FIRST EXPERIMENTAL RESULTS ON LANDAU CAVITIES IN BESSY II

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Abstract

The 1.7 GeV 3rd generation light source Bessy II is serving for experiments since Jan. 1999. As the design current was doubled in routine operation to 200 mA in the meanwhile, it is planned to increase beam lifetime as well. Thus it was decided to add a passive higher harmonic cavity system as have been proven earlier to rise the Touschek lifetime without deteriorating brightness.

Tests with a four cavity system in parking position resulted in a trouble free operation of the ring especially no degradation of the longitudinal bunch-by-bunch feedback system was observed up to intensities of 300 mA. In bunch lengthening mode a longitudinal stable (Landau damped) was obtained at 300 A.

1 INTRODUCTION

Bessy II, a 1.7 GeV 3rd generation low emittance high brilliance light source started service to the scientific program in Jan 1999 [1]. Designed for electron intensities of 100 mA the current was doubled since [2]. As the beam lifetime is very much limited by Touschek effect increasing the intensity is counteracted by an equivalent reduction in beam lifetime. Thus it was decided to add 3rd harmonic cavities for bunch lengthening. Adding a passive higher harmonic cavity (HHC) system has earlier been proven to rise the Touschek lifetime without deteriorating brightness.

Major parameters of Bessy II are listed in table 1. One of the performance limitations of Bessy II is the small emittance. Small emittance leads to a low Touschek lifetime thus even at excellent low vacuum pressure the lifetime is poor. A well-proven way to raise the lifetime, without deteriorating the beam performance as emittance, is to add HHCs in order to lengthen the bunches and thus reduce the charge density and therefore improving the Touschek lifetime [3, 4]. Next to this effect the sum of voltages of fundamental and harmonic cavities results in a nonlinear acceleration field which gives rise to a spread in synchrotron frequency of the bunches leading to strong Landau damping. This is the reason to name them Landau cavities.

A passive cavity system was chosen, working on the third harmonic, 1.5 GHz, of the fundamental RF frequency. Higher frequencies had been considered, but with the given vacuum pipe dimensions, such system would have suffered from too low shunt impedance. The 1.5 GHz choice is a well working solution at MAX II and ALS. The voltage that is required determines the shunt impedance. For an optimum in performance the voltage required in the HHCs should be 1/3 of the total voltage delivered by the main cavities. Thus the number of HHC and their shunt impedance need to match this requirement. At BESSY II with a total voltage of 1.2 MV from the main accelerating resonators the harmonic cavities need to deliver 400 kV in total. The cavities are tuned on the Robinson unstable side of the carrier voltage and need to be detuned such that the damping from the main cavities exceeds the excitation in the HHC. The more detuned the better. However when the detuning is $> 1/2 \cdot f_{rev}$, the upper rotational band at $3 \cdot f_{main} + f_{rev}$ is excited. Where f_{main}=500 MHz and f_{rev}=1.25 MHz. Adding many cavities more detuning is needed and a design value of 10 MΩ was chosen for the total cavity shunt impedance. A more detailed description of the cavities is given in [5]. Fig. 1 shows a photograph with the HHCs installed to the BESSY storage ring.

Table 1: Bessy II parameters without Landau cavities

Parameter	Design value	Achieved value
Energy	1.7 GeV	0.85-1.9 GeV
Current	100 mA	400 mA
Life time * I, Iτ	600mAh	850 mAh
Bunch length	18 ps	17 ps
Emittance	6 nmrad	6±1 nmrad
Coupling	3 %	0.5-1.6 %
Pressure	10E-9 Pa	5*10E-10 Pa

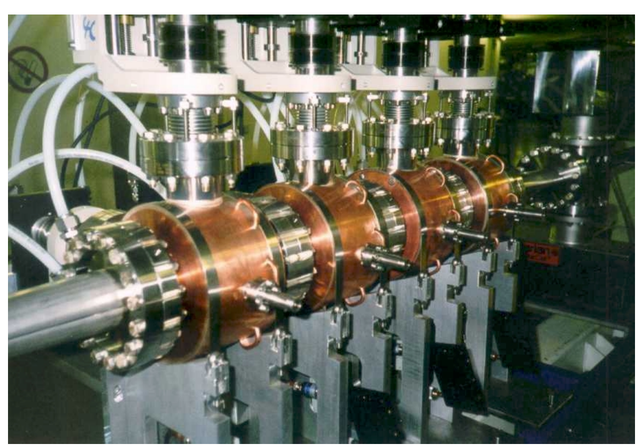

Figure 1: Four Landau cavities inserted into Bessy II

2 THEORETICAL EXPECTATIONS

Calculation using programs developed for MAX II and ALS [6] done prior to the experiment gave initial parameters for the tuning of the harmonic cavity. The ideal voltage for cancellation of the slope is ~V_{main}/n where $n=f_{HHC}/f_{main}$. Where f_{HHC}=1.5 GHz. The Zero slope condition for Bessy II is shown in figure 2.

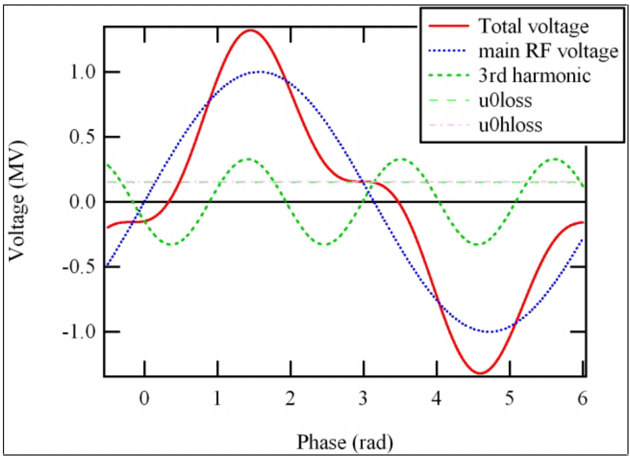

Figure 2: Plot of the voltages in the 500 MHz main cavities and in the 1.5 GHz cavities, summing up a zero slope results to the beam at the synchronous phase

3 COMMISSIONING AND RESULTS

Each of the four Landau cavities is equipped with two plungers and two RF-loops. The cavity loops had previously been calibrated and the (R/Q) of the cavity is known from calculations. This is used in the current feedback loop. The probe signal was additionally calibrated by tuning the harmonic cavity onto resonance at low current. At resonance the voltage in the cavity is given by $V = R_{sh} \cdot I$, where R_{sh} is the shunt impedance and I is the current. By this the voltage in the cavities $U = R_s \cdot I \cdot 10^{\frac{RF_{low}-RF}{20}}$ is always know. By connecting both loops to a spectrum analyser with tracking generator in situ S_{12} measurement of the modes is possible, see figure 3. This way the frequencies of the 1.5 GHz as well as the first higher order modes (HOM) are known.

To tune to the cavity to the right frequency avoiding higher order modes both plungers were used. The two plungers tune the fundamental and the higher order modes differently. The first HOM, the TM011 can be tuned safely between two rotational bands while the fundamental frequency is placed in bunch lengthening position.

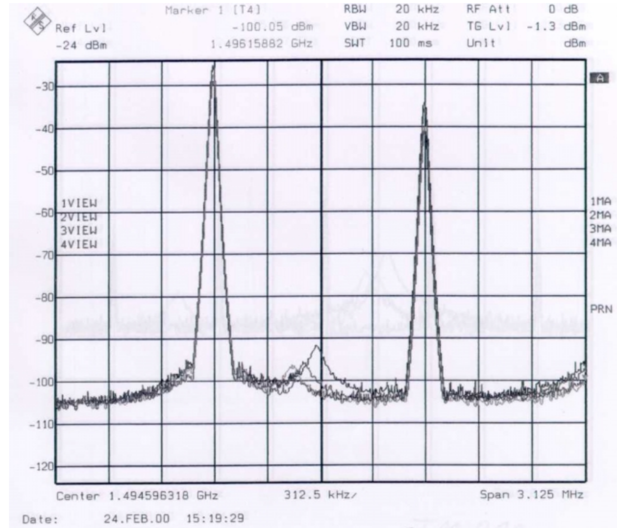

Figure 3: In situ S_{12} measurement showing all the four Landau cavities tuned in between two rotational bands

For the bunch length measurements a Hamamatsu streak camera was used [7]. When the cavities were tuned into bunch lengthening mode and electrons were accumulated in the storage ring the cavity voltages increased and so the bunch lengths. Bunch lengthening is seen already at 100 mA. Up to currents of 300 mA the longitudinal feedback system was able to sufficiently damp instabilities excited by the TM011 HOM of the HHC. Above this current the feedback amplifier power was near saturation causing unlocking of the feedback loop. Figure 4 a and b show streak camera pictures showing the bunches with and without Landau cavities, both figures are with feedback in operation.

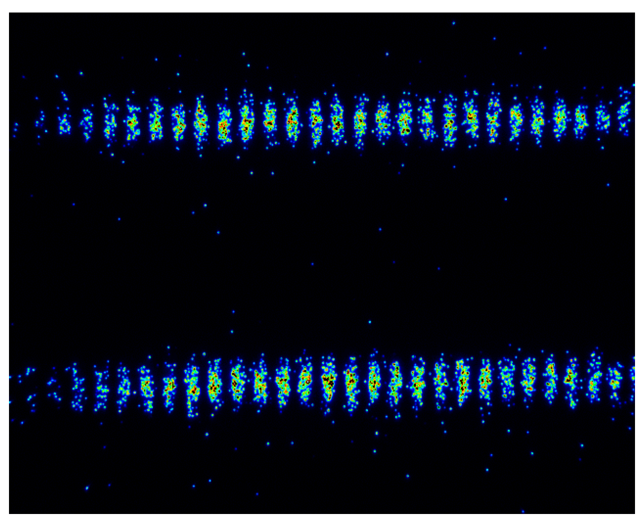

Figure 4a: 121mA Landau cavities tuned to parking position, feedback on

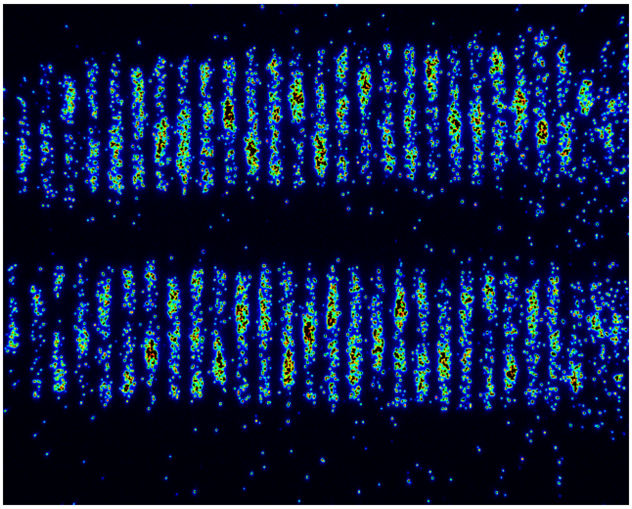

Figure 4b: 220 mA 1MV in the main cavity and totally 140 kV in the Landau cavities, feedback on

At present the cavities are set to a low power mode, i.e. detuning some hundreds of kHz apart from the rotational band $3 \cdot f_{main}$ such that the beam induced voltages are just 30 kV in each cavity. In this mode bunch lengthening starts around 100 mA and lengthens the bunches by a factor of 1.7 at 200 mA, see figure 5. This already results in a significant increase in the total beam lifetime, see fig. 6. Though at the time of the test the machine is still influenced by the poor vacuum conditions, as a dose of 35 Ah had been accumulated since the last installation period, the gain in the product of beam current times lifetime is a factor of 1.5.

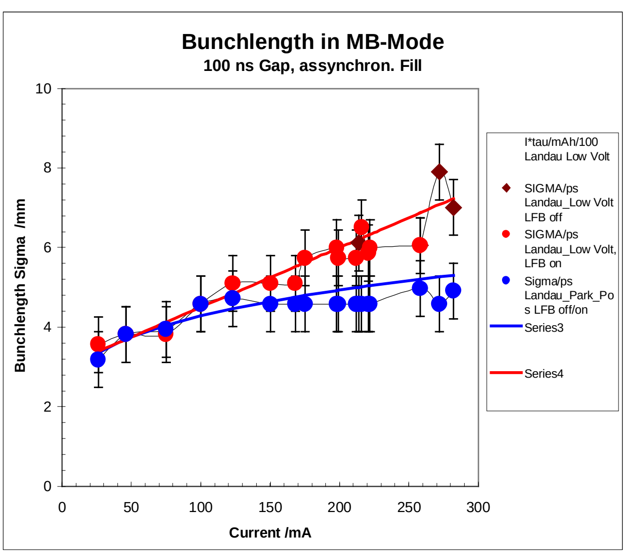

Figure 5: Bunch length in multibunch mode

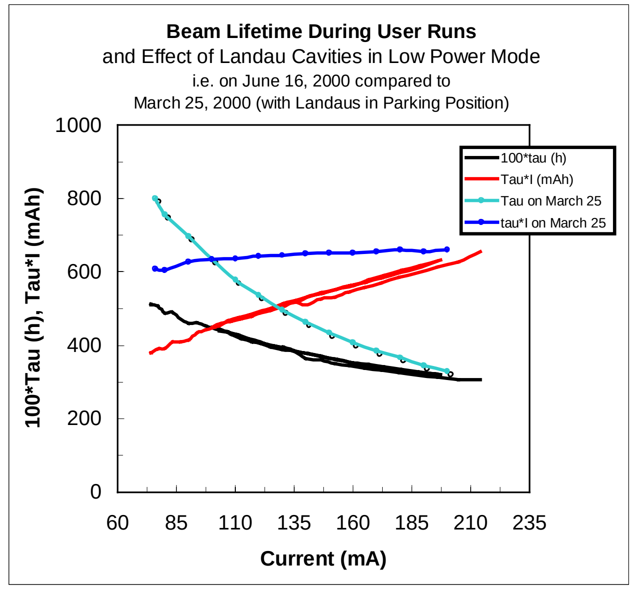

Figure 6: Bunch lifetime in multibunch mode, with and without Landau cavities and with different vacuum conditions

4 CONCLUSIONS

A longitudinal stable (Landau damped) beam was obtained at 300 mA. In parking position the Landau cavities do not spoil the functionality of the longitudinal bunch to bunch feedback system up to currents of 300 mA.

At present the cavities are detuned to a fixed position and the induced voltage is dependent on the beam current. Bunch lengthening occurs already at 100 and a factor of 1.7 in bunch lengthening is achieved when the current is at 200 mA or doubled. Thus already in the low voltage mode the Landau cavity systems significantly improve the performance of the synchrotron radiation source.

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[7] Hamamatsu double sweep streak camera Model C5860.