PERFORMANCE OF THE MAX II INJECTOR

Å. Andersson and L.-J. Lindgren, MAX-lab, Lund University, Sweden

Abstract

The third generation synchrotron radiation source MAX-II has recently been commissioned. The small MAX-I multipurpose ring, is in this context used as a slow cycling (1 pulse/minute), large current (200 mA) injector. Due to the low repetition rate, it has been almost necessary to monitor, in a non-destructive way, the quality of each extracted beam pulse. Beam parameters have been measured in the MAX-I ring just prior to extraction, and at the end of the extraction beam transport line close to the injection point. This paper describes the extraction procedure and the hardware used. Measured beam parameters are presented and compared to the theoretical ones.

1 FAST EXTRACTION MODE

The fast extraction mode of the MAX-I ring [1] is similar to the storage mode in the way that 100 MeV electrons are injected and accumulated to about 300 mA before acceleration to 500 MeV, where a current of about 200-250 mA is stored. The stored beam is given a suitable working point and position prior to extraction. After extraction the magnets are taken down to zero and finally up to the injection point again. This procedure takes approximately one minute.

1.1 Principle of Extraction

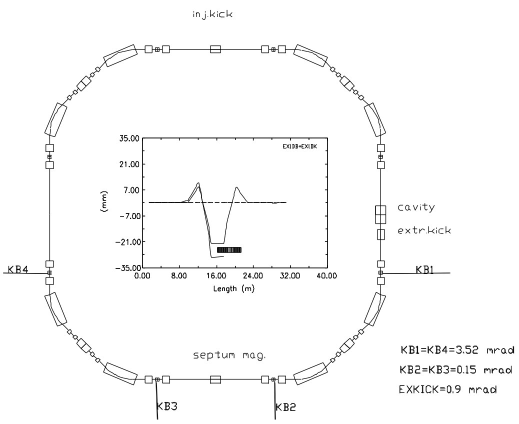

Figure 1: The MAX-I lattice. Inside- closed orbit for the bumped beam and also the extracted beam.

The goal of the fast extraction is of course to shift out the circulating beam to the extraction channel with as high efficiency as possible. We assume that the beam has been accelerated to 500 MeV and the appropriate working point and position have been established. The optics is such that the straight sections have no dispersion in the extraction mode. The position of the extraction elements are found in Fig. 1.

The degree of successful extraction is mainly depending on two critical elements, the extraction kicker and the septum magnet. The thickness of the septum and the size of the beam prior to extraction determines the minimum step that must be supplied by the kicker. The circumference of MAX-I is 32.4 m which corresponds to beam pulse of 108 ns. The stored beam is centered about 25 mm from the septum edge and its size is about 0.6 mm rms. The damped 500 MeV beam is slowly (30ms) moved towards the septum by the bumpers KB1 and KB4 the beam is thus positioned near the septum sheet. The final beam position is illustrated in Fig 1. At this time the lifetime is short and the fast kicker is activated.

The kicker pulse should have a very fast rise time followed by a flat pulse long enough for the beam. During the rise time the beam hits the septum and some part is lost in our case about 15 ns. During the rest of the rise of the kicker field the beam is extracted but is moving in the horizontal plane and can be considered as an extracted beam with diluted emittance. The extracted pulse is seen in Fig. 2.

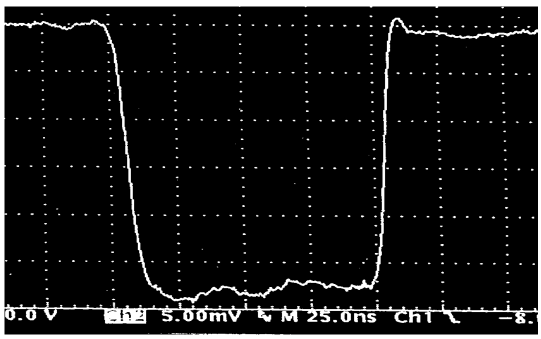

Figure 2: An oscilloscope picture of the extracted beam.

1.2 Extraction Elements Details

Magnetic septum:

An old magnetic septum [1] used for injection and slow extraction in the pulse stretcher mode [2] is now also used for fast the extraction of the 500 MeV beam. The angle of extraction is then 6 deg. vertically and after 0.5 m the beam is further bent 7 deg. to stay clear from the ring quadrupoles. The situation is shown in Fig. 3.

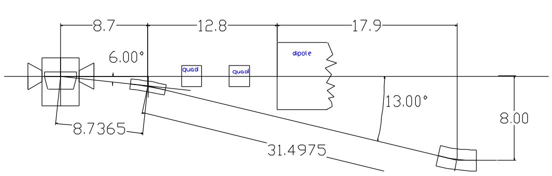

Figure 3: Septum magnet and the first part of the transport line. Dimensions in dm.

Kicker magnet:

The magnet is of window frame type built by ferrite blocks of 0.25 m length (Fig. 4, Tab.2). Excitation current is nominally 192 A supplied by a delay line coaxial thyratron switch. Rise time is below 50 ns. The magnet core is placed over a ceramic vacuum pipe coated on the inside by a thin layer of titanium.

Table 1: Kicker magnet details.

Max deflection angle	1.5 mrad
Nominal deflection angle	1.0 mrad
Beam energy	500 MeV
Effective length	0.25 m
Field strength	67 gauss
Type	50 ohm delay line
Flat top	> 100 ns
Aperture (H*V)	73*24 mm2
Ferrite window	90*36 mm2
Amplitude stab.	2 %
Time stab.	< 5 ns

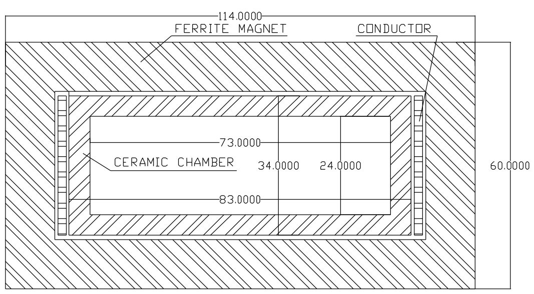

Figure 4: Cross-section of the kicker magnet.

2 THE TRANSPORT LINE

The transport line, which we tacitly have defined as a part of the MAX-II injector, can be seen in Fig. 5. It is approximately 60 m and comprises two vertically bending magnets, ten quadrupoles, two inclined horizontally bending magnets and ten correcting magnets. Optically the beam is transformed to match the injection point in MAX-II. More details can be found in [3]. The injection process is described in [4].

3 BEAM DIAGNOSTICS

At the MAX-I ring we have a beam profile monitor system [5], which utilizes the visible bending magnet synchrotron radiation to form an image of the beam on a CCD camera. By this we are able to determine quite accurately the stored beam emittance and energy spread. We can even have a look at the “bumbed” beam if we chose a trigger mode of the camera. In the transport line we have a number of “beam viewers”, which are fluorescent screens that are moved into the beam path. These have proved to be most useful for alignment, during commissioning and for major fault search. However, they are destructive and since the repetition rate is low we lose a lot of time by using them. Moreover, they cannot be used for accurate beam size measurements. For this reason we installed a beam profile monitor, similar to the one at MAX-I, in the last bending magnet (HBE2) in the transport line. The light intensity from one single-pass pulse is sufficient for diagnostics. This system gives for each extracted pulse (if it reaches HBE1) a frozen two-dimensional contour plot of the beam cross-section in the magnet.

4 MEASURED BEAM PARAMETERS

The beam parameters measured in MAX-I is given in Tab. 2. The rms beam sizes are given for the extraction point, i.e. center of septum magnet.

Table 2: Measured beam parameters in MAX-I.

Current	200 mA
Hor. emittance	47 nmrad
Ver. emittance	2.7 nmrad
Energy spread	0.0018
Rms hor. beam size	0.59 mm
Rms ver. beam size	0.09 mm

Regarding the vertical emittance, the value is given for a beam cleared from ions by help of a gap in the bunch train. Without this ion clearing we suffer from the enlarged emittance. For the “bumped” beam the parameters do not differ significantly.

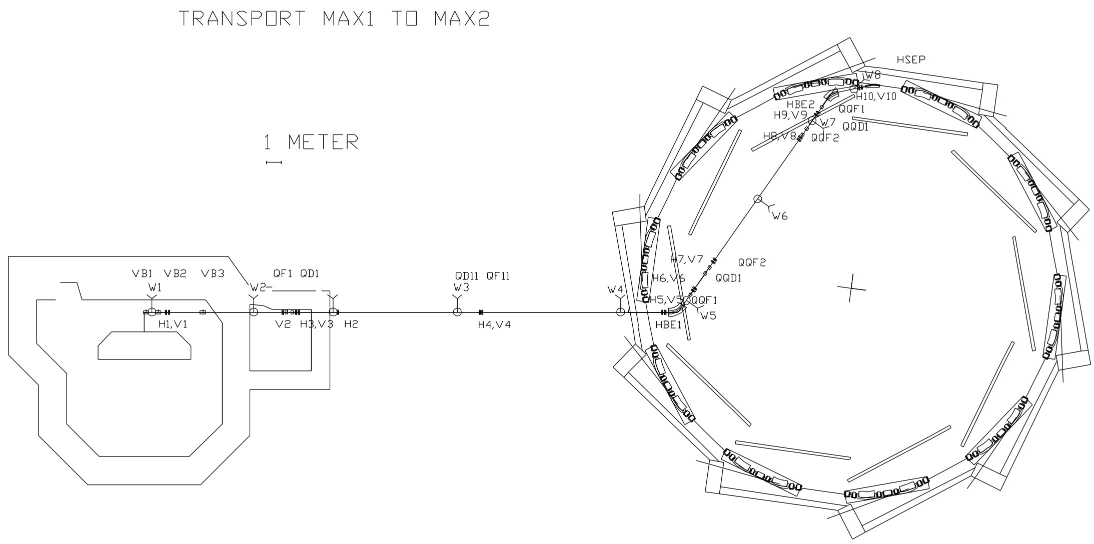

Figure 5: Transport from MAX-I to MAX-II.

Our intention in the design phase was to measure the beam sizes at the end of the transport line and in this way find out if the above mentioned horizontal emittance dilution was serious. However we have from experience learned that it can be tricky to have such a precise knowledge over the transport line lattice functions that one can precisely state the emittance growth. This is illustrated in Fig. 6. By varying the strength of the quadrupole QQF1 just ahead of HBE2, we strongly alter the lattice functions in the measuring point. The curves illustrate the theoretical rms beam sizes in HBE2, given the emittances and energy spread from MAX-I, for different set values on the quadrupole. Comparing to the measured values, one can quite nicely see the systematic discrepancies.

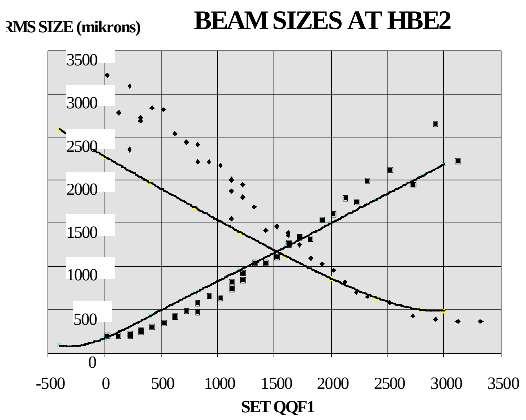

Figure 6: Rms beam sizes in last transport bending magnet as a function of the preceding quadrupole excitation. Hor.- triangles; Ver.- squares.

5 CONCLUSIONS

The MAX-I ring has turned out to be a reliable injector for MAX-II. The repetition rate of one pulse per minute can be kept due to the fast stacking of MAX-I. Almost all current that is extracted can be transported to the injection point in MAX-II. However, it has been quite time consuming to tune in the transport line and make the injection efficient, mainly due to the low pulse rate. The emittance dilution due to the extraction process does not seem serious. It has been a larger problem finding the correct transport lattice element settings. However, once a good setting for efficient injection has been found, the non-destructive beam profile monitor at the end of the transport line, has turned out to be most valuable. Often a small change in beam position or beam profile at this position, reveals that something is misbehaving.

REFERENCES

[1] M.Eriksson, *Nucl. Instr. and Meth*.A196,331 (1982).
[2] L.-J.Lindgren, M.Eriksson, *Nucl. Instr. and Meth*.A214,179 (1983).
[3] Å.Andersson et al, Design report for the MAX II ring, NTMX-7019, (1992)
[4] G.LeBlanc, L.-J.Lindgren, "The Injection Scheme for the New 1.5 GeV Storage Ring, MAX-II", These proceedings.
[5] Å.Andersson, J.Tagger, "Beam profile measurments at MAX", *Nucl. Instr. and Meth*. Vol. A364, 4 (1995).