MEASUREMENTS OF TRANSIENT BEAM-LOADING EFFECTS INDUCED BY THE 3RD HARMONIC SYSTEM IN THE SLS STORAGE RING

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Idle harmonic cavities can be used in low emittance storage rings in order to lengthen the stored bunches and therefore decrease the intra beam scattering dominating the beam life time (Touschek scattering). Asymmetries in the filling pattern, as current gaps for ion clearing, can induce a significant transient beam loading effect in the harmonic system, which results in bunch length and bunch phase variation along the electron train. This non linear behavior mainly results in a reduction of the mean achievable lengthening, and has some direct consequences on the storage ring operation as for example the evolution of the filling pattern in the top up mode or the temporal resolution of the x-ray experiments in camshaft mode. Here below we report on recent streak camera measurements carried out at the SLS diagnostic beam line (DB) which quantify experimentally the transient beam loading effects induced by the superconducting third harmonic system and show a possible improvement for the time resolved measurements in camshaft mode.

INTRODUCTION

Due to the low transverse emittance in the SLS storage ring and the large charge density per bunch, the intra-beam scattering (Touscheck scattering) is largely dominating the beam lifetime. At the SLS design average current of 400 mA the lifetime doesn't exceed 3-4 hours. To overcome this problem and to reach a better longitudinal stability of the beam, an additional idle superconducting third harmonic RF system is routinely used at the SLS. The first experimental results and a description of this system, which flattens the global RF voltage seen by the particles and elongates the electron bunches can be found in [1].

In the SLS storage ring an 18.7 % gap is commonly used to suppress ion-trapping instabilities. In the "Camshaft mode" we benefit from this circumstance by filling one single bunch within the gap, which is then used for time resolved x-rays measurements without perturbing the normal users. As observed in other third generation light sources and recently better understood with the help of tracking codes [2] the gap in the filling pattern generates a transient beam loading effect along the train that substantially limits the maximum average bunch lengthening achievable. The length of the camshaft bunch, which is directly related to the temporal resolution of the x-rays measurements, depends as well on the transient effects in the harmonic system. Here below we report on some streak camera measurements performed at the SLS Diagnostic Beamline [3], which experimentally quantify the transient beam loading effect and its consequences on the camshaft bucket.

TRANSIENT BEAM LOADING EFFECTS AND CAMSHAFT MODE

As shown by the non-linear simulations and the experimental results, the maximum average lengthening achievable strongly depends on the filling pattern profile. The measurements shown on Fig. 1 quantify the influence of the transient beam loading effects on the bunch length for an average beam current of 300 mA. We observe that without the gap the maximum lengthening can be increased by almost a factor of 2. The harmonic voltage with uniform filling is substantially higher and can be pushed above 700 kV, 650 kV being the measured instability threshold with an 18.7 % gap.

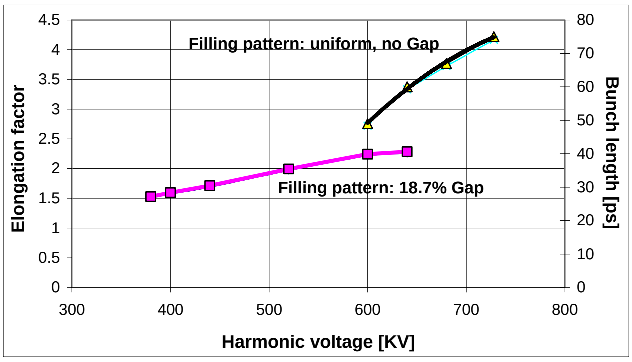

Fig. 1: Streak camera measurement, average bunch length in the SLS storage ring with 300 mA uniform filling pattern and with 18.7 % empty gap.

Fig. 2a shows a streak camera snapshot of one turn in the storage ring, with a camshaft bucket of 1 mA placed 90 ns from the head of the bunch train (390 buckets). The experimental results confirm that the zero phase drift with respect to the synchronous phase (Fig. 2b and 2c), which is optimum for bunch lengthening, occurs approximately in the middle of the bunch train and it is maximum (here ± 16 deg) at its extremes. As demonstrated by the non-linear simulations [2] the harmonic voltage can fluctuate as well, especially with a normal conducting harmonic system, going trough a minimum approximately in the center of the train and remaining approximately constant along the gap. In the SLS case the behavior of the camshaft bunch depends mainly on its position with respect to the synchronous phase. Since the phase drift of the 3rd harmonic cavity is varying almost linearly along the gap we expect a maximum bunch lengthening in the middle of the gap with the phase crossing zero. The streak camera measurements (300 mA average current – 40 % gap) summarized in Fig. 2b and 2c for two position of the camshaft bunch confirms these considerations.

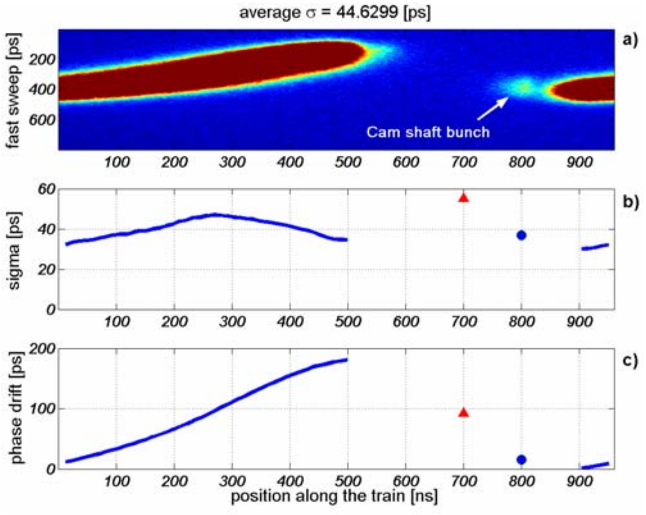

Fig. 2: a) Streak camera snap shot with 40 % gap in the filling pattern and a camshaft bucket at 90 ns from the train tail. **b)** 1σ bunch length along the train and for a centered (triangle) and non-centered (circle) camshaft bucket. **c)** Phase drift with respect to synchronous phase. The camshaft bucket in the middle of the gap (at “zero” phase crossing) experiences the largest lengthening.

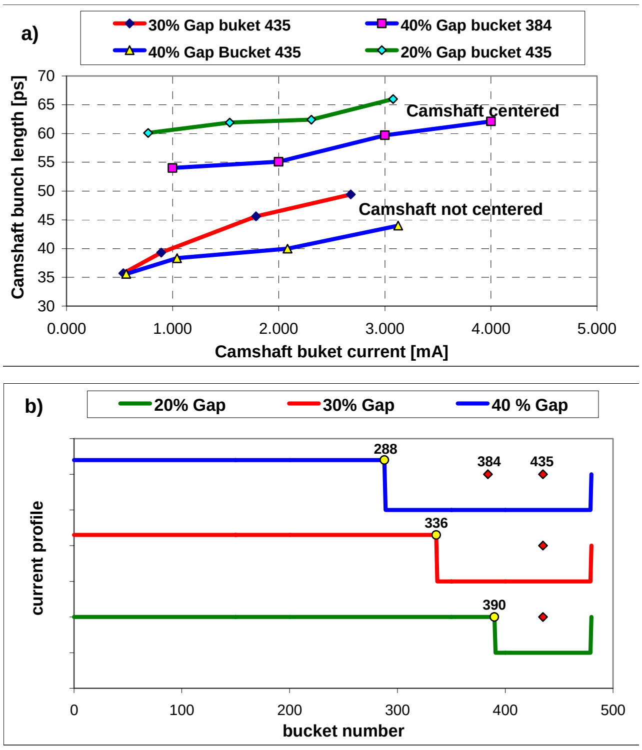

Fig. 3: (top) length of the camshaft bucket for different filling pattern configurations, (bottom) filling pattern profiles (continuous line) and location of the camshaft buckets (diamonds) during the streak camera measurements.

Fig. 3 summarizes the bunch length measurements for the camshaft bucket versus its current made with 3 different gaps. The usual SLS filling pattern of 390 filled buckets and centered camshaft bucket is here the less favorable for time resolved X-ray measurements. However these results indicate some margin for improvement.

REFERENCES

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