NOVEL TECHNIQUES USED IN MAX II

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Abstract

A new third generation VUV synchrotron radiation ring called MAX II has just been constructed and commissioned. The boundary conditions regarding economy, space and manpower have been rather tight so some novel techniques have been used in the design and construction of the ring to keep a high performance level while staying within the boundary conditions mentioned above.

In this paper, the most relevant design features and some of the commissioning experience will be described. The magnet lattice yielding finite dispersion in the long straight sections, the combined sextupole/quadrupole magnets, the aligning technique, the vacuum system design, the injector choice and the production methods chosen will then be described.

1 INTRODUCTION.

The synchrotron radiation activity at MAX-lab increased steadily after the commissioning of MAX I 1986. Pretty soon, it was quite evident that a third generation light-source was needed in the mid-nineties to cope with an increasing demand of high-brilliance radiation in the VUV and soft X-ray spectral region. It was also quite evident, that a new light-source had to be constructed within rather tight boundaries in terms of space, economy and man-power.

The MAX II ring was then designed with the aim to simplify the ring construction and to choose technologies to optimise the cost/performance ratio rather than maximise the ring performance. Some of the solutions chosen are of a novel character while other have been used earlier. The ring is described in more detail in ref 1 and 2.

2 DESIGN BOUNDARY CONDITIONS

In 1989 a national ad hoc committee defined the specifications for the MAX II ring. The most important ones were:

1. An electron energy of 1.5 GeV.
2. An electron emittance less than 10 nmrad.
3. 10 straight sections longer than 3 m for insertion devices.

Other boundary conditions implied:

4. A maximum ring circumference of 100 m.
5. Some 40 man-years available for design and mounting.
6. Low budget ring.

3 DESIGN PHILOSOPHY

The main idea was then that the MAX II ring should be delivered in few and big blocks from the supplier. The individual cells should be sufficiently small to allow all the magnets within one cell to sit on the same girder. Complete cells including girder, magnets, diagnostics and vacuum equipment should then be delivered as a unit. No individual adjustment of the magnet positions should be necessary.

Mounting and survey should thus be as simple as possible. Ten cell units should be put in position and interconnected by the straight sections. To minimise administration and to clarify responsibility questions, one main supplier should have the overall responsibility for the complete cells and subcontract other suppliers. Another question of economical importance was that specifications given to the main supplier was in the form of mechanical and electrical tolerances, not in terms of ring performance.

To match the conditions mentioned above, some demands must be fulfilled:

1. A very compact lattice was needed to squeeze down the cell length.
2. New methods for mounting and alignment must be developed.

To solve the last question, industrial designers with an up-to date knowledge of the performance and limitations of the newest numerical machines were engaged.

4 LATTICE

To meet the design specifications, the ring lattice must be very compact. The two-bend achromat was used as a starting point. Earlier experience with the MAX I ring had shown that the ring emittance could be decreased substantially if a finite dispersion was used in the long straight sections. The overall emittance, including the contribution from the dispersion, could then be reduced with a factor of 2-3 compared to the zero-dispersion case. A simple 10-cell structure was then sufficient to meet the specification of an emittance less than 10 nmrad at 1.5 GeV.

The looking-glass was then put on the magnet structure. It is since long well-known that the ideal position for the chromaticity correcting sextupoles are in the centre of the quadrupole magnets where the beta-functions are as most separated and attain their maximum values. The sextupole strength can thus be minimised if they are positioned in the quadrupoles, which favours the dynamic aperture. Moreover, the energy acceptance is also maximised in this way since off-momentum particles see an undisturbed lattice.

The decision was thus taken to include the nominal sextupole component in the iron surface of the quadrupole magnets.

This solution called for some tuning means for the sextupoles. Back-leg windings on the quadrupole/sextupole magnets were then added to adjust the chromaticity of the ring. These windings will also introduce dipole components, but since these are highly periodic, their influence on the closed orbit is limited and quite easy to compensate.

A very important parameter when designing the magnet lattice is also the optimum length of the straight sections for the insertion devices. The brilliance increases quadratically with undulator length for short undulators but for the spectral region used at MAX II, the brilliance growth flattens out and becomes linear for undulator lengths exceeding 2 m. The performance to cost ratio thus called for a straight section length of about 3m.

The ring structure is seen in fig. 1 and the machine functions are shown in fig. 2.

5 CELL AND MAGNET DESIGN

The lattice chosen thus permitted us to put all the cell equipment on the same girder. This girder had to be rather stiff, its strength was rather defined by the need to push up its eigenfrequencies including the magnet loads to frequencies above 50 Hz rather than to handle the static magnet loads.

The next problem to be solved was the alignment and mounting of the individual magnets. This problem called for some extra attention since the tolerances for the alignment of the individual quadrupoles are tighter than those for the complete cells.

The idea then is to use the outer surfaces of the magnets as a reference for the alignment. The need to use the

magnet centre as a reference was thus avoided. The problem of building magnets with very well-defined surfaces had already been solved at AMPS. The magnet laminates are of the commercially pre-glued “silent transformer” type. Another nice feature with this gluing technique is that it is pretty cost-effective. The magnet design is presented in more detail elsewhere at this conference [3).

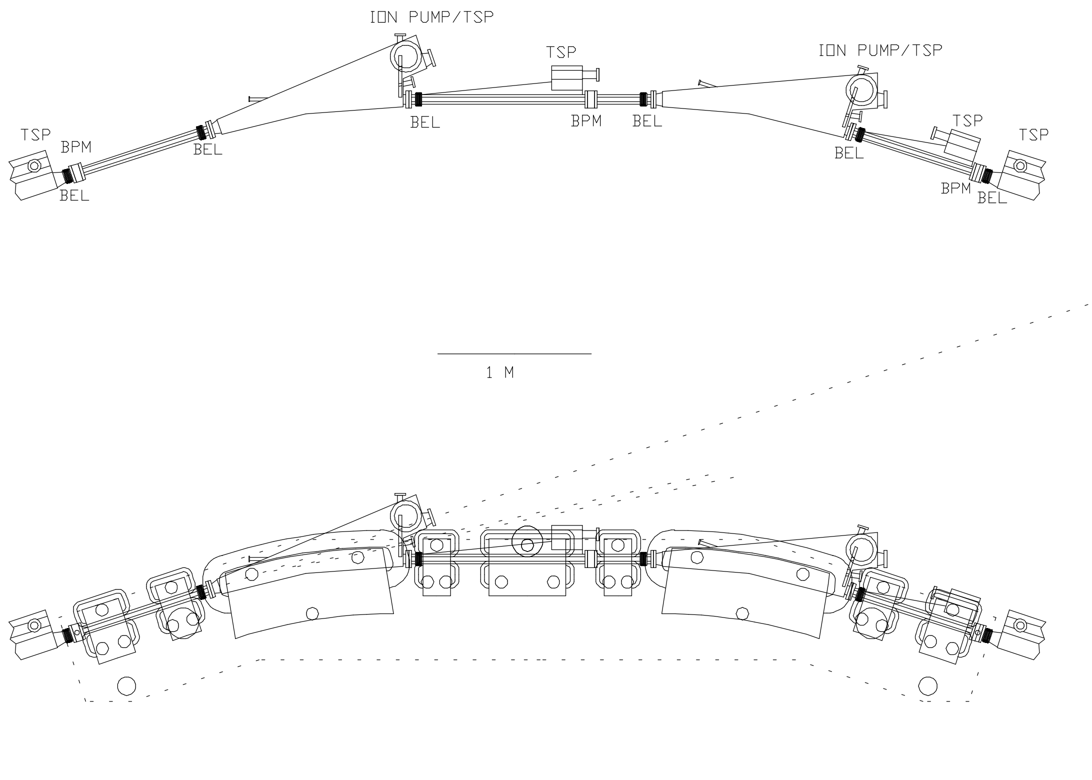

Fig. 1. One magnet cell.

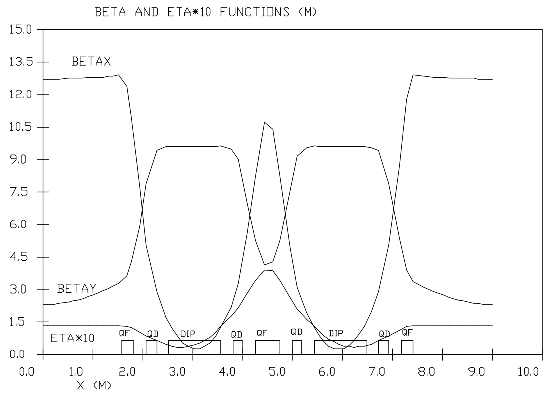

Fig. 2. MAX II machine functions.

On top of this girder, small stainless steel disks, three for each magnet, were welded to the girder as indicated in fig. 1. Some additional disks for alignment purposes and for mounting of the BPMs were added as well. The girder was then put in a big numeric machine and the upper surfaces of the disks where machined to a well-defined level. Only small areas were thus machined. Reference holes were also drilled in the disks to define the position of the magnets and BPMs with the same numerical machine. Steel pins could then define the position of the magnets, the steel pins fitting into stamped grooves in the magnet laminates. The RMS positional deviation for the magnets and BPM's were then specified to 30 μm relative the girder.

This alignment solution offered a simple solution to the vacuum system baking problem. According to our experience, baking of the vacuum system is necessary, especially before commissioning, but is then a rather rare event.

In-situ baking equipment tend to increase the magnet aperture and increases the operational cost since the magnet power consumption increases strongly with aperture. Moreover, for a given saturation level in the magnet iron, the field gradient decreases with increasing aperture with a less dense lattice as a consequence. Of these reasons, the in-situ baking equipment was omitted. When baking the MAX II vacuum system, the magnets are simply removed from the girder and we get free access to the naked vacuum system, which is seen on the upper half of fig. 1. Since no additional aligning is needed when putting the magnets back, the process of moving the magnets will just marginally increase the total baking time.

All the light beam ports are equipped with one radiation absorber and a valve to avoid venting the system at beam-line connections.

6 VACUUM SYSTEM

Stainless steel is used throughout the system. The vacuum system is only fixed to the girders via the BPMs, which are heavily bolted to the girders to keep them in fixed positions. The remaining part of the vacuum system is floating in that sense that it is suspended flexibly to the girders and some mm clearance is left to the quadrupoles. The bellows are arranged in such a way that no forces are transmitted to the fixed BPMs at movements of the vacuum chamber.

The heat absorbers consist of water-cooled copper pins mounted perpendicularly to the beam direction. We have tried to put these absorbers in the magnet leak fields to restrict the range of the photoelectrons responsible for the gas desorbtion. The idea was then to minimise the area exposed to these photoelectrons which are responsible for the beam-induced desorbtion.

7 INJECTION

As an injector, the 500 MeV MAX I ring is used. This ring is injected from a 100 MeV race-track microtron. Some 200 mA are ramped in the MAX I ring, the ramped beam is kicked out from the MAX I ring and brought to MAX II [4,5] . Due to the differences in circumference between the two rings, three shots should in principle be needed to fill MAX II to 200 mA. The cycling period for the MAX I ring is 1 minute.

8 BPM SYSTEM

The BPMs are calibrated in situ by using the quadrupole shunt technique [6] . All quadrupole magnets are equipped with a remote controlled calibrated shunt which enables us to measure the betatron functions and the beam position around the ring. The BPM system and beam position measurements are presented elsewhere at this conference [7] .

9 COMMISSIONING

During the commissioning done so far, we have been able to test most of the design ideas.

Generally speaking, mounting and aligning of the cells have gone as planned. One exception though, we had to strip the magnets from the cells more often than planned to bake the system prior commissioning.

Alignment, on the other hand, was a very positive experience. All the ring cells can be re-aligned in a day or two using a central pillar as a reference.

At injection, some 15 mA/shot is typically trapped in MAX II. This means that the injection efficiency just is some 25% and we are now trying to increase the trapping efficiency. However, only some 15 shots are needed to fill MAX II to 200 mA. The injection time will then generally take some 15-30 minutes. A maximum current of 250 mA has been injected, which meets the specification.

At injection, the natural emittance is only 1 nm rad, the damping time is long, 0.2 s so many effects like intra-beam scattering and some collective instabilities are quite visible [8)]. These effects are however harmless as long as the beam stays in the machine. During ramping, radiation damping and the landau damping increase and suppress the instabilities.

The chromaticity correction with the fixed sextupoles works well. Some chromaticity tuning is however needed during the ramping, since the dipoles saturate at high excitations. This is done as described above with the back-leg windings.

The drift and reproducibility of the beam position have been investigated. Following a defined magnet cycling process, these effects are quite tolerable [7)].

The aligning method with the quadrupoles fixed to the girders works quite nicely. The first injections could be done without any closed orbit corrections. We have also had the opportunity to check the reproducibility of the magnet positions since two cells have been stripped off their magnets once for baking reasons. The closed orbit shifted some 2 mm from its previous position when the magnets were brought back which is quite consistent with an RMS positional reproducibility of the 30 μm of the individual magnets as specified.

The method of restricting the range of the emitted photoectrons seems to have a positive effect on the time needed for conditioning. After some Ah of vacuum conditioning, the ion pump current readings generally indicate a pressure in the low nTorr region with 100 mA circulating current at full energy. There are two exceptions with readings in mid 10 nTorr region and that is at the only places where we have large areas exposed to the photoelectrons. We will soon introduce magnet fields at these suspected absorbers to measure the difference.

The beam-size measurements are underway [8)] . So far, they indicate an emittance close to the specifications.

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