECS
Duty factor	0.036 %
Emittances	0.3 mm – mrad

Table 1: Linac specifications.

This accelerator has a very poor duty factor and the addition of a pulse stretcher ring would greatly enhance the performance of the facility. Initial studies were initiated in 1969 and a long overdue funding was obtained in 1983.

The goal of the pulse stretcher is to produce a beam with the characteristics listed in Table 2.

Energy range	50 – 300 MeV
Maximum CW current	70 µA
Energy spread	0.1 %
with Chromaticity -15	0.01 %
Duty factor	0.6 – 0.85
Emittances	0.3 mm – mrad

Table 2: PSR specifications.

2. Principle of the Pulse Stretcher Ring

The linac pulses are 1 microsec long and so extend over approximately 300m. The time separation between pulses is 2.78 msec. The pulse stretcher ring has a circumference of approximately 107 meters. The linac pulses are injected in the ring over three turns and are then extracted slowly over the available time between pulses. The mode of extraction is based on a one-third resonance scheme. Every three turns the particles come back to approximately the same trajectories. A non-linear field is introduced via sextupoles. This non-linear field excites the resonance and, as the amplitude of the transverse motion of the particles increase, they are captured by an electrostatic septum. In the present operation of the pulse stretcher ring, the tune varies with the particle energy. The ring is tuned so that

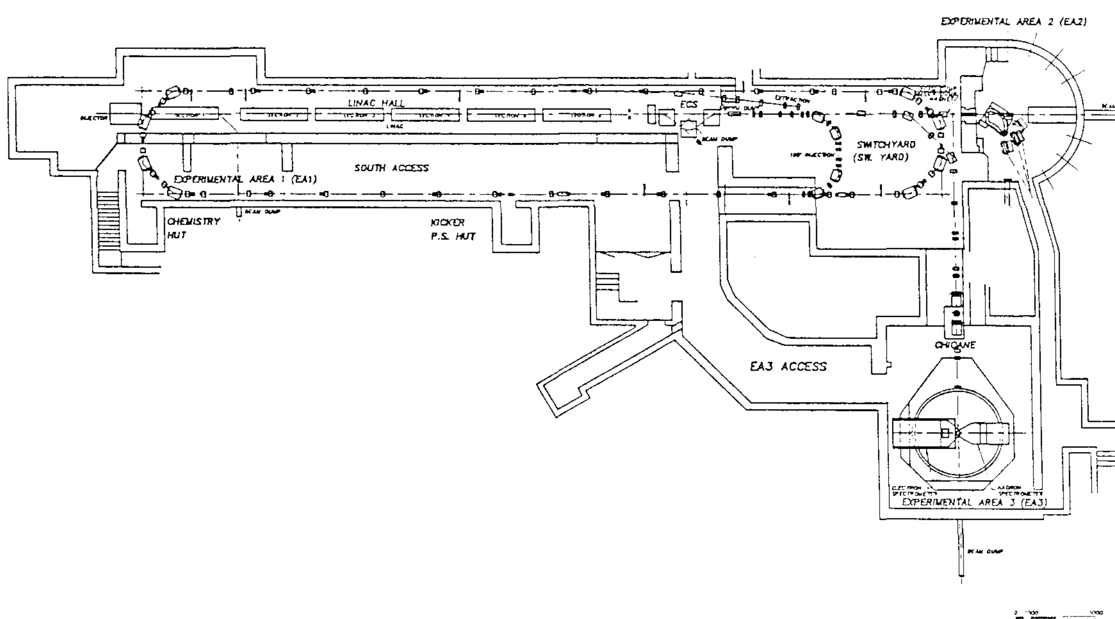

Figure 1: Pulse stretcher ring layout.

the particles reach the resonance condition as they lose energy via synchrotron radiation. In this process all extracted particles have the same energy and the ring acts as a monochromatizer. For more detail on the operation we refer the reader to references.[1,2,3,4]

3. Design of the Ring

The layout of the ring is shown in figure 1. The curved sections are pseudo achromats with unit transfer matrices. The straight sections serve to tune the machine and contain the injection and extraction elements. The extremities of the straight sections contain matching transformers between the long fodo straight cells and the short fodo curved cells. Because of lack of space the quadrupole and sextupole elements of the curved cells are combined in one magnetic element, each having its own set of coils. The injection septa are magnetic. The injection orbit kickers and the extraction septum are electrostatic. Detailed information can be obtained from internal reports of the Accelerator Laboratory.

4. Modes of Operation

As described in paragraph 2, synchrotron radiation losses are used to bring the particles to the resonance condition. Since synchrotron radiation losses vary with the fourth power of the energy, successful extraction with a high duty factor only occurs in a narrow energy band (less than 50 MeV). The optimum energy in our case is 160 MeV. For higher energy, an RF cavity at 2856 MHz (same frequency as that of the linac) is used. The particles are captured in the RF bucket. As the bucket size is reduced to zero over the gap time (2.78 msec), the particles that are outside the stable area of the bucket lose energy and reach the extraction condition. This mode of operation allows to operate satisfactorily up to the maximum energy of the linac (300 MeV). At energies lower than 160 MeV, one uses a lower repetition rate. This increases the time gap between pulses and allows extraction of the full beam at energies as low as 100 MeV.

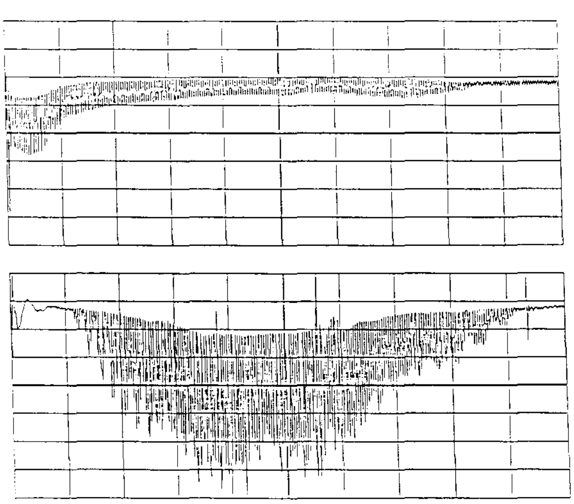

Figure 2: Circulating beam and Extracted beam versus time, 0.5 ms per division.

5. History of the Project

Initial design work on the project started in 1969. Much information and help was obtained from the ALIS group at Saclay.[5] After many unsuccessful applications for funding, the project was approved and funded with a new layout in 1983. As soon as the ring was capable of accepting pulses from the linac, commissioning started and on December 19, 1986, a low intensity beam was successfully injected in the ring and stored for a few seconds. By spring 1987, while construction was still proceeding, we reached our goal of a storage time of 20 minutes which allowed us to study the ring parameters. After correcting some crude misalignments and calibration errors in the magnetic fields of some elements, the tunes were found to be correct to 0.01 and the beta function values correct to 10%. Still juggling time between commissioning and construction, extraction of a beam was successful in the fall of 1987. A beam of 1 micro-ampere (μA) with a duty factor of about 50% was measured in the spring of 1988. The status of the pulse stretcher ring in June 1988 is given in Table 3.

Operating Energy	160 MeV
Maximum CW current	4 μA at 360 Hz
Energy spread	0.1 %
Duty factor estimated	0.6 – 0.85
Emittances	≃ 1.0 mm – mrad
Efficiency	95 %

Table 3: PSR achieved values.

Since June 1988 the experimental program has started and the first experiment has been completed successfully.

The next commissioning steps involve the increase of the energy and the use of RF for extraction. Multiturn injection, to provide higher currents, will follow shortly.

6. Some Highlights of the Commissioning

In Figure 2 the extracted beam is shown as a function of time. The time dependence of the extracted beam matches the energy spectrum of the beam. Comparison with theory is very satisfactory. The theoretical prediction of the shape of the extracted beam is contained in Figure 3. It was obtained by tracking simulation of an injected beam with a gaussian distribution over the energy spectrum.

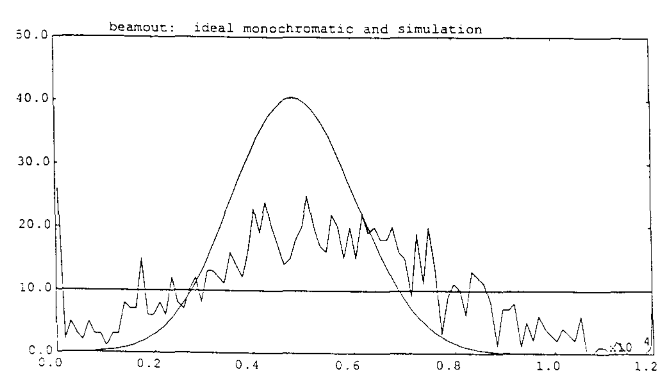

Figure 3: Simulated extracted beam versus number of turns.

Not every attempt at extraction was successful. After some excessive manipulation of the beam orbit, a beam with multiple strands was stored in the ring. This is shown in figure 4. When such a set up is reached, it is impossible to extract the beam with the one-third resonance. This situation arises when the triangular separatrix pattern is distorted and the outgoing separatrices close on themselves preventing any extraction. The magnetic field multipolar terms needed to create this distortion arose (in our case) from the combined quadrupole and sextupole elements of the curved sections. Indeed soon after this pattern was produced, we found that three such elements had shifted out of alignment very severely. After correction, the extraction proceeded smoothly.

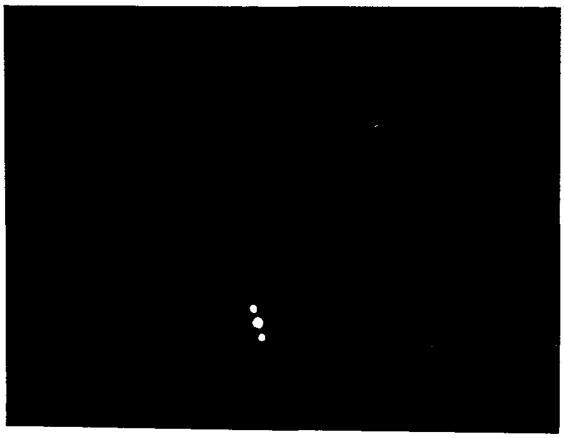

Figure 4: Split stable beam.

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