INSTALLATION OF A BEAM LOSS MONITORING SYSTEM AT THE S-DALINAC*

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Abstract

The S-DALINAC is the superconducting linear accelerator of the Institut für Kernphysik at Technische Universität Darmstadt (Germany). In order to get a short-time response about occurring beam losses and their locations a new system based on PIN-diodes was installed. The readout of the commercially available beam loss monitors is done via an in-house developed system compatible to our EPICS-based control system. The system and the results of the commissioning will be presented in this paper.

INTRODUCTION

Since 1987 the S-DALINAC serves nuclear- and astrophysical experiments at TU Darmstadt [1]. It is fed by either a thermionic gun or a photoemission gun which delivers a spin-polarized electron beam [2]. After pre-acceleration up to an energy of 10 MeV by the injector module the electron beam can either be used for experiments at the Darmstadt High Intensity Photon Setup (DHIPS) [3] or it is guided through a 180°-arc to enter the main linac. By passing the linac up to three times the maximum energy of about 130 MeV can be reached. The beam current can be adjusted from several pA up to 60 µA.

In order to improve the accelerator's performance and also to decrease the contamination of the surrounding by undetected beam losses, a beam loss monitoring system has been set up. Comparable machines are using several different monitors based on e.g. ionizing chambers, scintillators, glass fiber or semiconductor detectors. The requirements for an operation at the S-DALINAC are sensitiveness for (secondary) electrons, easy mounting and space-saving dimensions. In addition the detectors should provide a short-time readout in order to provide the operator with direct feedback for an improved beam tuning.

Beam Losses at the S-DALINAC

At the S-DALINAC beam losses typically occur because of small misalignments in the beam line or deviations in the magnetic fields. Therefore part of the beam is lost in the walls of the vacuum chamber. Depending on the electron's initial energy the produced secondary radiation can penetrate and activate the beam tube and surrounding equipment.

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BEAM LOSS MONITORING SYSTEM

Originally designed and implemented at HERA [4] the chosen Beam Loss Monitor (BLM) is currently manufactured and distributed by Bergoz Instrumentation [5]. The beam loss detection is based on a coincidence setup of two PIN-photodiodes interacting with ionizing radiation. The coincidence reduces the zero counting rate caused by the dark currents of the photodiodes. The operating principle is shown in Fig. 1.

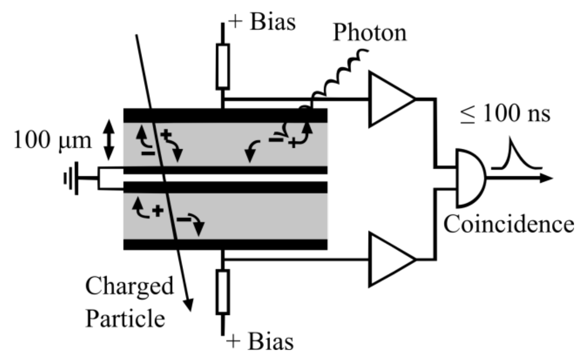

Figure 1: Operating principle of the Beam Loss Monitor [5].

Figure 2 shows the BLM circuit board with highlighted PIN-diodes of the BPW34 type. During operation the upper half is shielded from light and electromagnetic noise by a metal enclosure. The overall size is 69 x 34 x 18 mm³. To increase sensitivity, the original type of PIN-diodes can be exchanged by larger diodes.

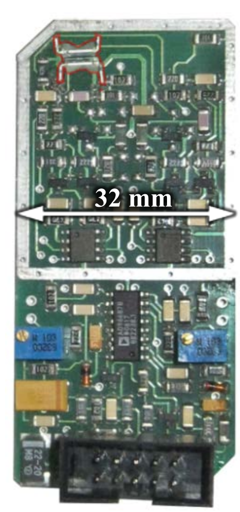

Figure 2: BLM circuit board with PIN-diodes at the upper left part.

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To adjust the level of amplification for each diode separately, two potentiometers (in blue) are included. The BLM is supplied via the 10-pin connector with ± 5 V and + 24 V. Positive TTL pulses with rates up to 10 MHz are driven towards the used counter. Its radiation hardness has been tested for up to 10^8 Rad [5].

In-house Developed Readout Electronics and Supply Unit

For easier integration into the existing, EPICS-based [6], accelerator control system at the S-DALINAC [7], readout electronics and voltage supply unit has been developed in-house. The supply, which is also including differential line-drivers, can be seen in Fig. 3. Each BLM needs its own supply unit within a maximum distance of 5 m. The conditioned pulses are sent to the counting cards located outside the accelerator hall. The maximum driving rate is 20 MHz while the BLM itself is limited to 10 MHz. The signal transport is done via standard Cat5 twisted-pair cable.

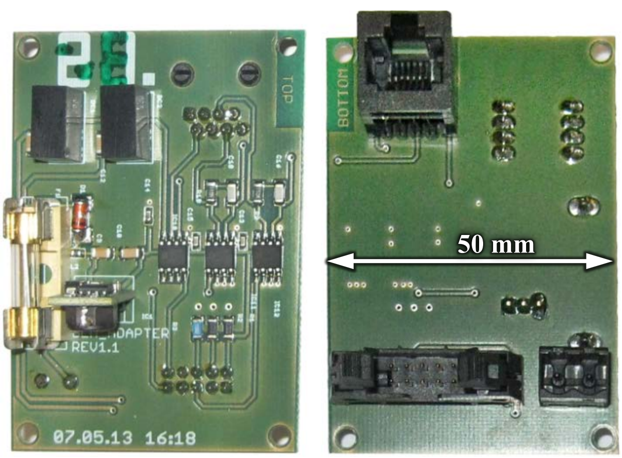

Figure 3: Back and front of BLM supply unit including the differential line-drivers.

Each counting card provides two input channels. The front panel indicates the actual counting rates by flashing LEDs. The longest readout interval of this device is $^1/_7$ s.

Integration into the EPICS-based Accelerator Control System

For easy integration into the existing, EPICS-based control system, the fast counting cards are designed to be compatible to the existing in-house developed QM07 multipurpose-measurement system. Hence the occurring count rates can be transferred to the control room via the already existing EPICS IOC. Control System Studio (CSS) [8] is used to allow the operator to access most of the data. For practical use an overview of the floor plan was combined with small displays showing the actual measured beam loss rate at each monitored position. CSS also offers to make customized changes if necessary with very small effort. So it is common to draw a special user interface, only including the BLMs which are important for this special operating mode. One example for the DHIPS mode of our accelerator control system is given in Fig. 4.

The window contains the beam current at the radiation production targets in the upper half. The current is measured by two separate plates. By recording the ratio of both, deviations of the beam energy can be indicated. The chart in the middle shows the beam current over the last 30 minutes. The two fields below display the concurrent beam loss rate behind the injector module. The recorded beam loss rate is drawn in the small charts below and can be archived optionally.

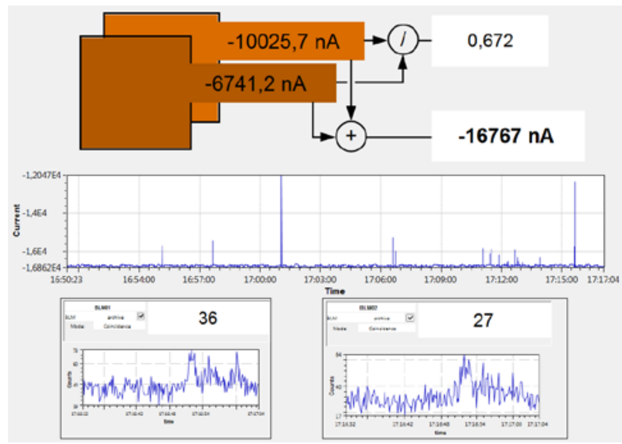

Figure 4: Customized CSS window for DHIPS experiments showing the beam current at the radiation production targets in the upper half and the beam loss rate behind the injector cryostat below. Slow changes over time are indicated by the two charts.

Calibration

For the purpose of adjusting the levels of amplification for each diode separately, the counting card supports disabling one channel of the coincidence set-up to measure the other's zero counting-rate. After adjusting the amplification levels, the 20 BLMs for the S-DALINAC were calibrated with a radioactive source (^{60}Co, 60 MBq) normalizing the BLM count rates [9]. Factors between 0.5 and 2 were tolerated; otherwise the amplifier gains were changed again. Using this normalization, it is possible to mount several BLMs at the same position around the beam tube to gain information about the direction of deviation of the beam from the ideal orbit.

BLM set up and first Commissioning

The threshold for particle detection is around 1 MeV [10]. This prohibits measuring beam loss before acceleration above this threshold. Hence at the S-DALINAC these BLMs are sensitive from the first superconducting acceleration stage on. The space-saving BLM can be mounted easily, e.g. by a cable tie to the beam tube. For this reason changing the monitored positions is possible on short notice. An overview plan of the currently monitored positions is given in Fig. 5.

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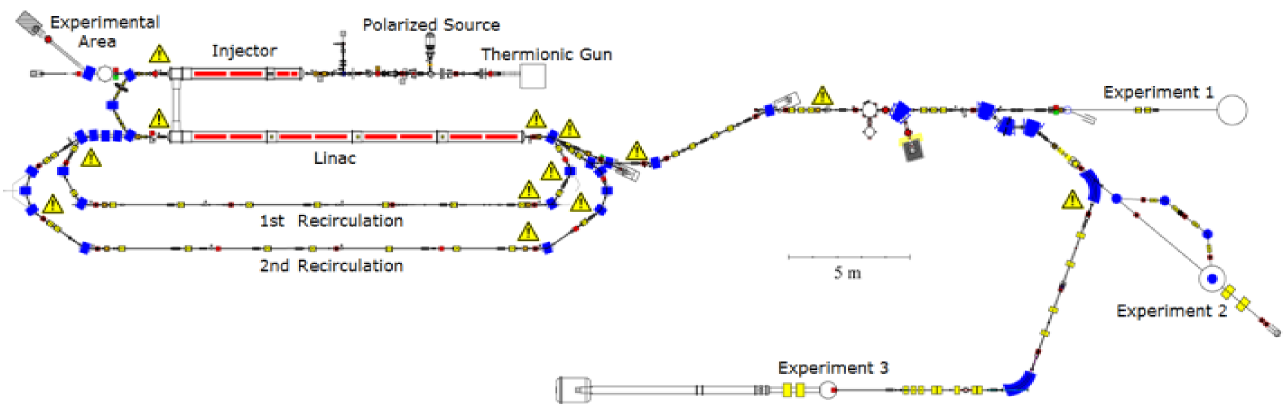

Figure 5: Floor plan of the S-DALINAC, including the experimental area. Positions of BLMs are indicated using exclamation marks (⚠).

The 10 MeV injector module's exit is prepared with two BLMs, one on the right side, the other on the top. Also the 40 MeV Linac module is monitored with several BLMs. At the entrance, three BLMs are mounted, while four are mounted right behind its exit. By the use of more than one BLM at a single position, more information can be gained, e.g. about the direction the beam deviates from its ideal orbit. The BLMs turned out to be a very helpful feature, not only for safety reasons during the operation, but also while optimization of the tuning parameters, the beam loss rates give information about the right settings.

By recording the rates for extended periods, drifts and charging effects have been monitored which have not been noticed before and were corrected later on. As an example an image of a short-period charging effect can be seen in the screenshot in Fig. 6.

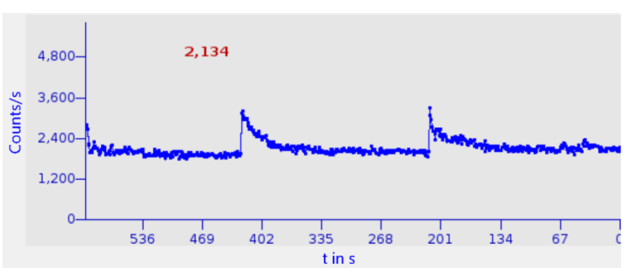

Figure 6: CSS window showing BLM rates over 10 min. An unnoticed charging effect could be discovered.

FUTURE PLANS

The S-DALINAC is a superconducting, recirculating electron linac and is showing transverse beam break up. This occurs already at low threshold currents of some μA. Several methods to counteract the beam break up are to be experimentally investigated [11] in future in order to gain information for future high current Energy Recovering Linacs (ERLs). For these measurements the beam loss monitoring system shall be spread around the accelerator to indicate the effect of each setting to the beam break up limit.

CONCLUSION

The new beam loss monitoring system of the S-DALINAC provides on-line beam loss rates which can be visualized and archived in several ways, using EPICS and CSS. The flexibility gives the option to change the monitored positions within a few minutes. Not only for operation safety, but also for efficient and fast beam tuning, the installed system is a useful, non-destructive tool.

ACKNOWLEDGEMENTS

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