THE BEAM HALO MONITOR FOR FLASH

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Abstract

The Beam Halo Monitor (BHM) for FLASH (Free-Electron LASer in Hamburg) based on pCVD diamond and monocrystalline sapphire sensors has been successfully commissioned and is in operation. It is a part of the beam dump diagnostics system purposed to ensure safe beam dumping. The description of the BHM is given and the results on the performance obtained during its operation are reported in this paper.

INTRODUCTION

Different diagnostics systems are necessary to ensure safe operation of an accelerator and to avoid the situations which could lead to dangerous conditions for the environment and the machine itself. The Beam Halo Monitor for FLASH [1, 2] is a vital part of the beam dump diagnostics system. Operating in conjunction with the other subsystems the BHM makes sure that the beam and also the beam halo stay inside the beam pipe close to the beam dump. Fast response of the BHM sensors makes it possible to signal earlier than other systems a displacement of the beam towards the beam pipe. The system has been commissioned and in operation since September 2009. The performance of the system both under normal and undesirable conditions has been studied.

SYSTEM DESCRIPTION

The module containing the BHM has been installed in the last section of the electron beam pipe behind the vacuum window and directly in front of the dump. Eight sensors – four pCVD dianonds and four artificial monocrystalline sapphires – placed inside cups are uniformly distributed in azimuthal direction as shown in Fig. 1. The distance between the center of the beam pipe and the edge of each sensor is 50 mm. Four loops of magnetic-coupled beam position monitor (BPM) are situated close to the BHM sensors. The sensors placed inside the beam pipe have to withstand high radiation doses. The radiation tolerance of the samples of such diamonds and sapphires has been investigated at the S-DALINAC. The sensors revealed moderate signal degradation up to the doses of 10 MGy [3].

The sensors are operated as solid state ionization chambers. The bias voltage feed and signal readout scheme for each BHM sensor is depicted in Fig. 2. Two coaxial cables are used to provide bias voltage and one to read out the signal. The bias voltage supply and readout electronics are in the counting room. A HV filter and voltage supply box containing capacitors to support bias voltage close to the sensors resides in the accelerator tunnel. The length of the cables connecting the HV filter box and the devices in the counting room is about 60 m. The length of the cables between a sensor and the box is around 4 m. Raw signals are transmitted to the counting room. They are limited and shaped by the signal filter and protection box to match the requirements of the fast direct conversion 14-bit in use.

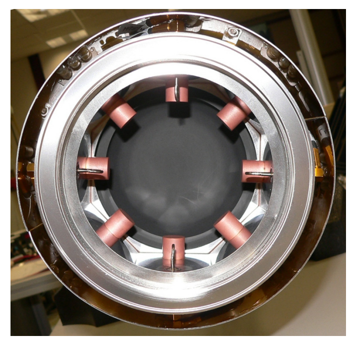

Figure 1: View of the BHM from the dump. The BHM sensors are inside the caps. Four loops of the magnetic-coupled BPM are right in front of the BHM sensors.

OPERATION EXPERIENCE

The experience gained during the operation of the BHM was of two kinds: normal machine operation without dangerous conditions and the special conditions which could be potentially dangerous. The results presented here cover both of these cases.

Normal Conditions

Normal conditions of FLASH operation imply bunches with the charge of up to 1 nC. To prevent thermal damage to the beam exit window in the case of longer bunch it is necessary to move the beam impact position. This is done with a sweeper magnet. The bunch impact positions follow the circles in the plane of the beam exit window and also in the plane of the BHM sensors. The radii of the circles are still small in comparison to the radius at which the BHM sensors are installed. Nevertheless, clear signals are observed from the diamond sensors when the beam approaches them, as can be seen in Fig. 3 (top). The signals from the sapphire sensors are, due to lower charge

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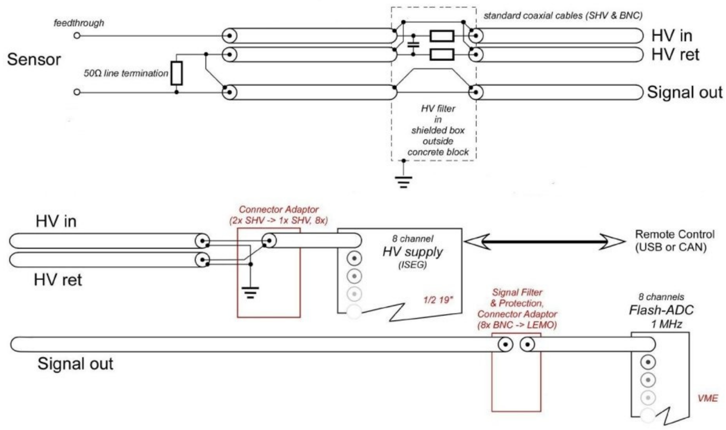

Figure 2: The bias voltage feed and signal readout scheme for each BHM sensor.

collection efficiency, much smaller, as shown in Fig. 3 (bottom). The Fig. 4 shows a FFT of the sapphire signal in the Fig. 3. One can notice the frequency with corresponds to the sweeping frequency of 1.1 Hz.

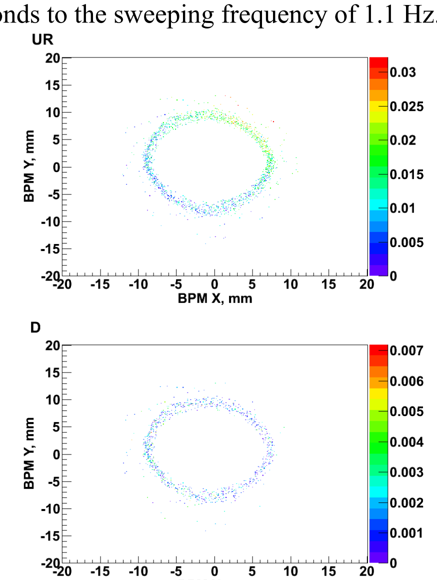

Figure 3: The signals (in V/nC) from a diamond (top) and a sapphire (bottom) sensor as a function of the beam positioning the azimuthal plane (as measured by the BPM). The bunch charge is 500 pC.

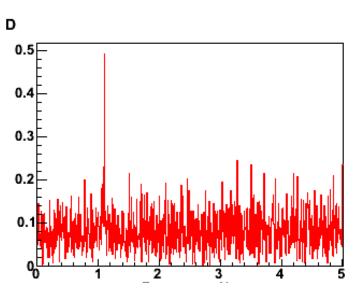

Figure 4: The signal from a sapphire sensor in frequency domain.

Special Conditions

In order to study the behaviour of the BHM system under extreme conditions the sweeping was increased and the measurement of the BHM sensors' signal was performed. The Fig. 5 shows the signal from a diamond and a sapphire sensor as a function of beam position for the case of the bunch charge of 1 nC.

The Fig. 6 shows the responses of all diamond and all sapphire sensors as a function of the bunch charge in the machine. The sweeping radius is the same as for the previous figure. Response from diamonds reach saturation, the ones from sapphires under the same conditions do not.

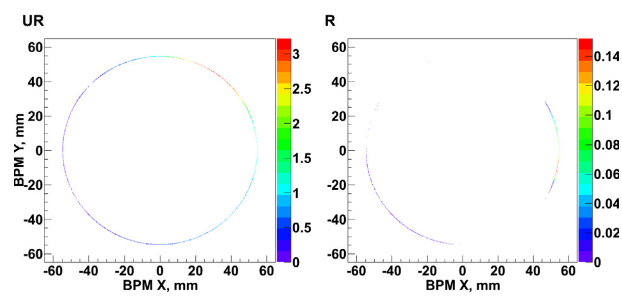

Figure 5: The signal (in V/nC) from a diamond (right) and a sapphire (left) as a function of the beam position. The beam position has been calculated on the basis of the reading from the BPM corrected with the theoretical deflection of the beam by the sweeper magnet. The bunch charge is 1 nC.

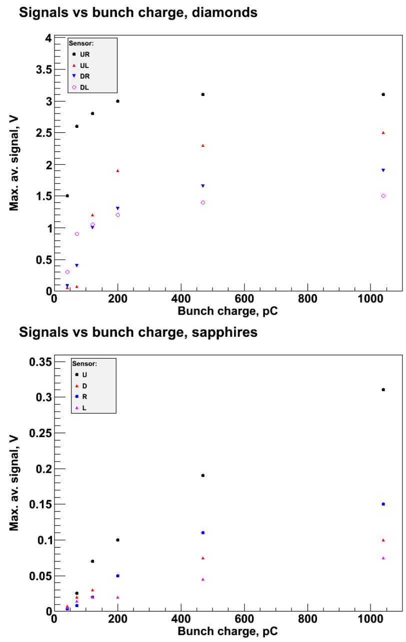

Figure 6: Signal from all diamonds (top) and all sapphires (bottom) as a function of the bunch charge in the machine.

THE BHM SYSTEM FOR THE XFEL

The BHM system at FLASH has been successfully operated. A similar system is planned as a part of the beam dump diagnostics system at the European X-ray Free Electron Laser (XFEL) [5, 6] for two dumps: the injector dump and the main dump. In the Fig. 7 the last section of the injector dump with the BHM is shown. The BHM system will be placed in front of the absorber. The main difference from the system at FLASH is the position of the sensors. The will be installed outside the beam pipe.

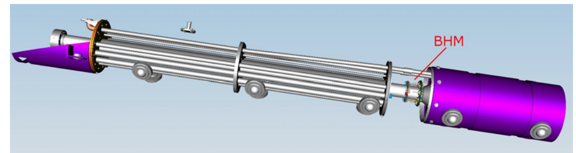

Figure 7: View of the BHM system designed for the injector dump of the XFEL.

CONCLUSIONS

The BHM for FLASH has been in operation since September 2009. The system gives possibility to detect even small beam offsets inside the last section of the beam pipe. Diamond sensors are more sensitive than the sapphires. The latter ones are able to provide useful information even at high loads. A similar system will be used as a part of beam dump diagnostics for the XFEL.

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