STATUS OF BUNCH DEFORMATION AND LENGTHENING STUDIES AT THE ANKA STORAGE RING *

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Abstract

At the ANKA storage ring (Karlsruhe, Germany) we use a Hamamatsu synchroscan streak camera to study the current dependent bunch lengthening and deformation effects. Previously the camera was used at an IR port, being available only occasionally. In October 2010, a dedicated beam line for the streak camera became operational. It is designed to have minimum dispersion and sufficient flux in the optical range at which the camera is most sensitive. This allows us to measure bunch profiles for a single bunch with a charge of less than 15 pC (40 μA), previously more than 55 pC were required to obtain a comparable signal. Along with the design and built-up, we present further measurements of bunch length and shape for different momentum compaction factors, RF voltages, beam energies and bunch charges to provide a complete bunch length map of the low alpha mode at ANKA.

INTRODUCTION

To achieve a better characterisation of the low-α_c-mode at ANKA [1] a dedicated visible light diagnostics beam line became operational in October 2010. Previously all visible light diagnostics like streak camera measurements [2] and time-correlated single photon counting measurements [3] had to be performed at an infrared beam line. This brought a few disadvantages such as the relatively low optical power in the visible range (gold mirrors); the measurement equipment had to be set up each time for the measurement since the IR beam line is only available for diagnostics measurements when there are no users occupying it, so those measurements could not easily be done parasitically.

Some key parameters of ANKA are shown in Table 1.

Table 1: ANKA low-α_c machine parameters

Parameter	Value during low α_c
Circumference	110.4 m
f_{rev}	2.715 MHz
f_{RF}	499.69 MHz
Harmonic number	184
Energy	0.8 - 1.6 GeV
σ_z (RMS)	down to 2 ps
Filling pattern	single- or multi-bunch

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BEAM LINE DESIGN

The new diagnostic beam line has been built up using an existing unused front end. In contrast to the IR beam line, the diagnostics beam line uses the constant field radiation of a bending magnet rather than the edge radiation.

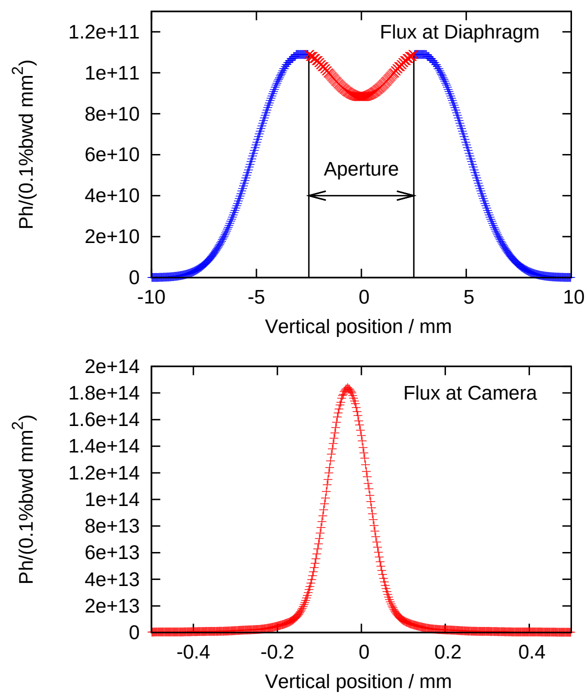

Figure 2: Top: Simulated photon flux at the diaphragm in dependance of vertical position. The part marked in red between -2.5 and 2.5 mm can pass through the aperture, the rest is absorbed. Bottom: Simulated photon flux at the focus point where the streak camera is placed.

The set up is shown in Figure 1. Starting from the source point in the bend the opening in the main SR absorber defines the acceptance for the beam line. A cooled planar mirror deflects the beam upwards to establish a chicane to pass the shielding wall above the plane of the bremsstrahlung radiation. An off-axis paraboloid mirror 3.5 m from the source point with a 1.2 m focus length deflects the light into the horizontal and focuses it to a point 1.8 m from it. The light passes the shielding wall and is reflected downwards by a planar mirror followed by a last reflection into the horizontal direction by an off-axis paraboloid mirror with 0.1 m focus length and focussed into the entrance slit of the streak camera. The cooled mirror and both the off-axis paraboloids have an aluminum coating to increase the

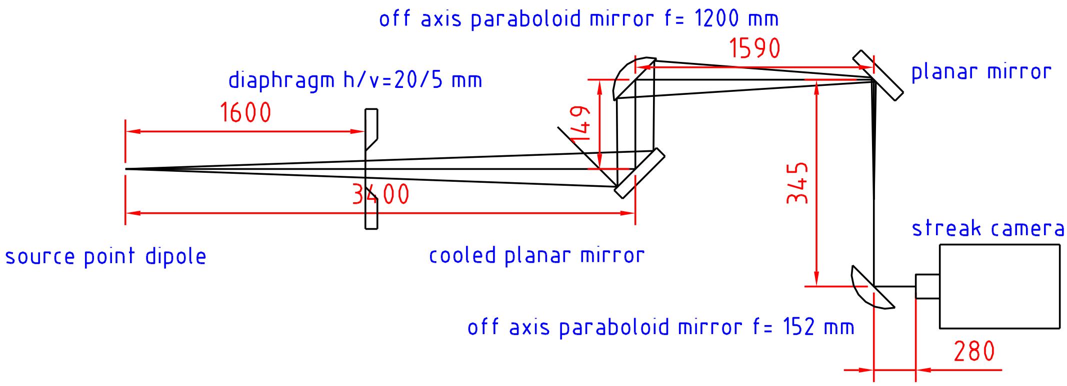

Figure 1: Beam path from the source point inside the bend to the streak camera with the distances shown in mm.

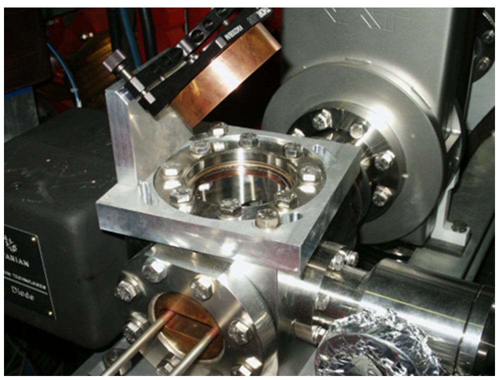

Figure 3: Photon beam exit of the streak beam line front end with cooled mirror, quartz window and parabolic mirror. The set up is covered by a lead box (removed).

reflectivity in the visible range, the remaining planar mirror is silver-coated.

Propagation of the light has been calculated with SRW [4]. The top of Figure 2 shows the vertical profile at the aperture 5 mm x 20 mm of the absorber and at the entrance of the streak camera. The 5 mm vertical aperture (which is of no limitation for x-rays) cuts off 60% of the visible light. The bottom shows the simulated photon flux at the focus point, where the streak camera is placed. Figure 3 shows a picture of the front end, where the vacuum window (lying in the horizontal plane) and the paraboloid mirror with the long focal length can be seen. The beam then is transported in free space through the radiation safety wall.

EXPERIMENTAL RESULTS

The measurements were performed with a Hamamatsu C5680 streak camera that is extended with a synchroscan plugin and a dual time base extender (double sweep unit). The synchroscan unit operates at half the RF frequency, so signals from bunches in odd and even RF buckets can be separated. For all measurements the fastest deflection was used with a resolution of 190 ps / 512 pixels (370 fs per pixel). The blanking amplitude (slow deflection) was varied between 100 μs and 2 ms, depending on the signal strength. To benchmark the performance of the diagnostics beam line, we measured the bunch length in dependence of the single bunch current (0.1 mA $\widehat{=}$ 37 pC for ANKA) as done previously at the IR beam line [2]. The same evaluation method as stated in the above reference with the correction of longitudinal oscillations was applied.

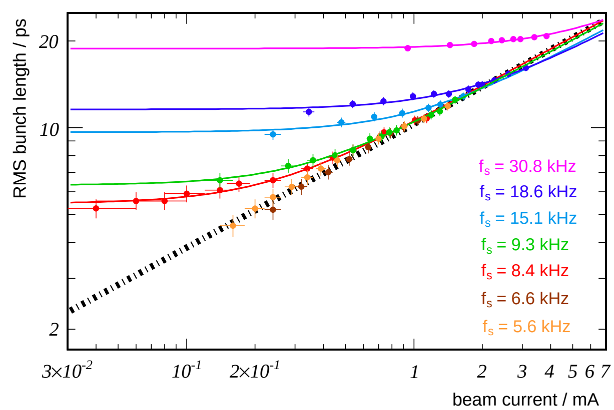

Figure 4: Bunch length as a function of bunch current for different low α_c optics is visualised. A static uncertainty of $\pm$ 2 pixels on the FWHM of the bunch profiles from which the bunch length data is extracted has been assumed. The dotted black line marks the bursting threshold for ANKA: $\sigma_z = k \cdot I_{bunch}^{3/7}$ [5] where k = 10.3 for ANKA (for an RF voltage of 0.6 MV). The data set for f_s = 8.4 kHz (red) has been recorded at the new beam port.

Figure 4 shows a new data set (red, f_s = 8.4 kHz) together with the previously recorded data. Now the light intensity at a bunch current of 40 μA (15 pC) is still more than sufficient to measure bunch profiles (see Figure 5) that allow for the correction of synchrotron oscillations. At the IR beamline about 170 μA were required to obtain a comparable signal. For the measurements depicted in Figure 7 even at 20 μA a sufficient signal strength was achieved.

In Figure 6 the bunch length is shown as a function of bunch current for different RF voltages. The constant k in the bursting threshold $\sigma_z = \mathrm{k} \cdot I_{bunch}^{3/7}$ changes with the RF voltages in the following way $\frac{\mathrm{k}_1}{\mathrm{k}_2} = \left(\frac{V_2}{V_1}\right)^{1/6}$ ([5] by tak-

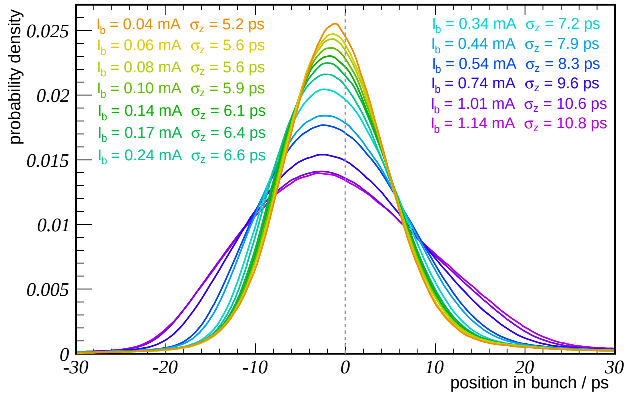

Figure 5: The corresponding bunch profiles for the new data (f_s = 8.4 kHz) from Figure 4.

ing into account that $\sigma_{z,0} \propto (V_{RF})^{-1/2}$). The data follows this behavior nicely.

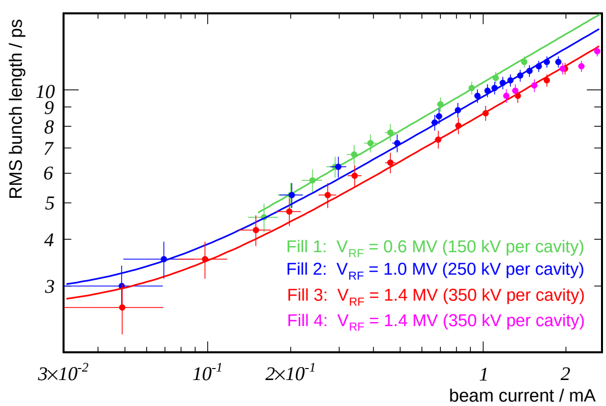

Figure 6: The bunch length as a function of bunch current for different RF voltages at a fixed momentum compaction factor is shown. A static uncertainty of $\pm$ 2 pixels on the FWHM of the bunch profiles from which the bunch length data is extracted has been assumed. The constant factor, but not the exponent of the bursting threshold changes with the RF voltage (leads to an off-set in the logarithmic scale). Bunch lengths as low as 2.7 ps RMS have been measured.

Furthermore, bunch lengthening measurements were carried out for two different beam energies of 1.6 GeV and 1.3 GeV (α_c was slightly higher for 1.6 GeV). The corresponding data is shown in Figure 7. There it can be seen that in the bursting regime, starting around 0.7 mA, (here the bunch length is independent of α_c as seen in Figure 4), the bunches are shorter for 1.6 GeV than they are for 1.3 GeV. So for high currents, the higher energy lowers the bunch length in a similar way as the higher RF voltage does in Figure 6. For lower bunch currents the bunches with 1.6 GeV are longer than the ones with 1.3 GeV. This comes from the higher energy and α_c.

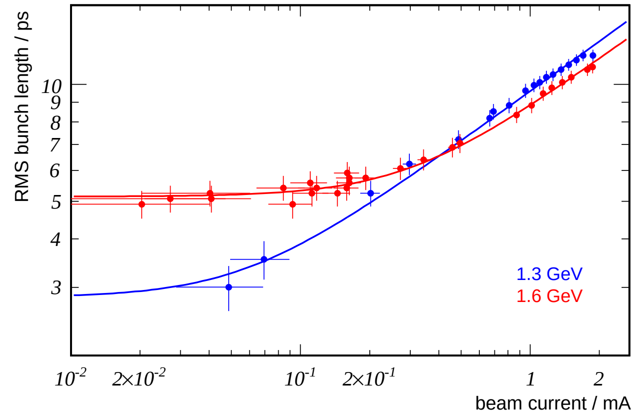

Figure 7: The bunch length as a function of bunch current for different beam energies. The fluctuations in bunch length for currents between 0.1 and 0.2 mA are due to changes in camera settings (slow sweep speed was changed). The RF voltage was set to 1.0 MV (250 kV per cavity). The data for 1.3 GeV is the same as depicted in Figure 6.

OUTLOOK

The ongoing studies of current dependent bunch lengthening and deformation have been greatly improved with the installation of the new visible light diagnostics beam port. There is still need of characterization of the low-α_c-mode at ANKA, especially for different energies, and the deformation effect will have to be analyzed in more detail.

ACKNOWLEDGEMENTS

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REFERENCES

[1] A.-S. Müller *et al.*, 'Far Infrared Coherent Synchrotron Edge Radiation at ANKA', PAC05 Knoxville, USA (2005) 2518.

[2] N. Hiller et al. 'Observation of Bunch Deformation at the ANKA Storage Ring', IPAC10

[3] B. Kehrer et al. 'Filling Pattern measurements at the ANKA storage ring', these proceedings

[4] O. Chubar, P. Elleaume, 'Accurate And Efficient Computation Of Synchrotron Radiation In The Near Field Region', proc. of the EPAC98 Conference, 22-26 June 1998, p.1177-1179.

[5] F. Sannibale et al. 'A Model Describing Stable Coherent Synchrotron Radiation in Storage Rings', Phys. Rev. Lett. 93, 094801 (2004)