STUDIES USING BEAM LOSS MONITORS AT ANKA

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ISS, Forschungszentrum Karlsruhe, Germany

Abstract

ANKA is a Synchrotron Light Source that operates in the energy range from 0.5 to 2.5 GeV. In order to investigate electron beam losses, two kinds of beam loss monitors have been installed: 24 PIN Diode from Bergoz [1] distributed around the storage ring, and one Pb-glass calorimeter located in a high dispersion region. The PIN Diodes are used to obtain information about the distribution of the losses while the Pb-glass detector provides higher sensitivity. The PIN Diodes allow to locate and distinguish the regions of higher losses due to Touschek and Elastic scattering. Furthermore, regions of higher losses at injection have been identified. The Pb-glass detector has been used to determine the beam energy with the resonant spin depolarisation technique. The spectrum of the beam losses has been obtained by connecting the loss monitor signal directly to an spectrum analyser.

INTRODUCTION

ANKA is a Synchrotron Radiation facility with a nominal energy of 2.5 GeV, a horizontal emittance of 90 nmrad and currents up to 200 mA. Currently we are commissioning a wiggler -with vertically smaller vacuum chamber- for an environmental beam line and investigating new optics for the installation of an in-vacuum superconducting undulator at the end of this year. The installation of beam loss monitors (BLMs), 24 Bergoz PIN Diode [1] and one Pb-glass detector, will help us to analyse the effects of these changes in the storage ring.

INSTALLATION

The PIN Diode detectors are small devices that can be attached easily to the vacuum chamber, as can be seen in Figure 1. 24 of them have been distributed around the storage ring, covering the straight sections and the achromat in points of high and low dispersion. To obtain a higher sensitivity and reproducibility, the active area of the detector has been centered in the plane orbit of the beam and is perpendicular to the beam direction.

The Pb-glass detector has been installed in one point where the dispersion function has a maximum in order to increase the sensitivity to Touschek scattered particles, thus to use it for the energy calibration measurement, see ref. [2]. At the Pb-glass detector, the electrons are absorbed producing a cascade and a substantial amount of light via Cherenkov radiation, which is detected with a photomultiplier tube.

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The PIN Diode detectors have been implemented in the ANKA control system via a COSYLAB counting board [3, 4]. The operator has access in the control room to the loss rate at each point of the storage ring, updated each second. Figure 2 shows a screen shot of the loss rate panel.

The Pb-glass detector has been connected to a home made pulse counter and a dedicated PC.

The signal coming from both detectors can be fed to an oscilloscope and real time analysis can be done.

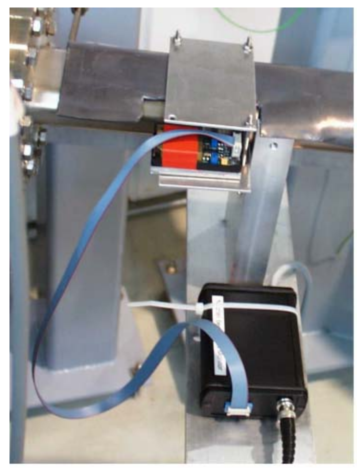

Figure 1: Installed PIN Diode Beam Loss Monitor with its power supply.

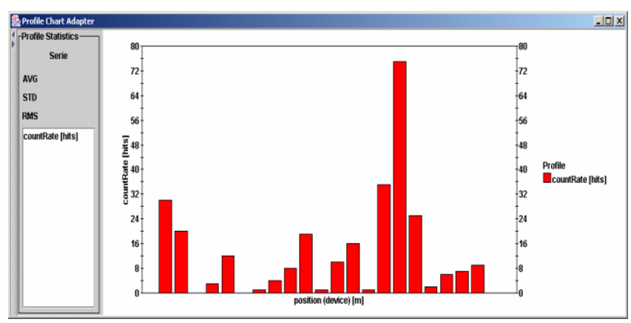

Figure 2: Loss rate at each PIN Diode Detector as seen in the control room.

MEASUREMEMTS

Energy Calibration

A very precise way of finding the energy of an electron beam is by measuring the electron spin precession frequency [5]. This is done by exciting the beam perpendicularly to the spin direction at the spin precession frequency in order to destroy the polarisation. When this occurs the Touschek losses increase. By measuring the electron losses at a Touschek dominated point in the accelerator while scanning the excitation frequency one can find out the electron spin precession frequency and then calculate the energy. In Figure 3 two of these scans are shown for different RF frequencies. The point (scaled to the frequency of the scan) where the losses increase is related to the energy of the electron beam. Precision up to few times 10^{-5} can be reached [2].

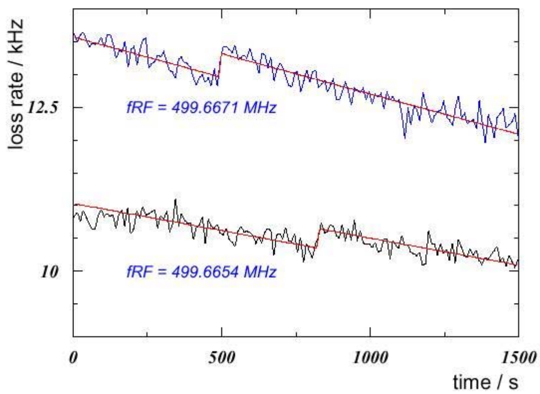

Figure 3: Energy determination by measuring the electron spin precession frequency with the help of the Pb-glass detector.

Residual Gas Scattering

During the 2003 summer shut down, a quarter of the storage ring was vented in order to install a new vacuum chamber for the undulator of the soft X-ray new beam line. In addition, an accident in the diagnostic beam line did vent another quart of the machine. After resuming operation of the storage ring the vacuum in half of the accelerator was quite bad, so we had a chance to observe the residual gas scattering contribution to the beam losses.

After each injection, we recorded the vacuum readout of the ion pumps, the electron beam current and the losses at the PIN Diode detectors for five minutes. We averaged these values and analysed it as a function of the accumulated Ah dose since after the shutdown. The count rate of the detectors was divided by the beam current in order to normalise it for different fillings of the accelerator. The results are shown in Figure 4.

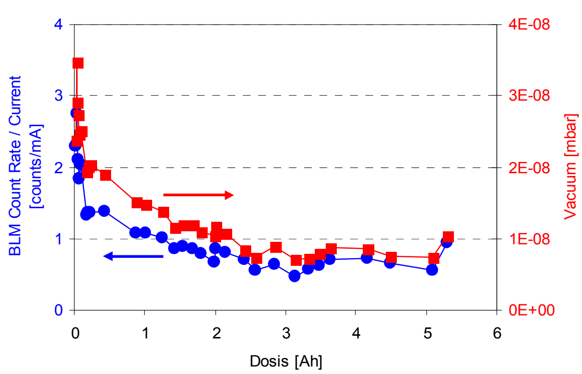

Figure 4: Average vacuum and electron losses as a function of the accumulated Ah dose.

One can observe that the tendency down of the count rate is the same as for the vacuum, confirming that the main electron losses after the shutdown come from the residual gas scattering process.

Touschek Scattering

In order to localise the regions where higher Touschek losses occur, the coupling was changed and the vertical emittance increased. The losses at the PIN Diode detectors where recorded for different coupling settings, so for different beam volume. In Figure 5 top the vertical beam size is shown for three different couplings. Figure 5 bottom shows the difference between the losses at high and low coupling. It shows clearly the points of the machine which are Touschek limited. It also shows a point in the middle where the losses decrease. This is just after the vertically smaller vacuum chamber: a smaller vertical beam size do in fact decrease the elastic gas scattering, see next section.

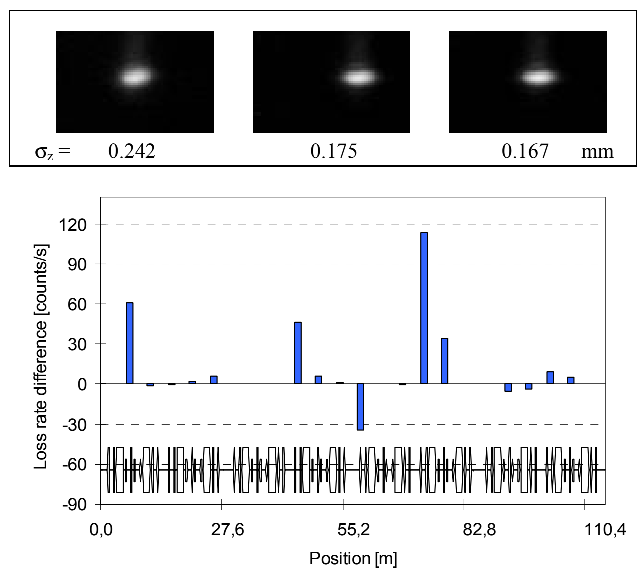

Figure 5: Touschek dominated points, by measuring the difference in loss rate for different vertical beam sizes (top).

Comparing the results with the beam optics, no correlation could be found with the dispersion function. In order to cross check these results, a different experiment was done. We filled the storage ring with two different filling patterns and the same current. One filling has double number of bunches than the other. The positions where Touschek losses were detected were the same, confirming the experimental data but puzzling us in the interpretation.

Elastic Gas Scattering

The vertical beta function at the straight sections, where the vertically smaller vacuum chamber of the wiggler is, was reduced by changing the quadrupole settings. The losses at the BLM after the straight section were recorded. Figure 6 shows the results. By reducing the vertical beta function to half of the nominal value, the measured losses almost vanish. Which means that a measurable elastic gas scattering occurs at this point that contributes to a lower overall lifetime for the nominal settings.

Unfortunately, this optics increases the beta functions in the achromat, increasing the overall losses in the storage ring. New optics maintaining the actual beta functions in the achromat and reducing it in the straight sections are under investigation. The main purpose is to avoid elastic losses at the small vertical aperture of the super-conducting undulator to be installed at the end of this year.

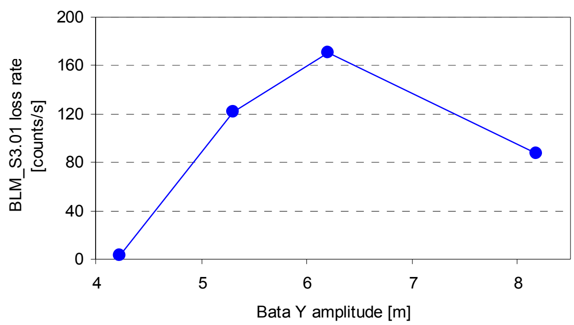

Figure 6: Losses at the wiggler vacuum chamber as a function of the vertical beta function.

Injection Losses

The injection losses were analysed by measuring the difference between the losses of the stored beam with all the injection elements on and the booster off, and the losses during injection, see Figure 7. As can be seen the higher losses occur at the vertically smaller vacuum chamber. In addition higher losses are observed in sector 3 (between positions 60 and 80 m) indicating some kind of asymmetry in this sector. We have not yet identified the reason, but LOCO calculations show a higher dispersion function in this section in comparison with the others, which could explain it.

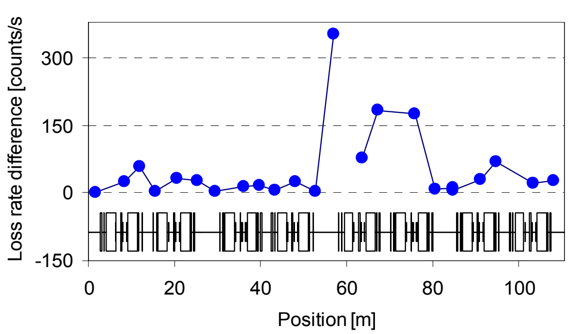

Figure 7: Losses during injection

We have to add that the losses at the septum position can not be measured because it is such a big avalanche that the detector saturates. We know that it is there where the maximum losses occur.

Beam Spectrum

If we plug the output of the Pb-glass or the PIN Diode directly to an oscilloscope (with FFT) or to a spectrum analyser, one can observe the spectrum of the losses, i.e. at which frequency the losses occurs, see Figure 8.

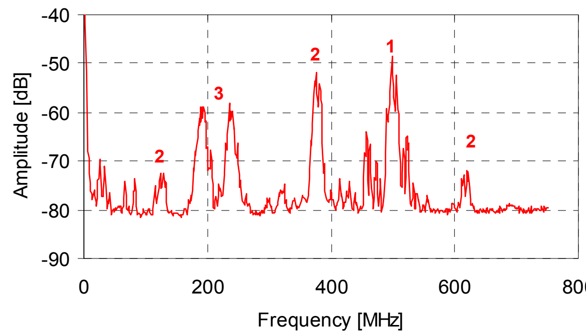

Figure 8: Beam loss monitor spectrum.

The spectrum has not yet been completely analysed, but there are trends that show that the loss spectrum do have the information of the temporal structure and the oscillations of the beam.

1) Losses around 500 MHz, the main RF frequency of the beam
2) Losses at 621 MHz, is the frequency of one longitudinal HOM excited in the beam. Mirrors of it are seen at around 122 and 380 MHz
3) Losses at around 194 and 240 MHz, which could be related to the filling pattern of the beam or to some orbit resonance.

CONCLUSIONS

The installation of beam loss monitors, PIN Diode and Pb-glass detectors, do provide a valuable tool for diagnostics in an accelerator. Energy calibration, analysis and differentiation of scattered particles (gas, elastic and Touschek), injection losses and the frequencies involved in the losses are examples of the studies that can be performed.

REFERENCES

[1] Beam Loss Monitor, Bergoz, www.bergoz.com
[2] A.S. Mueller et al., "Energy Calibration of the ANKA Storage Ring", these proceedings.
[3] B. Jeram et al., "The Control System for the Accelerator of ANKA", EPAC 1998.
[4] HERA Board, Cosylab Ltd. www.cosylab.com
[5] P. Kuske et al. "High Precission Determination of the Energy at BESSY II", EPAC 2000.