Beam Loss Detection at Radiation Source ELBE

P. Michel, J. Teichert, R. Schurig, H. Langenhagen
Forschungszentrum Rossendorf (FZR), Dresden, Germany

Abstract

The Rossendorf superconducting Electron Linac of high Brilliance and low Emittance (ELBE) delivers a 40 MeV, 1 mA cw-beam for different applications such as bremsstrahlung production, electron channeling, free- electron lasers or secondary particle beam generation. In this energy region in case of collisions of the electron beam with the pipe nearly all beam power will be deposited into the pipe material. Therefore a reliable beam loss monitoring is essential for machine protection at ELBE. Different systems basing on photo multipliers, compton diodes and long ionization chambers were studied. The pros and cons of the different systems will be discussed. Ionization chambers based on air-isolated RF cables installed some cm away parallel to the beam line turned out to be the optimal solution. The beam shut-off threshold was adjusted to 1 μC integral charge loss during a 100 ms time interval. Due to the favourable geometry the monitor sensitivity varies less than +/- 50 % along the beam line (different shielding conditions).

Introduction

The Forschungszentrum Rossendorf is constructing a superconducting Electron Linac with high Brilliance an low Emitance (ELBE) which can deliver a 1 mA cw beam of 40 MeV. The electron beam is used to generate infrared light (Free Electron Lasers), X-rays (electron channeling), MeV-bremsstrahlung, fast neutrons and positrons. [1] The safe and reliable operation of the accelerator is essential for a user facility like the ELBE radiation source. The machine should run over many shifts and for long periods with constant and reproducible parameters. The facility must be able to be operated by a minimum number of trained operators. Because of the high beam power (max. 40kW) and the electron energy range of 15-40 MeV the prevention of beam losses in the beam line plays a special role. Due to the average electron penetration depth at these energies approximately the full beam power can be deposited into the vacuum pipes. Apart from the production of ionizing radiation and activation, the vacuum pipes can be melted. It is inevitable that the vacuum system, and in particular the superconducting accelerator cavities, would be contaminated. The result would be long down-times and substantial costs for repairs.

Detectors

Multiple detectors for the measurement of the beam loss were tested at the ELBE beam line. These were photomultipliers (PM), Compton diodes (CD) [2] and long ionization chambers (LIC) [3] constructed from air-filled high frequency cables.

Photo Multipliers: Photomultipliers (Electron tubes P30P) were installed approximately 3m away from the beam line. The detector shows very short response time (~ 1 ns) and is able to detect extremely low levels of radiation (~ 10 nA beam loss). Due to the nonlinear behaviour of the PM signals saturation effects in the PM problems appear at very high dose rates. At very fast increasing and extremely high beam losses the PM saturate before the necessary signal level for the accelerator shut-off is reached. In addition, the continuous monitoring of the beam pipe can be guaranteed only when a large number of detectors (~ one PM per meter) is used due to the strong dependence of the monitor signal on the distance between PM and the location of the beam loss.

Compton Diodes: Compton diodes were installed similar to the PM's. They showed a very good linear behaviour up to extremely high beam loss levels. The Compton diodes exhibit an angle dependent signal and thus a directional characteristic based on the geometry of the detector. This can be used in order to supervise certain segments of the beam line with increased sensitivity. Nevertheless, the crucial disadvantage remains the same as for the PM. A complete beam line monitoring with approximately constant sensitivity is attainable only with a very large number of detectors.

Long Ion Chambers: Air-filled high frequency cables of the type Andrew HJ5-50 (diameter 22.2mm) were mounted approx. 20cm away parallel to the beam pipe. The cables were operated as ionization chambers applying a high voltage to the outer conductor and

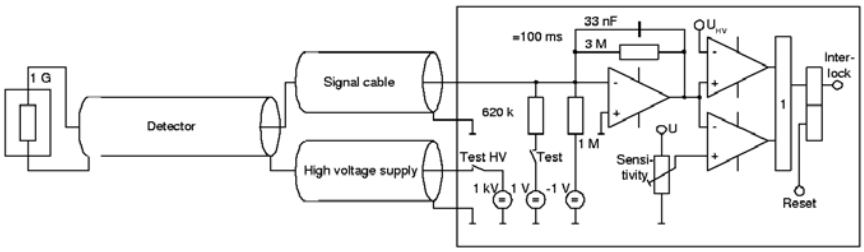

Figure 2: Block diagram for the cable ionisation chamber electronics.

measuring the ionization current. The detector showed a very good linear behaviour up to the maximum possible beam loss. The sensitivity to low beam loss levels is approximately 100 nA . The perfect geometry of this detector permits the installation parallel to the beamline. Thus a uniform sensitivity for all potential beamloss locations is reached.
The response time of all three detectors is sufficient for fast shut-off system (<1ms).

The ELBE BLM system

The LIC was chosen because of the ability to monitor the entire beamline with the same shut off level and the small number of electronics that is required for such a system. The Andrew HJ4-50 (diameter 12.7mm) Heliax cable was selected for the ionization chamber. The system was segmented corresponding to the logical sectioning of the ELBE beamlines, adding some segments with special shielding conditions (e.g. large chicane vacuum chamber). The cable is covered with a plastic tube to prevent damage and to provide high voltage insulation. It was mounted as closely as possible (approx. 200mm) to the beamline. The cable was installed within the iron yoke of the dipole magnets to avoid their shielding effect. Fig.1 shows the BLM signal of various

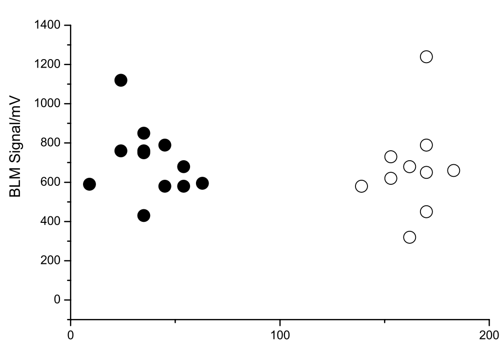

Figure 1: BLM signal from the same beam loss current at different locations along the beam line. Full and open circles are measured with different cable sections. The open circle section belongs to the chicane vacuum chamber.

detector sections with artificially produced beam loss at different locations along the ELBE beam line. Due to the ideal geometrical constellation, the BLM signal varied approximately only 50% along the beamline, which is caused by the inhomogenous distribution of attenuating material (magnets, flanges ect.).

In order to prevent damage to the system, all the electronics was installed outside of the accelerator enclosure. A self check system monitors the high voltage and signal acquisition. Fig. 2 shows the layout of BLM readout electronics. The beam shut-off threshold of the system in the present stage (limited beam energy) was set on 1 µC loss charge integrated over 100 ms. In consideration of all fluctuations of the signal a maximum beam loss current of 10µA in CW operation at 12 MeV beam energy is tolerated. In the worst case 120 W of thermal power are deposited into any beam line components. Thus, a safe operation of the accelerator is ensured.

Outlook

Since the system very sensitively measures beam loss currents of few µA a second system for on-line monitoring the beam transmission during accelerator operation is under construction. This system is divided into sections with a length of 0.5m and a special serial read out electronics is under development [4]. Fig. 3 shows schematically the layout . Thus a position resolved measurement of the beam loss becomes possible. The operator will be able to judge and correct the quality of beam transmission while running the machine in high beam power mode.

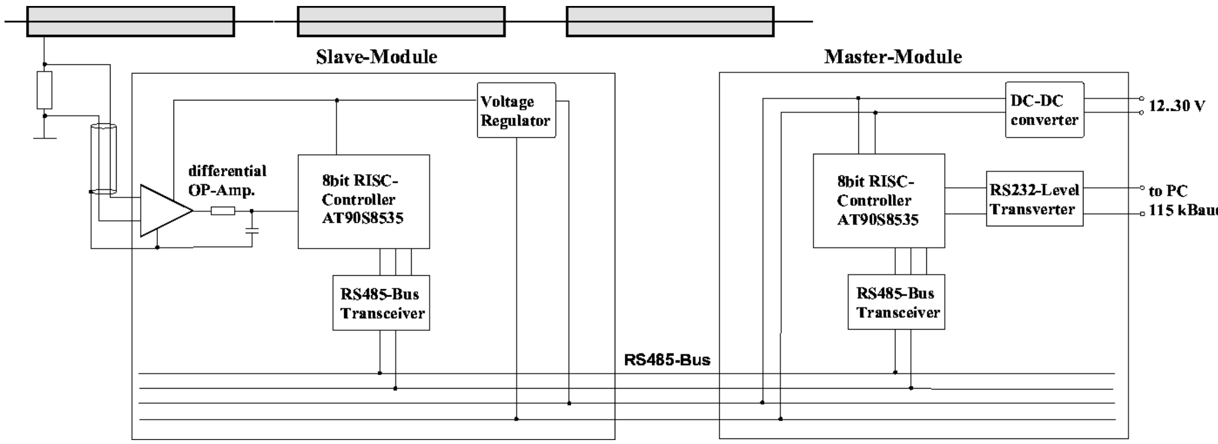

Figure 3: Acquisition electronics for segmented BLM system with longitudinal resolution.

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