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Status of MAX II

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A new third-generation VUV synchrotron radiation ring called MAX II has just been built and commissioned in Lund, Sweden. Owing to tight boundary conditions regarding economy, space and manpower some novel techniques have been used in the design of the ring. The present status of the ring as well as the motivation for the parameter choices and techniques chosen are presented.

Keywords: MAX II; third-generation sources; beamlines.

1. Specifications, boundary conditions and solutions

The MAX accelerators are shown in Fig. 1. The first synchrotron light ring was started up in 1986 for experiments. Although the MAX I ring showed a very high performance there were limits in terms of a low operating energy, a limited number of straight sections and an emittance of 40 nm. A national *ad hoc* committee was formed in 1989 and presented a performance specification of a new third-generation light ring (Andersson *et al.*, 1992; see Table 1).

Table 1
MAX II specifications.

Operating energy	1.5 GeV
Circulation current	0.2 A
Number of straight sections for insertion devices	8
Length of straight sections	3 m
Beam lifetime	10 h
Electron-beam emittance	10 nm rad

The boundary conditions, imposed by a small staff, limited space availablity and a very limited budget, called for some unconventional physical and technical solutions to reach the given specifications:

(*a*) Non-zero dispersion in the straight sections. Early experience from MAX I had shown that if a finite dispersion could be allowed for in the straight sections, the overall beam emittance, including that given by the beam energy spread and the ring dispersion, could then be lowered by a factor of 2–3 compared with the zero-dispersion case. This option was studied carefully and a finite dispersion of 13 cm was allowed for in the MAX II ring. This implied that a simple lattice giving a ring of small circumference could be used whilst still meeting the ring specification.

(*b*) Integrated quadrupole–sextupole magnets. The ideal position of the sextupole magnets is at the location of the quadrupole magnets. Off-energy particles will then see an undisturbed lattice. The sextupole strength needed for the chromaticity correction will furthermore be minimized in this way which favors dynamic aperture. The integrated magnet scheme compresses the lattice further. Some sextupole tuning flexibility will, however, be lost.

(*c*) All ring items like magnets, the vacuum system, beam-position monitors (BPMs) *etc.* are attached to machined disks welded to the stiff girders as seen in Fig. 2 with no means of adjustment. Although this solution calls for strong nerves, as any later correction of eventual mistakes is hard to carry out, it does reduce the construction and mounting cost substantially.

(*d*) The MAX I ring should be used as an injector for MAX II. A 500 MeV beam will then be shot from MAX I to MAX II. Three shots should be needed to fill the MAX II ring. This is then ramped to the final energy of 1.5 GeV.

2. Present status

During the last year, ring construction and commissioning of the MAX II ring has almost been completed. The construction and commissioning has been carried out on 'accelerator physics weeks', during Mondays allocated for accelerator physics and maintenance, and during some Tuesdays, which generally are allocated for single-bunch operation in MAX I. Little scheduled operation time has been lost for MAX I.

The following performance has been achieved:

(*a*) Injection. 10–15 mA is trapped per shot from MAX I. This is considerably less than the 50 mA shot^{-1} foreseen, but 200 mA can nethertheless be trapped in MAX II in half an hour. The maximum current trapped in MAX II so far is 250 mA (specified current 200 mA). Since the maximum current is 200 mA at full energy, no further attempts have been made to increase the injected current further.

(*b*) Ramping. Losses during ramping are marginal. Some mA are lost at the end of the ramping cycle due to betatron tune shifts induced by saturation in the dipole magnets. This can be compensated for by adjusting the ramp table.

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(*c*) Full-energy operation. The final energy is 1.56 GeV (specified 1.5 GeV). Since the ring has not yet been fully conditioned, we have so far limited the maximum current to 120 mA.

(*d*) Beam lifetime. The beam lifetime is some 10 h at the injection energy. At full energy we have a beam lifetime of 10–15 h at currents lower than 50 mA. At higher currents the beam lifetime fluctuates between 12 h and seconds. The reason for this poor value is multipactoring at the radio-frequency-cavity window, which was uncoated. At full radio-frequency power and high currents the pressure rose heavily in the cavity with a shortening of the beam lifetime as a consequence. Without multipactoring, the beam lifetime seems consistent with the calculated vacuum and Toushek lifetimes. This multipactoring problem is now taken care of.

(*e*) Emittance. Some rough beam-size measurements have been carried out confirming the calculated emittance. More detailed measurements will be carried out during autumn 1997.

(*f*) Beam stability. The short time stability (*f* larger than 1 Hz) is very small, smaller than 2 μm. No local feedback has thus been considered so far. Some slow drift of the beam position is present due to thermal changes in the quadrupole magnets. This drift is rather easily compensated.

(*g*) Instrumentation. The beam-position monitor, being the very backbone in the diagnostic system, is capable of measuring the beam position with 2 μm reproducibility. The correction algorithm should, however, be developed to give a faster convergence. The beam-size measuring

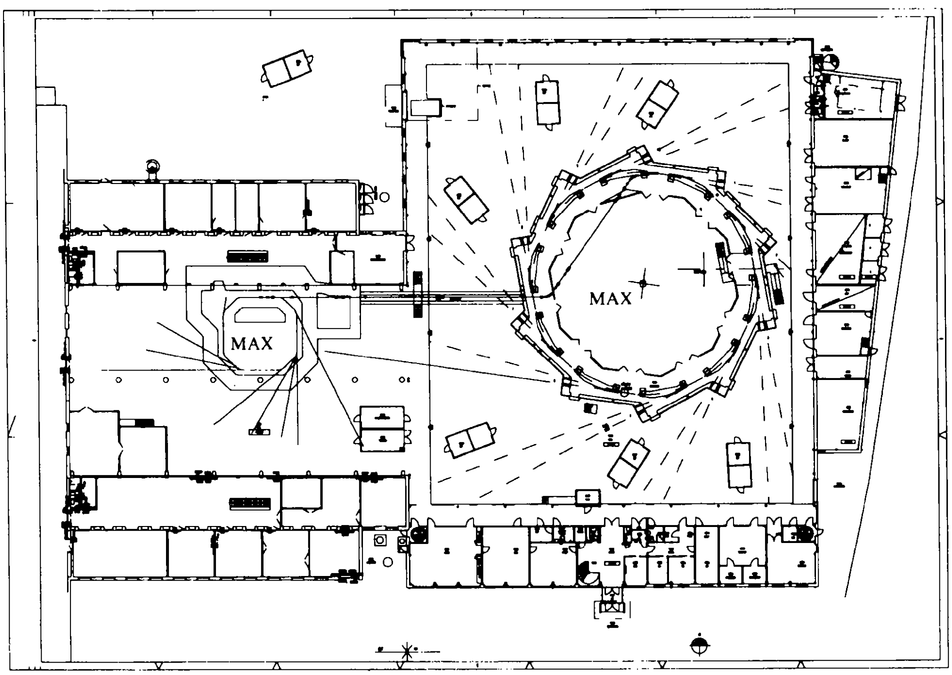

Figure 1
The MAX accelerators.

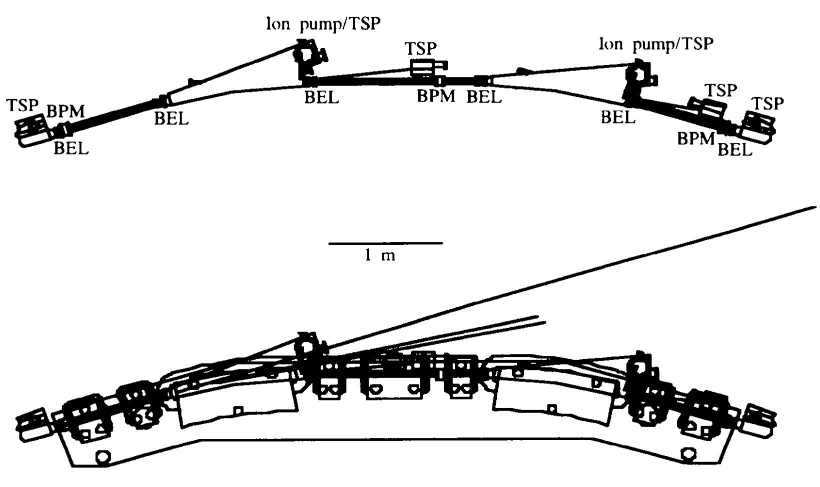

Figure 2
One magnet cell.

equipment has a resolution of 20 μm. The calibration of this system has been carried out at injection energy at 'zero' current where the beam natural emittance is less than 1 nm rad.

(*h*) The chromaticity correction with the integrated sextupoles works as planned. Some minor sextupole tuning is achieved by special back-leg windings on the magnets.

(*i*) The ring items resting on the machined surfaces are positioned very accurately. The r.m.s. positional deviation is estimated to be 15–20 μm from uncorrected closed-orbit measurements.

3. Beamline development

There are six beamlines under construction in the first instrumentation phase:

(*a*) A 32-pole 1.8 T wiggler will serve a protein crystallography beamline. This beamline will be commissioned during autumn 1997.

(*b*) A white-beam beamline used for X-ray lithography and LIGA applications is close to operation.

(*c*) A 5 cm-period undulator will serve photoelectron microscopy. This beamline will be installed in early 1997.

(*d*) A photoelectron spectrometer will sit on another undulator. This beamline will be commissioned in parallel with the one above.

(*e*) Two VUV beamlines will be moved over from MAX I to MAX II during 1998.

References

Andersson, Å. *et al.* (1992). *Design Report for the MAX II Ring.* MAXlab, Lund, Sweden.