USING SUPER-ACO's FIFTH HARMONIC CAVITY AS A PASSIVE LANDAU CAVITY

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Abstract

At the Super-ACO positron storage ring, a double RF system, 100 MHz active plus 500 MHz active, is in use for bunch shortening for ring based FEL operation. Only the 100 MHz system is used during normal synchrotron radiation user operation. The new MAX-III electron storage ring, which is currently being built at MAX-lab, is also designed with a double RF system, 100 MHz active plus 500 MHz passive. The passive Landau cavity will be used in bunch lengthening mode, in order to increase the beam lifetime while damping coupled-bunch oscillations to avoid any increase in the beam's effective energy spread. A joint experiment was therefore performed at Super-ACO with the two goals of gaining experience for MAX-III and improving beam lifetime and stability for user operation at Super-ACO. Thus, in this experiment at Super-ACO, the 500 MHz cavity was used passively in the bunch lengthening mode. The high shunt impedance of the 500 MHz cavity-transmitter system, allowed us to reach the ´zero-slope´ case of the total RF-voltage already at large detuning of the cavity. Both significant bunch lengthening and a reduction of coupled-bunch mode oscillations were established. No particular problems with higher-order modes in the cavities were encountered.

1 INTRODUCTION

At MAX-lab [1] a new 700 MeV third generation electron storage ring MAX III [2], for synchrotron radiation production is under construction. The machine design parameters for MAX III are given in table 1. Crucial parameters for an accelerator of this type are the energy spread of the electron beam and the beam lifetime. The RF system that is chosen plays an important role for these parameters. Experience from the 1.5 GeV storage ring MAX II shows that implementing a double RF system optimises both these parameters significantly [3]. The double RF-system lengthens the bunches, giving less longitudinal electron density and the Touschek lifetime increases. It also gives a non-linear RF-voltage at the bunch position, enhancing Landau damping. The Landau damping suppresses coupled-bunch instabilities that would otherwise deteriorate the performance of the accelerator. At MAX II a 500 + 1500 MHz RF-system is chosen, this choice would be poor for MAX III due to the Robinson instability. Instead, in this respect, a suitable RF combination for MAX III would be 100 MHz active plus 500 MHz passive. In order to gain practical experience from such a combined system, a joint experiment was performed on the Super-ACO ring [4], at LURE Université Paris-Sud, Orsay. In 1995 Super-ACO added a second active RF-system to the main 100 MHz system, for improvement of the ring based free electron laser [5]. A 500 MHz ´Elettra type´ cavity then shortens the bunch for the FEL. However, the objective of the experiment presented here, is to tune this cavity to the bunch lengthening side and use it passively. The machine parameters for Super-ACO are given in table 1.

Table 1: The machine parameters for Super-ACO and design parameters for MAX III.

	S-ACO	MAX III
Energy	800 MeV	700 MeV
Maximum current	400 mA	300 mA
Fundamental RF	100 MHz	100 MHz
Synchrotron frequency	14 kHz	36 kHz
Harmonic number	24	12
Momentum compaction factor	0.0148	0.035
Emittance	38 nmrad	13 nmrad
Coupling	100 %	10 %
Natural energy spread (%)	0.053	0.06
Energy spread (%) at 200 mA	0.13-0.28	
Lifetime at 200 mA	20 h	12 h
Natural bunch length	90 ps	93 ps
Higher harmonic cavity	500 MHz	500 MHz
Natural bunch length w. HHC	220 ps	230 ps

2 THEORETICAL EXPECTATIONS

The ideal voltage for cancellation of the slope is $\sim V_{main}/n$ where $n=f_{HHC}/f_{main}$. The ideal condition for Super-ACO is shown in figure 2. Simple calculations give by hand the needed detuning of the Higher harmonic cavity (HHC) to reach this case. A code developed for ALS [6] gives the expected natural bunch lengths, the synchrotron frequencies and spreads, for different excitations of the HHC. The bunch lengths are shown in figure 3, as the solid line. The first four modes of the Robinson instability was calculated to be damped over the used tuning range.

The RF cavity parameters for Super-ACO and MAX III are given in table2.

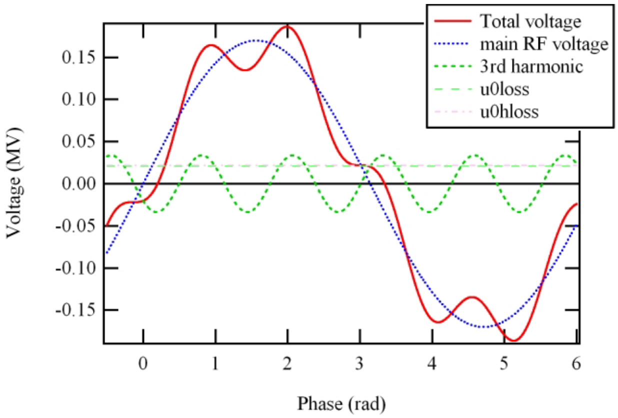

Figure 2: The voltages of 100 + 500 MHz

Table 2: Cavity parameters

	S-ACO	MAX III
Main cavity	100 MHz	100 MHz
Shunt impedance	6.5 MΩ	3.2 MΩ
Q	26000	19000
Type	Pillbox	Re-entrant
Voltage	170 kV	200 kV
Coupling	1.15	2
Fifth harmonic cavity	500 MHz	500 MHz
Shunt impedance	6 MΩ	7 MΩ
Q	36000	40000
Type	Bell shape	Pillbox
Voltage	34 kV	40 kV
Coupling	1	0

3 EXPERIMENT

The cavity loops had previously been calibrated and the (R/Q) of the cavity is known from Elettra's calculations. Therefore measuring transmitted power allowed us to determine the induced cavity voltage. We additionally calibrated the probe signal by tuning the harmonic cavity onto resonance at low current. At resonance the voltage in the cavity is given by $V = R \cdot I$, where R is the loaded shunt impedance and I is the current. For this known voltage, the transmitted power through the loop was measured with a spectrum analyser. We noted cavity voltage, tuner position, synchrotron frequency and bunch length.

3.1 Bunch length

A Hamamatsu streak camera [7] is used for the bunch length measurements. Former measurements, without the HHC, have shown that Super-ACO is affected by turbulent bunch lengthening [8]. A bunch current of 10 mA gives a bunch length of about σ_L=175 ps. The bunches are shorter, down to the natural value of σ_L=90 ps, at lower bunch currents, about 4 mA/bunch. In normal multi-bunch operation, the beam suffers from coupled-bunch instabilities, see figure 4.

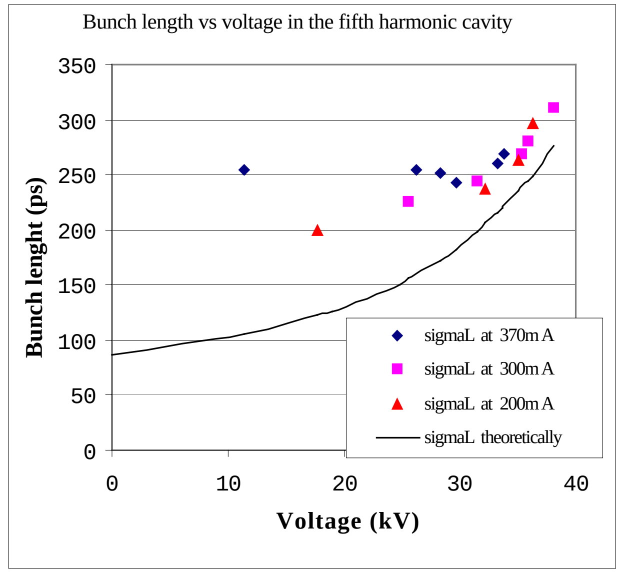

Figure 3: Natural bunch lengths are compared with the measured bunch lengths in Super-ACO

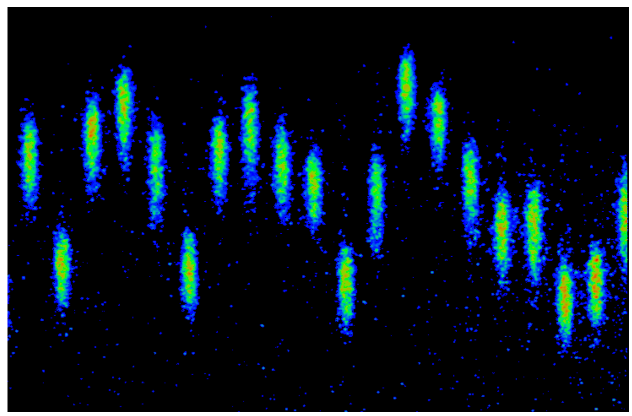

Figure 4: I=95 mA in 24 bunches, σ_L=90 ps. Coupled bunch instability in Super-ACO

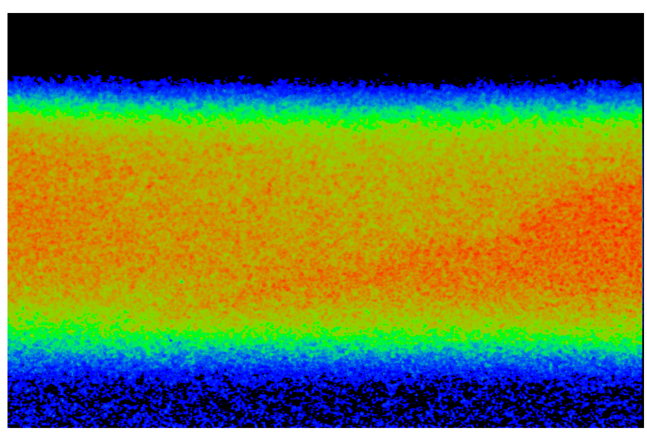

Figure 5: I=370 mA in 24 bunches, σ_L=220 ps. Elongated bunch in Super-ACO

When tuning the HHC close to the zero-slope case an effective bunch lengthening was seen. On the zero-slope conditions the beam appeared very stable and the bunch length was measured to around σ_L=250 ps. See figure 5. It was even possible to go over the zero-slope condition and reach a double hump bunch as seen in figure 3. The bunch length under this case was measured up to σ_L=300 ps.

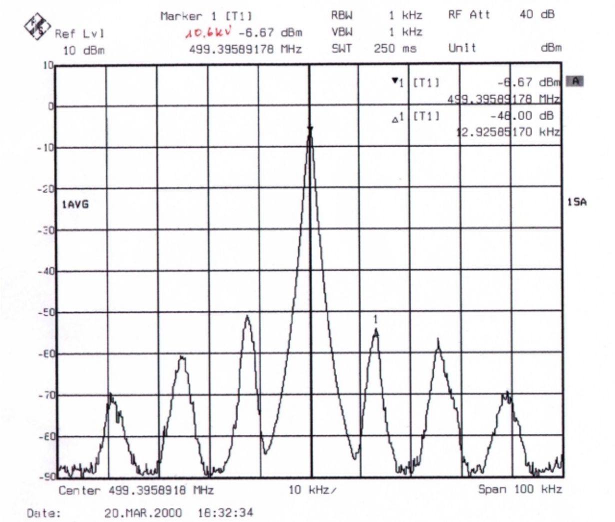

Figure 6: Synchrotron tunes with the fifth harmonic cavity detuned

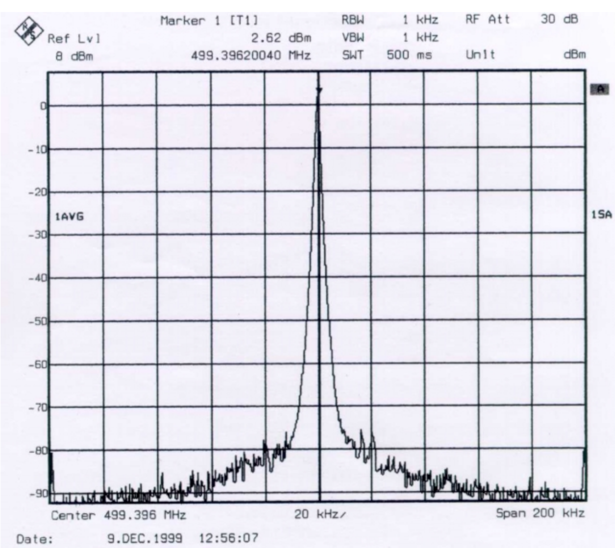

Figure 7: The synchrotron tunes has disappeared with 34 kV in the fifth harmonic cavity

3.2 Synchrotron frequency

We measured the synchrotron frequency while tuning the cavity towards resonance, see figure 6. Tuning the cavity towards the resonance the synchrotron frequency decreased. At zero-slope condition the synchrotron frequency disappeared and the beam appeared stable, see figure 7.

3.3 Lifetime

No improvement in lifetime was seen. We think that the lack of improvement in lifetime was due to the fact that with the coupled bunch instabilities the effective bunch length is somehow increased, yielding a longer lifetime than expected.

3.4 Energy spread

Preliminary measurements with a synchrotron radiation monitoring at a dispersive source point, show that the energy spread is suppressed from 0.28% to 0.13% at 200 mA. Further measurements are planned at higher currents.

4 CONCLUSIONS

We did achieve a considerable bunch lengthening and a decreased energy spread. But we could not see any increase in beam lifetime. This is probably due to the fact that with the coupled bunch instabilities the effective bunch length is somehow increased, yielding a longer lifetime than expected. The bunch lengthening has been done also in user operation at Super-ACO, but the technique is not currently used routinely, because the lifetime is slightly lower with bunch lengthening than without and in addition the beam seems more sensitive to transverse instabilities.

For MAX III the experiment was a good experience. Both significant bunch lengthening and a reduction of coupled-bunch mode oscillations were established. No particular problems with higher-order modes in the cavities were encountered. Therefore our work with a 100 MHz + 500 MHz RF-system will continue.

REFERENCES

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