The Injection Scheme for the New 1.5 GeV Storage Ring, MAX-II

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Abstract

MAX-II[1] is a third generation compact synchrotron light source recently commissioned at MAX-lab. Electron bursts are transferred from MAX-I and injected into MAX-II at an energy of 500 MeV. This paper will describe the injection procedure and the hardware used. Simulation tracking of the injection is compared to the results obtained during commissioning. Results such as efficiency, burst bunch structure, and instabilities are presented and discussed.

1 INCOMING BEAM PARAMETERS

The MAX-II storage ring is injected with bursts of 500 MeV electrons from the MAX-I storage ring. The bursts are 50 ns long and the pulse current is between 100 mA and 300 mA. The twiss parameters of the beam entering MAX-II are transformed from those in the MAX-I ring to those of the MAX-II ring by the transport line. The emittance of the incoming beam is approximately 50 nmrad and the energy spread may be as high as .002[2].

2 THE INJECTION PROCEDURE

2.1 The Injection System

The injection system for the MAX-II storage ring consists of a 20 degree injection septum at the end of the transport line from the MAX-I storage ring and three injection kicker magnets as seen in figure 1. The septum magnet is in the middle of one of the ten straight sections. One of the three injection kickers is located in the injection straight section and the other two are located in the adjacent straight sections. The positions of the injection elements are seen in figure 1. The reason for this arrangement, as opposed to the ideal situation with all of the injection elements in the same straight section, is that the straight sections in a compact lattice like that of MAX-II are too short.

2.2 The Injection Bump

During the injection of a burst of electrons from MAX-I into MAX-II, the three injection kicker magnets are excited by current pulses with a half sine wave form with a base of 4 μ s. This generates a bump in the closed orbit at the injection septum position. The amplitude of the bump can be considered as constant under the duration of the incoming electron burst.



Figure 1: The Injection Section of MAX-II

2.3 The Kicker Strengths

The relative amplitudes of the injection kicker excitation is dependent on the optics of the storage ring. The first of the injection kickers, KB1 in Figure 1, determines the amplitude of the bump. The second, KB2, corrects the orbit so that it passes through the center of the third kicker, which returns the beam to the original closed orbit. Thus, the bump is a local bump over the three sections that it spans and the orbit should be unchanged in the rest of the storage ring. A nominal bump is shown in Figure 2, which was generated with a DIMAD model[3][4].



Figure 2: A nominal injection bump in MAX-II.

2.4 Tracking of the Injected Beam

The injected beam is tracked during the kicker excitation. The electrons enter at the septum when the excitation is at a maximum. The stored beam is closest to the septum at this time as well. Figure 3 shows such a tracking. The oscillations seen once the bump is over are damped before the next injection.



Figure 3: The injected beam in horizontal phase space.

2.4 Nonlinear Effects

Due to the non-linear elements of the storage ring, the relative kicker strengths are also dependent on the bump amplitude. This results in a residual oscillation of the electron beam as seen in Figure 4, which is a horizontal phase space tracking of the stored beam during the bump.



Figure 3: Stored beam in MAX-II during injection.

3 OBSERVATIONS FROM THE COMMISSIONING PROCEDURE

3.1 Expected Injection Efficiency

In the design of the injection to the MAX II ring it was assumed that MAX I was ramped to 300 mA and that at least 200 mA could be extracted. Also it was assumed that the effective length of the extracted pulse was 50 ns. The reduction from a possible length of 100 ns to 50 ns is due to the expected rise time of the fast extraction kicker in MAX I. The above considerations yielded a fill time for MAX II of some 6 minutes, corresponding to 6 pulses from MAX I with a repetition rate of one pulse per minute.

3.2 The First Injections

The first successful injections were made at the horizontal tune of 8.2. The design value for the horizontal tune is 9.2. The beam entering the septum was measured to be well above 50 ns effective length, but the horizontal size was diluted giving a somewhat larger beam at the injection point[2]. The horizontal tune was kept at 8.2 for some time in order to establish control over the injection process and make the initial orbit corrections.

During the initial commissioning activities, it was observed that the injection kicker magnets were being excited by some unknown process. This put a rather undesirable limit on the amount of current that could be stored in the ring. The problem was remedied by altering the electronic trigger circuit indicating that the stored electron beam was influencing the electronics of the trigger circuit. The rf signal from the beam was somehow leaking in to the sensitive elements of the electronics. The circuit was changed and we were able to continue the commissioning process and soon reached the design current of 200 mA.

It was also found that an alignment error between the incoming transport line and the injection point of the order of 10 mrad could not be corrected by the standard correctors, but required an additional magnet which was installed directly before the injection septum. During this first commissioning phase we reached routinely 35-40 mA in each shot from MAX I.

The kicker settings were found to match the calculated values for this optics apart for a reduction of kicker 2 at the injection straight section due to leakage of the magnet field from the injection septum. Due to the preferable emittance conditions for the design tune, we have gone over to this operating condition. So far we have not reached the same level of injection efficiency. Presently, the injection rate is some 10-15 mA /minute which, at present, is sufficient for the continuing conditioning of the ring.

4 HARDWARE

The injection kicker magnets are of a window frame type. The magnets are identical, except that KB2 is poled opposite to the other two. The maximum kick which they can give a 500 MeV beam is 3.5 mrad. They are built of ferrite blocks 0.25 m long. The blocks are placed around a ceramic vacuum chamber section in the ring. The inside of the ceramic chamber is coated with a 10 nm thick layer of titanium consistent with UHF vacuum requirements. The power supplies for the injection kicker magnets have the following characteristics:

- Excitation type : Half sine wave, base 3.9 µs.
- Magnet inductance: 3.16 µH, 2 turns.
- Current : 467 A in a two turn magnet.
- Capacitance : 0.566 µf
- Impedance $: (L/C)^{1/2} = 2.36 \Omega$
- Voltage : U=2.36*467=11000 V

• Repetition rate : 1 Hz

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