# STATUS OF THE MAX-II STORAGE RING

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*Abstract*

The MAX-II storage ring is a third generation synchrotron light source recently commissioned in Lund, Sweden. A description of the ring is presented along with an evaluation of the performance during commissioning. The status and most recent results of the early stages of operation are also presented.

## 1 INTRODUCTION

The MAX-II storage ring was designed [1] and built in such a way as to optimize the cost/performance ratio rather than the performance per se. In addition, there were constraints far as space, economy and manpower, which necessitated the use of some novel techniques [2]. The commissioning procedure has proven that these techniques were successful.

## 2 MACHINE DESIGN

A national committee defined the specifications for the MAX-II ring. The most important ones were:

- An electron energy of 1.5 GeV.
- An emittance of less than 10 nmrad.
- 10 straight sections at least 3meters long for insertion devices.

There were also conditions, which necessitated the following constraints:

- A maximum ring circumference of 100 meters.
- Approximately 40 man-years for design and construction.
- The ever present limited funds.

### *2.1 Solutions*

The idea was to build a very compact machine that would be delivered in blocks. Each block would be one cell of the ring, with vacuum chamber, beam position monitors and magnets mounted on a rigid girder. One main supplier would have the responsibility to deliver the cells and subcontract the various components as necessary. The design specifications were given in terms of mechanical and electrical tolerances rather than ring performance.

### *2.2 Lattice*

The double bend achromat was taken as the starting point for the lattice design. It was known from previous experience with the MAX-I storage ring that allowing finite dispersion in the straight sections would permit a substantial reduction in the emittance. A ten-cell structure would meet the specification of less than 10 nmrad emittance at 1.5 GeV. The ideal position for chromaticity correcting sextupoles is in the middle of the quadrupoles. This combined with the desire for a compact lattice led to the decision to design the sextupoles in the pole profiles of the quadrupoles. A back-leg winding allows for chromaticity correction. An evaluation of the magnets can be found in reference [3]. The machine functions for the unit cell are seen in figure 1.

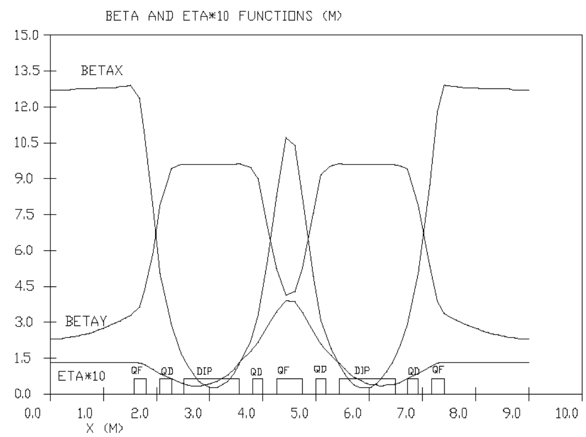



Figure1: MAX-II machine functions.

### *2.3 Magnets and Girders*

The goal was to manufacture the magnets in such a way as to be able to mount them on the girders in well-defined positions, eliminating the need for further adjustment of individual magnets. The girders were fitted with knobs that were machined in a numerical planer. The magnets are built with stamped grooves, which are used to align them on the machined knobs.

The BPMs are also placed on machined knobs, eliminating the risk of movement with the thermal expansion of the vacuum chamber. The stainless steel vacuum chamber is connected to the BPMs with bellows on either side. Otherwise it hangs freely, with strategically placed bellows to allow for thermal expansion.

Once assembled, the girders are aligned using a central reference pillar. Two people can adjust the alignment of the whole ring in two days.

### *2.4 Injection*

The need to be cost efficient led to the existing, 500 MeV MAX-I storage ring, being used as the injector. MAX-I is injected with 100 MeV electrons from a racetrack microtron, the energy is ramped to 500 MeV, and the beam is extracted in one shot and sent through a transport line before being injected into MAX-II. Several shots are required to fill the ring with the 200 mA design current before the energy is ramped to 1.5 GeV.

## 3 PRESENT STATUS

The storage ring is performing well and the first synchrotron radiation experiments will be performed soon. The alignment procedure proved to be effective when the first attempt to store a beam was accomplished without the use of corrector magnets.

### *3.1 Injection*

The MAX-I storage ring is functioning well as an injector to MAX-II [4]. It takes a couple of minutes to cycle MAXI from extraction of the beam to injection from the microtron to a stored beam at 500 MeV. The whole process takes approximately 20 minutes, as seen in figure 2. With a circulating current of 200-250 mA in the “injector” we have succeeded in injecting approximately 30mA in each shot into MAX-II. Taking the difference in machine circumference into account, this means an overall efficiency of around 50% where the fast extraction, transfer, injection and capture procedures are included.

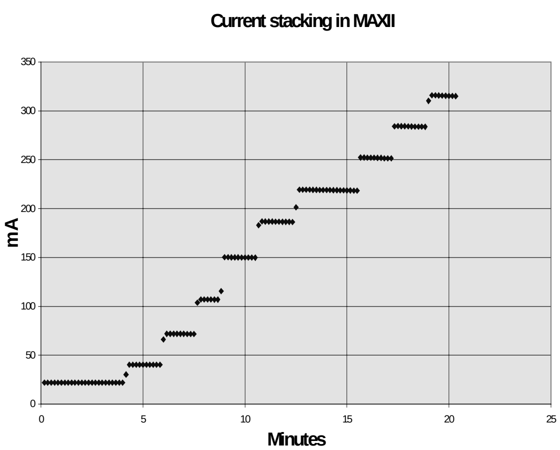



Figure 2: Current Stacking in MAX-II

### *3.2 Operation*

The target and achieved parameters are compared below.

| Parameter | Target | Achieved |
|---|---|---|
| Energy (GeV) | 1.5 | 1.53 |
| Current (mA) | 200 | 220 |
| Life time (Ah) | 2 | 2*) |
| Coupling (%) | 10 | <1 |
| Hor. Emittance (nmrad) | 8.8 | **) |
| Beam Long Term Drift (μm) | 20 | 7 |
| Energy Spread | 0.07 | **) |

*) At 5% coupling.
**) To be measured.

### *3.3 Emmitance Measurements*

Emittance measurements have been performed at "zero"- current and 1.5 GeV, where the results show that the nominal horizontal emittance (9 nmrad) is achieved. Choosing different coupling can vary the vertical emittance. At the lowest coupling an emittance of only 20 pmrad has been measured. At nominal currents the coupling can be chosen to about 1% without problem. However, at nominal currents the energy spread of the beam is larger than the natural one.

### *3.4 Insertion Devices*

At present, there are four insertion devices installed on MAX-II. In addition, there is a super conducting wiggler which is being conditioned outside of the ring for installation in the near future. Table 1 gives the parameters of the existing insertion devices.

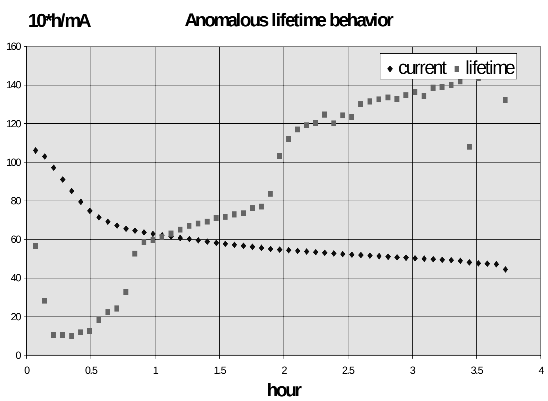
| | **I311** | **I411** | **I511** | **I611** | **I711** |
|---|---|---|---|---|---|
| $\lambda_u$ | 66 mm | 60 mm | 52 mm | 244 | 174 mm |
| $K_{max}$ | 4.50 | 3.63 | 2.69 | 140 *) | 29.3 |
| # of poles | 77 | 87 | 99 | 1/2 + 1 + 1/2 | 27 |
| Total length | 2.65 | 2.65 | 2.65 | 0.9 m | 2.65 |
| Magnet gap | 22 - 300 mm | 22 - 300 mm | 22 - 300 mm | 36 mm | 22 - 300 mm |
| Peak field | 0.74 T | 0.65 T | 0.55 T | 6 T *) | 1.8 T |
| Type | Hybrid, taper | Hybrid, taper | Hybrid, taper | Super conducting wiggler | Multipole wiggler |
| Status | In operation | In operation | In operation | Delivered | In operation |

*) To be measured

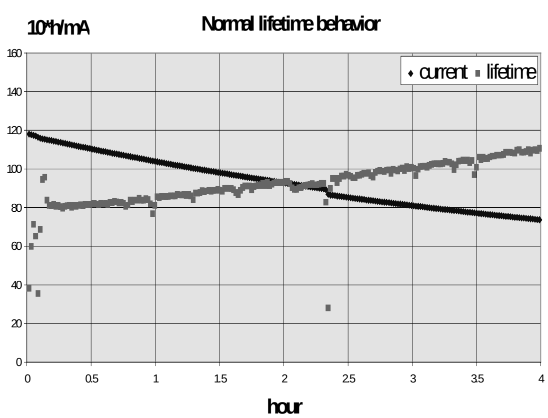
Table 1: Insertion devices for MAX II (May 1997)

# 4 LIFETIME PROBLEMS DURING COMMISSIONING

After filling the MAX-II ring with about 150 mA and ramping to 1.5 GeV, the lifetime was as expected for the first 10 to 20 minutes. Then suddenly the lifetime dropped to a much lower value, say about one hour. During this drop we did not observe any increased currents in the ion vacuum pumps. However, we did observe an increased radiation level in the extension of one of the short straight sections of a specific cell. After some time with a rapidly decreasing current the lifetime made a rather quick increment of at about the same time scale as the initial decrement. Some hours later we could observe another sharp lifetime increment. These abnormalities are seen in figure 3.




(a)




(b)

*Figure 3: Typical current/lifetime maps found a) before and b) after removal of remaining rf-shields.*

### *4.1 Possible Cause*

We had previously experienced problems with fingers of the rf-shields in the ring. These shields were installed to smooth the vacuum chamber in all bellow joints. After the first troubles they were dismantled in all cells but two. The rf-shields are made from thin sheets of a beryllium-copper alloy with a melting point at around 900deg/celsius. The sheets are cut finger-like and formed to fit the vacuum-pipe.

The observed radiation increase coincided with the position of the remaining rf-fingers. This led us to the conclusion that they might be responsible for the observed effect. It was previously observed that part of the rf-fingers might loosen from the vacuum chamber wall and even bend into the path of the electron beam. Assuming that this could happen, without fully understanding why, it could happen that such a finger might be hit by synchrotron light. The light would heat up the finger to the melting point, and start to evaporate it. The circulating beam would experience the metal vapor, which explains the reduced lifetime, however the vapor will not reach the ion-pumps.

### *4.2 Cure*

We decided to open up the last two cells and check the rf-fingers and found two melted fingers. We assume that the stepwise rising lifetime corresponds to the two situations when finger 1 and finger 2 stop evaporating. After starting up Max-II again we conclude that the beam lifetime problems have disappeared, and we now see a normal lifetime map.

## REFERENCES

[1] Å. Andersson et al., DESIGN REPORT FOR THE MAX-II RING ISRN LUNTDX/NTMX—7019—SE

[2] M. Eriksson, Novel Techniques Used in MAX-II, Proceedings of the Fifth European Particle Accelerator Conference, page 72.

[3] M. Eriksson and L.-J. Lindgren, The MAX-II Lattice Magnets Measurements and Conclusions, Proceedings of the Fifth European Particle Accelerator Conference, page 2198.

[4] Å. Andersson and L.-J. Lindgren, Performance of the MAX-II Injector, Proceedings of the Fifth European Particle Accelerator Conference, page 2494.