DYNAMIC TRANSFER FROM MIMAS TO SATURNE

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Abstract

MIMAS is a new synchrotron injector designed to increase the intensity of polarized and heavy ions in SATURNE. It is now routinely operating since 1987.

A fast extraction scheme is used to achieve about 100 % efficiency transfer of the bunch from MIMAS stationary bucket into one SATURNE dynamic bucket. The extraction process, beam transfer line tuning and rf handling providing transverse and longitudinal matching of the two machines are described.

Introduction

In MIMAS (commissioned in 1987 (1)) particles are accumulated at low energy (182.6 keV/amu for heavy ions) by means of a multi-turn injection. They are then trapped in one only bunch, accelerated up to $B\rho = 1$ T.m and finally fast extracted to be transferred into one of the three empty moving buckets of SATURNE (2).

To achieve properly this transfer without beam losses or emittances growth, we had to overcome two main difficulties :

- extraction occurs at MIMAS flat-top ($\dot{B} = 0$) while SATURNE guiding field is ramped ($\dot{B} = 4.2$ T/s),

- rf frequencies of the two machines are not equal ($f_{MIM} = 1.06\ f_{SAT}$) because of the circumferences ratio $R_{SAT}/R_{MIM} \neq 3$.

In addition, the beam transfer line between the two machines had to be designed and tuned in such a way that it achieves the exact matching of the two lattices.

Reference pulse train for the synchronization

The receiving machine beeing empty before the transfer, it is easy to modify its frequency in order to get phase and frequency matching. Therefore, MIMAS is the "master machine" (3). The reference train used for triggering both the fast ejection and the capture process is built from the sum of the two MIMAS cavities rf voltages. When both voltages and phase difference between the cavities are well controlled, this rf train is a good picture of the bunch position in the booster (4), it is a good "beam reference".

The process starting time is given by the B clock of SATURNE. It allows to match the magnetic field to the beam momentum at the transfer time which is triggered after 2000 reference train pulses. The duration of this train ranges from 0.8 to 3 ms ($f_B = 2.5$ MHz for q/a = 1 ions, $f_B = .66$ MHz for q/A = .25 ions), the stabilities of both MIMAS rf frequency and SATURNE $\dot{B}$ lead to $\Delta B/B < 2.10^{-4}$ at injection.

Bunch extraction

Bunch extraction from MIMAS is performed by a fast kicker (5) located in one long straight section and by two pulsed septum magnets placed one cell downstream from the kicker.

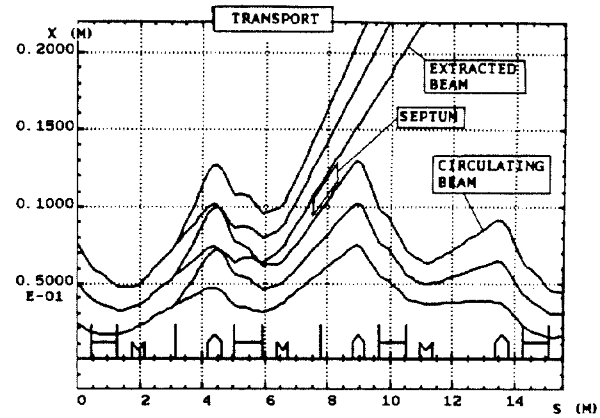

Figure 1 : beam extraction from MIMAS.

In order to reduce the kicker deflection angle, the circulating beam has to be moved to the outside by a distance of about 77 mm at the septum magnet entry (figure 1). This is achieved by powering 4 orbit bump coils located in 4 main dipoles surrounding the extraction section and by changing the rf frequency. Once adjacent to the septum, the beam is deflected by the kicker which is powered in synchronism with the rf reference train. Due to bucket length and revolution period, the rise time must be shorter than 200 ns and the pulse duration must be greater than 550 ns.

Beam transfer line

Once extracted from MIMAS, the bunch passes two septum magnets and enters a 20 m long transfer line which directs it to SATURNE (6). This line must achieve the exact matching of amplitude and dispersion functions of the two machines and allow measurement of the extracted beam characteristics (emittances and internal momentum dispersion). Due to these requirements, the line contains 6 independently powered quadrupoles and 3 dipoles providing a 90° total deflection (figure 2).

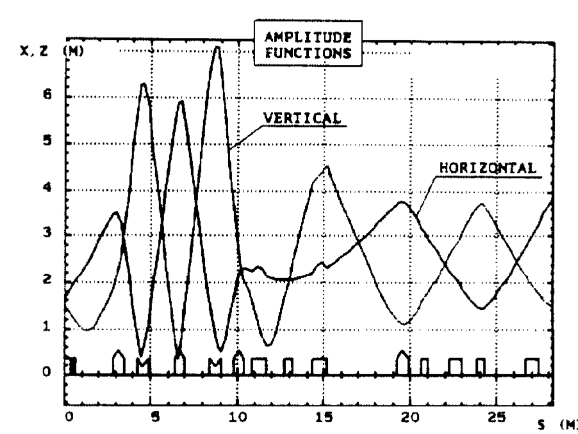

Figure 2 : amplitude functions in the transfer line.

For cost considerations, the quadrupoles are similar to the MIMAS ones (same lamination and profile) but are 50 % longer. The two main dipoles are identical to MIMAS ones and powered in series with them. The third dipole is necessary to compensate for the deviation defect (2.7°) due to the 3 % momentum deviation at extraction.

In addition to these components, the transfer line is equipped with diagnostics (7) and correction elements which are used to control beam size and beam position all along the line and at the injection point in SATURNE : 2 profile monitors, 8 pickup electrodes, 4 luminescent screens and 8 steering dipoles.

Finally at the exit to the line, the bunch enters a pair of septum magnets and is inflected into the SATURNE vacuum chamber. It then crosses the central orbit inside the injection kicker which completes the injection process by cancelling the slope (20 mrd) and placing the bunch on the proper SATURNE orbit.

Beam matching in longitudinal phase space

At transfer time, the MIMAS bunch shape has to be matched to the SATURNE dynamic bucket in order to avoid longitudinal emittance growth. When rf voltages of the two rings are carefully adjusted, emittance growth can be limited to ≈5 % as shown in figures 3 and 4.

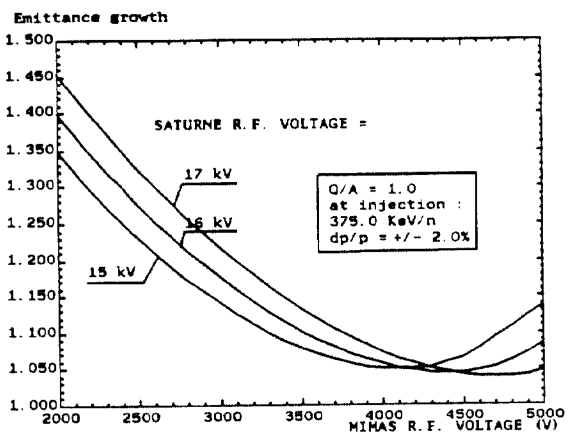

Figure 3 : emittance growth versus rf voltages.

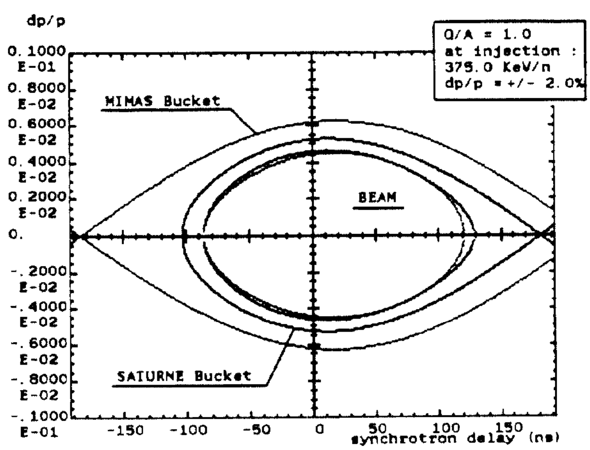

Figure 4 : MIMAS bunch matching to the SATURNE bucket

The momentum and phase errors must be as small as possible because the MIMAS bunch edges are close to the SATURNE bucket separatrix. To avoid large bunch oscillations and to limit the total emittance blow-up within 20 %, errors should be : $\Delta p/p < 2.10^{-4}$ and $|\Delta\phi| < 4°$ (figure 5). Beam losses occurs when $\Delta p/p > 6.10^{-4}$ or $|\Delta\phi| > 15$ °.

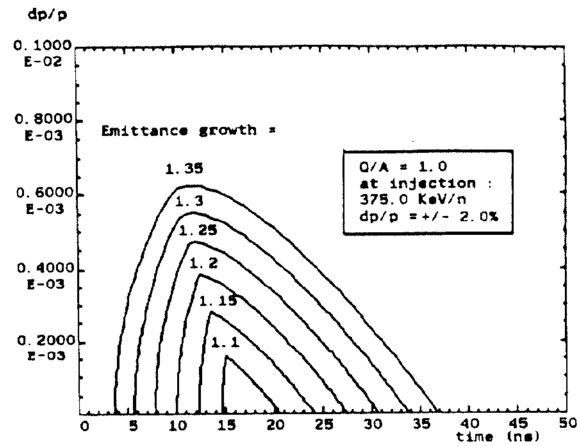

Figure 5 : emittance growth versus momentum and phase errors.

Figure 6 shows the electronic system which allows these required performances. All the devices are synchronized with the rf reference train.

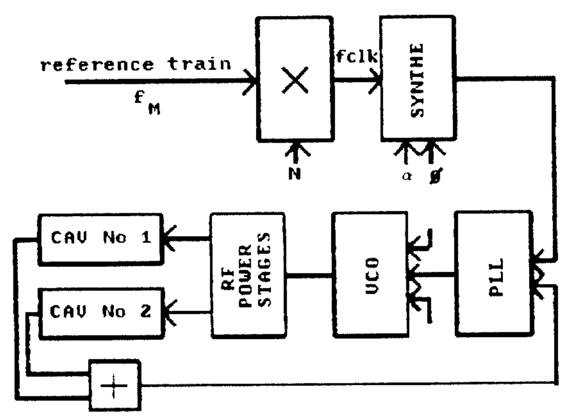

Figure 6 : block diagram of the electronic system for phase and frequency controls

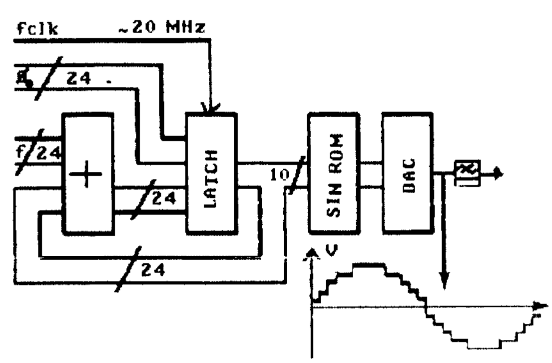

Figure 7 : digital frequency synthesizer

The main component is a home made synthesizer (figure 7) using the direct digital synthesis method (8). A frequency multiplier device delivers the synthesizer clock fed from the reference train : f clk = $N.f_B$, with N ajusted for each kind of particles in order to have the nominal clock frequency f clk $\approx$ 20 MHz. The output signal of the synthesizer can be adjusted (frequency $f_M = \alpha M \, f_B$ and phase), this is the reference of the fast phase lock loop which controls both the frequency and the phase of the SATURNE cavities.

Beam monitoring at injection

To improve the monitoring of the injection into SATURNE, we have developed two systems. The first one processes the two signals from a pick-up electrode located in the main ring (9). The pulse trains induced by the beam in two opposite plates are amplified then digitized using a Le Croy 9400 digital oscilloscope which samples the signals every 10 ns.

These informations are analysed by software to determine the horizontal or vertical positions versus turn. These data, which are continuously monitored, are used to adjust magnetic field as well as positions and angles in the two transverse planes in SATURNE at injection. In addition, the system can provide tune, chromaticity and other injection parameters (figure 8) by analyzing the position versus turn as described in ref (10). The parameters are obtained from a least-squares fitting code which fits the theoretical displacement fonction to the real data.

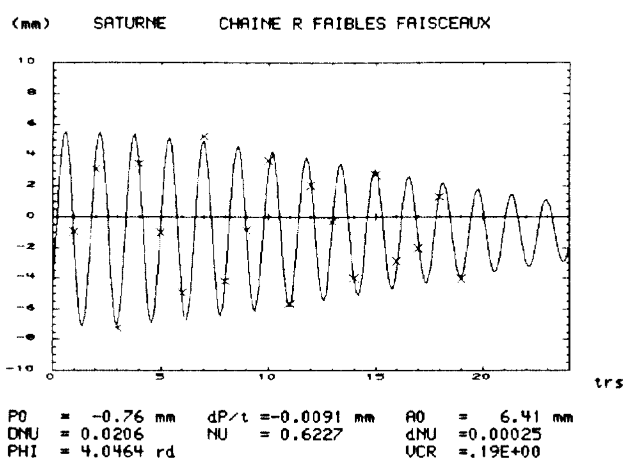

Figure 8 : horizontal position versus turn.

The second system is used to match the beam in the longitudinal phase space (11). Here, the Le Croy 9400 digitizes one signal from a beam current pick-up electrode and another from the sum of the two SATURNE cavities rf voltages. The software gives a well known "mountain range" (figure 9), this picture can be continously displayed on the control room TV monitors.

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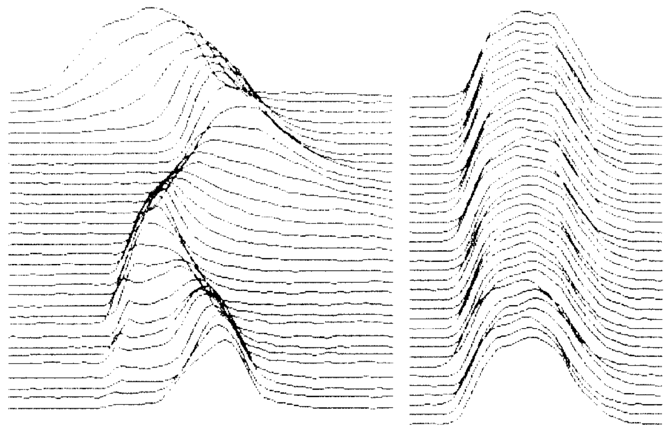

Figure 9 : longitudinal mismatching and correct matching

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