THE 100 MHZ RF SYSTEM FOR MAX-II AND MAX-III

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Abstract

The MAX-II synchrotron radiation source has since 1997 been operated routinely with a double RF system, 500 MHz active plus 1.5 GHz passive. Four Landau cavities have successfully provided increased Touschek beam lifetime, and damping of coupled bunch mode instabilities. However, the delivered power from the present 500 MHz RF system will be marginal for the operation of the planned MAX-II SC wigglers, with 250 mA circulating beam current. It is shown that it is favourable to change to a 100 MHz system, with one 500 MHz Landau cavity, both considering power consumption, beam lifetime and beam stability. The new RF system and the cavities, that are being built at MAX-lab, are described. The same RF combination and type of cavities will be used at the VUV source MAX-III.

1 INTRODUCTION

MAX-lab is now preparing to switch to a lower radio frequency (RF) system for the MAX-II ring [1], and to install a similar RF system for the MAX-III VUV ring [2]. One reason to consider a change of the MAX-II radio frequency, is the fact that the available power from the present system will be marginal when operating two (or three) super conducting wigglers [3] at 250 mA current in the ring. The cost for adding necessary power is rather high at 500 MHz, while a 100 MHz system utilising conventional FM-transmitters is considerably cheaper. Another reason for a lower RF, is the possibility to increase the beam lifetime considerably. This possibility and beam stability requirements are discussed in chapter 2. The actual cavity designs are discussed in chapter 3.

2 BEAM LIFETIME AND STABILITY CONSIDERATIONS

2.1 MAX-II

The present beam lifetime in MAX-II is acceptable, asking for only one injection per day. However there are two potential parameters, which are not fully exploited. The first one is the long vacuum beam lifetime. Measurements indicate a vacuum lifetime of 100-150 hours (@ 200 mA), while the Touschek lifetime is much shorter around 24-27 hours (@ 200mA and 5% coupling). The second one is the large transverse energy acceptance of the lattice, mainly due to the scheme with integrated quadrupole-sextupole magnets [1]. Measurements indicate a transverse energy acceptance of 3-3.5%, while the longitudinal energy acceptance (bucket height), with the present RF system, is only 1.7%. Increasing the bucket height would thus be most beneficial in our case. Again, it is quite costly to achieve this at 500 MHz, while going to 100 MHz, one can even allow a 25% reduction in RF voltage and still reach 3% bucket height. Furthermore, this scheme will reduce the synchrotron frequency from 20 kHz to 8 kHz. The shunt impedance demand for the higher harmonic cavities (Landau cavities), to secure Robinson stable operation of the double RF system, will then be much relaxed. Choosing 500 MHz for the higher harmonic frequency, 3 MΩ (linac definition) will suffice, and can easily be provided by only one cavity.

A summary of the MAX-II RF parameters is given in table 1 (numbers for three SC wigglers, maintaining the original bucket height, within brackets). As can be seen we will use one FM-transmitter to each cavity. This will make the system modular, and operable even if one transmitter fails. Since the transmitter efficiency is 60%, the net power consumption will stay below 140 kW, even with three wigglers.

Table 1: RF related parameters for MAX-II (numbers for three SC wigglers, maintaining the original bucket height, within brackets)

	MAX-II present	MAX-II future
Main RF system		
Frequency [MHz]	499.780	99.956
Harmonic number	150	30
No of cavity cells	3	3
No of transmitters	1	3
Cell radius [m]	0.23	0.41
Tot length of cavities [m]	1.1	1.5
Tot R_{shunt} (≡V*V/P) [MΩ]	20	9.6
Q-value	40000	20000
Tot Voltage [kV]	600 (700)	450 (530)
Cu losses [kW]	18 (25)	21 (29)
Beam power @ 250mA [kW]	35 (50)	35 (50)
Available power [kW]	75	90
Net power [kW]	150	135
Bucket height [%]	1.7	3.0
Synchrotron frequency [kHz]	20	8
Rms bunch length [cm]	0.66	1.7
Landau cavity system		
Frequency [MHz]	1499.340	499.780
No of cavities	4	1
Tot R_{shunt} (≡V*V/P) [MΩ]	8	3
Q-value	16000	25000
Cu losses @ opt tuning [kW]	5	2.7 (3.7)
Double RF bunch length [cm]	1.9	5.3
Touschek lifetime [Ah]	8	38

2.2 MAX-III

The predicted vacuum lifetime in MAX-III is shorter, in the range 13-26 hours @ 200 mA. This is mainly due to elastic scattering losses, which dominate in a low energy ring like MAX-III. In order to limit the number of fills per day to two, we need a long Touschek lifetime. We plan therefore to use a higher harmonic cavity also in MAX-III. For a conventional 500 MHz main RF, it turns out that the synchrotron frequency will be rather high, around 140 kHz, for the voltage needed to achieve a reasonable Touschek lifetime. This is in the same range as the needed detuning of a 1.5 GHz Landau cavity. Thus the system will be Robinson unstable. Again, by choosing a lower RF, we can with a moderate power get a larger bucket height. For a 100 MHz system we reach a bucket height of 2% for a voltage of 200 kV. At the same time the synchrotron frequency will decrease to 36 kHz, and a 500 MHz Landau cavity will not make the system Robinson unstable.

A summary of the MAX-III RF parameters is given in table 2. We will use the same FM-transmitter and cavities as in MAX-II.

Table 2: RF related parameters for MAX-III

MAX-III	
Main RF system	
Frequency [MHz]	99.956
Harmonic number	12
No of cavity cells	1
No of transmitters	1
Cell radius [m]	0.41
Tot length of cavity [m]	0.5
R_{shunt} (≡V*V/P) [MΩ]	3.2
Q-value	20000
Voltage [kV]	200
Cu losses [kW]	12.5
Beam power @ 500mA [kW]	6.5
Available power [kW]	30
Net power [kW]	32
Bucket height [%]	2.0
Synchrotron frequency [kHz]	36
Rms bunch length [cm]	2.8
Landau cavity system	
Frequency [MHz]	499.780
No of cavities	1
R_{shunt} (≡V*V/P) [MΩ]	3
Q-value	25000
Cu losses @ opt tuning [kW]	0.5
Double RF bunch length [cm]	6.7
Touschek lifetime @10% coup [Ah]	4.5

2.3 Higher Order Modes and Multi-bunch Instabilities

The higher order modes in the two types of cavities we are going to use could of course cause some trouble. Some special precautions have been taken in the design (se below), but two fundamental facts will hopefully help us somewhat. The first is that our rings have a relatively short circumference, which means that the dangerous beam frequencies are relatively well separated, and thus could be more easily avoided by tuning. The second fact is that by the use of our Landau cavities, bunches are elongated roughly a factor of three compared to the length set by the low RF. The beam spectrum is thus considerably reduced at higher frequencies.

3 THE CAVITIES

3.1 Main Cavity

The main cavities are of the capacity-loaded type. This makes it possible to keep them rather short, to fit three cavities plus the Landau cavity (and on injection bumber magnet) into the same MAX-II straight section. One half of the cylindrical symmetric profile is seen in Fig. 1. The capacitor gap is 40 mm, the capacitor plate radius 115 mm, the rod radius 60 mm, the cavity radius 410 mm and the cavity length 375 mm. This results in theoretical shunt impedance of 3.5 MΩ. For the same gap one can make the cavities even shorter, but to maintain the shunt impedance the outer radius then grows. Some shunt impedance could also be gained by •rounding• the corners in the main cell. However, we are manufacturing the cavity from a copper plate that are bent and welded together, so this was not an option for us. In fact, all details are made from copper to facilitate cooling. Most effort has been put into the cooling of the centre tube, since roughly half one of the total power losses is there.

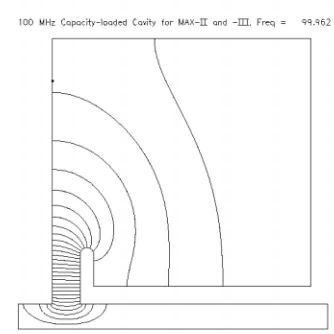

Figure 1: Main cavity profile.

In order to minimise the total length of the cavity system, one ion-pump is connected directly to the cavity body. Precautions are taken to avoid modes appearing in the combined cavity-pump system. Also necessary synchrotron radiation absorbers are put into the beam pipe, to prevent photoelectrons being produced nearby the accelerating gap, and to catch the light perpendicularly. The input power coupling loop is situated on the mantel surface.

The tuning is made by squeezing the cavity. By this we avoid a moving plunger and problems connected with RF springs. The whole mechanism for this is situated on the left endplate and the left part of the cavity mantel surface. This endplate is profiled to minimise the imposed stress. For a range of ±0.2 mm, the stress could be kept below 40 MPa. This range corresponds roughly to a tuning range of ±120 kHz. The de-tuning due to beam loading is only 20 kHz, but a larger tuning range is needed to compensate for temperature gradients in the cavity body.

Most of the higher order modes in this type of cavity have some electric field maximum ending in the right hand side endplate (see Fig. 1). In this endplate we have made it possible to insert three damping antennas at different radii. Also one probe and one excitation loop is situated at this endplate.

3.2 Landau Cavity

The Landau cavities are of simple pill-box type. One half of the cylindrical symmetric profile is seen in Fig. 2. One should though note that we have chosen a cavity body length of only 210 mm, instead of the usual half wave length. The reason is two-fold. For this short type pill-box cavity, the R/Q-value is lower than for the half wave type. This diminishes the de-tuning due to beam loading. In the MAX-III case it then becomes 375 kHz for a current of 500 mA. This could maybe be done by temperature control, considering that only half the range is needed if the ring is refilled at 250 mA. However, it might be that we need to tune away the Landau cavity quite far from the operating range, for example at injections. Therefore we will install one movable plunger, but we still hope to have it in fixed position during the current decay, and control the beam loading de-tuning only by temperature. The other reason is the fact that the TM_{011} mode (and all modes with non-zero in the longitudinal index) will raise in their frequency. This will reduce their response to the beam spectrum considerably, because of the long bunches.

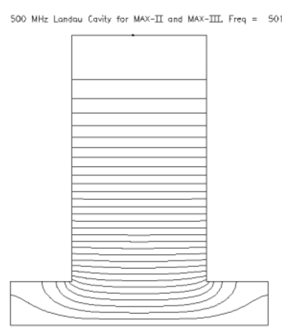

Figure 2: Landau cavity profile.

4 SUMMARY

We have found that for the MAX-II and MAX-III rings, it is favourable to choose a 100 MHz instead of a 500 MHz active system. We then get a modular system with relatively cheap conventional FM-transmitters. Together with 500 MHz Landau cavities, the choice allow us to fully exploit the possibility to achieve a long Touschek lifetime in both rings, without large amounts of RF power. The same system is attractive also for a high-brilliance 3 GeV ring like MAX IV [4].

5 REFERENCES

[1] Å. Anderson et. al. •The MAX II Synchrotron Radiation Storage Ring•, Nucl. Instr. And Meth. A 343 (1994) 644-649.

[2] G. LeBlanc et. al. •MAX III, A 700 MeV Storage Ring for Synchrotron Radiation•, EPAC’2000, Vienna, June 2000.

[3] G. LeBlanc, E. Wallén, •Evaluation of the MAX Wiggler, These Proceedings.

[4] M. Eriksson et. al. •MAX 4, a 3 GeV Light Source with a Flexible Injector•, These Proceedings.