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FIBER-BASED CHERENKOV BEAM LOSS AND BEAM PROFILE MONITOR AT BEPC II *

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Abstract

A fiber-based Cherenkov beam loss monitor (CBLM) consisting of large core (600μm), long (50 m) multimode fibers, has been developed as an long-range detection tool for the BEPCII: primarily designed for radiation safety in order to limit the dose outside the shielding of the machine, this monitor also serves as an tool to measure beam profile with the wire sccaner. In this paper, principal of operation, instrumentation and programming of these CBLMs are discussed. Some results of beam loss and beam profile measurement with these CBLMs are also presented.

INTRODUCTION

Beam loss monitor systems (BLM systems) are an essential part of linear accelerators and storage rings. They allow the understanding of beam loss mechanisms and provide an option for an emergency shutdown. A proper understanding of beam loss events can improve machine performance, which consequently reduces also the radiation level for the used accelerator components. Common beam loss system, like ionization chamber, combination of scintillator and photo multiplier and PIN photo-diodes etc. they do not cover the complete sections of the accelerator, and have an insufficient position and time resolution. Optical fibers offer the possibility to monitor beam losses over long distances in real time, with good position accuracy and sensitivity at a reasonable cost [1-5]. Besides, the CBLM can also do a transverse beam profile diagnostic together with wire scanners based on the emission and detection of Cherenkov radiation. In this paper principal of operation, instrumentation and programming of CBLM at BEPC II linac are described shortly. Some results of beam loss and beam profile measurement with the CBLM are also presented.

PRINCIPLE OF CBLM

Electrons that are not captured in the storage ring hit the vacuum chamber wall and produce secondary electrons outside the vacuum chamber. Secondary electrons that run through quartz fiber generate Cherenkov light provided the energy of the electrons is high enough. The basic idea behind the CBLM is to detect the Cherenkov radiation (CR) generated in optical fiber. Some of the Cherenkov photons propagate through the fiber and can be detected by PMT [6-7]. As shown in Fig. 1, a PMT at both ends of the fiber is used for the detection of a light pulse. With one loss point (Fig. 1), the source position is determined by measuring the arrival time of the Cherenkov light (t_1 and t_2 in the figure) using simple arithmetic

$$x=[L+(t_1-t_2)v_f]/2 \quad (1)$$

where v_{fiber} is the speed of light propagation in a glass medium, which is equal to 2/3 the speed of light in a vacuum (v_c).

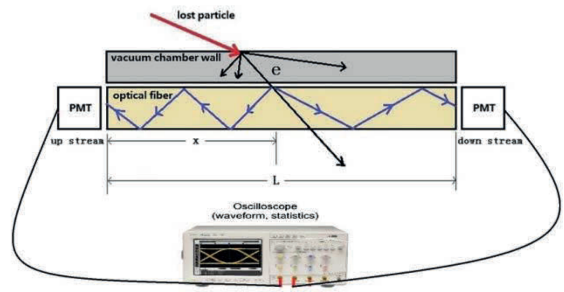

Figure 1: Scheme of beam loss monitor.

EXPERIMENTAL SET-UP

The experiments were carried out at the BEPC II linac, which has a maximum electron energy and repetition rate of 2 GeV and 50 Hz respectively. We selected all-silica, step-index large-core optical fibers, manufactured by OFS Furukawa (parts number:CF01493-14). Main characteristics of the fibers we used were listed in Table 1. The core diameter is a good compromise between the irradiation sensitivity and a required bandwidth. A black nylon buffer shields the fiber against the ambient light. The fiber was installed along the outer wall of the vacuum chamber (Fig. 2).

Table 1: Main Characteristics of the Fibers

Maker	Core(μm)	Index	Length(m)
OFS	600	step	50

Table 2: Specification of H10721-01

Type	Spectral response (nm)	Rise time (ns)	Optimum wavelength (nm)
H107 21-01	230-870	0.57	300-600

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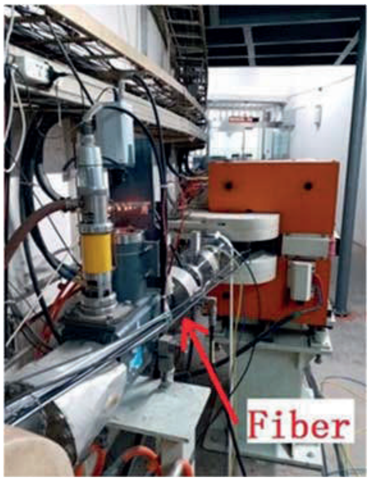

Figure 2: Black cables mounted on the side of the vacuum chamber are the optical fibers for the loss monitor.

The photomultiplier chosen was the Hamamatsu H6780-02 equipped with a FC adapter (FC connectors have a typical insertion loss below 0.3 dB). Main characteristics of the fibers we used were listed in Table 2.

BEAM LOSS DETECTION

The measurement set up for CBLM installed at BEPC II linac was shown in Fig. 3. The signals from the photomultiplier tubes (PMTs) set at both end of the fiber are read out with an oscilloscope. A trigger signal from the accelerator master oscillator is used as time reference. Typical curves of the Cerenkov light generated in the optical fibers over 50m length during routine operation at BEPC II are shown in Fig. 4. Both PMTs (upstream and downstream PMT) have obvious peaks. This indicates that the linac have natural beam losses within the 50m length during its operation. There are two OTR screens within the 50m length of the linac. To evaluate the position detection accuracy of the CBLM, No. 1 and No. 2 OTR screen were inserted respectively and caused an artificial beam loss. The signals in both PMTs were shown in Fig. 5 and Fig. 6. Compared with Fig. 4, the peaks generated by the No. 1 and No. 2 OTR screen were easy to identify. The location of the OTR screen can be calculated by the time difference between the maximum peak of the light pulse based on formular 1.

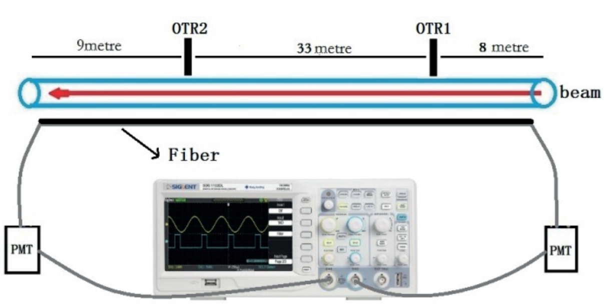

Figure 3: Scheme of the CBLM installed at BEPC II linac.

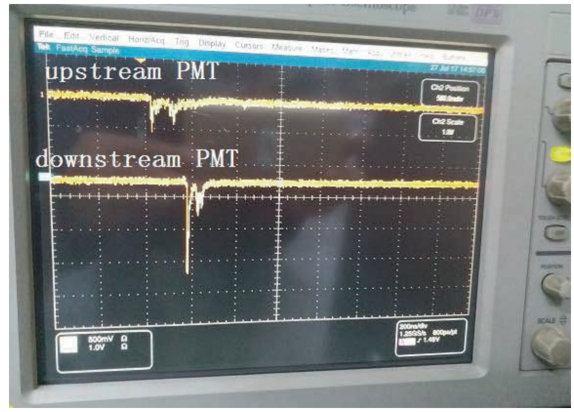

Figure 4: Typical curves of the Cerenkov light in BEPC II linac.

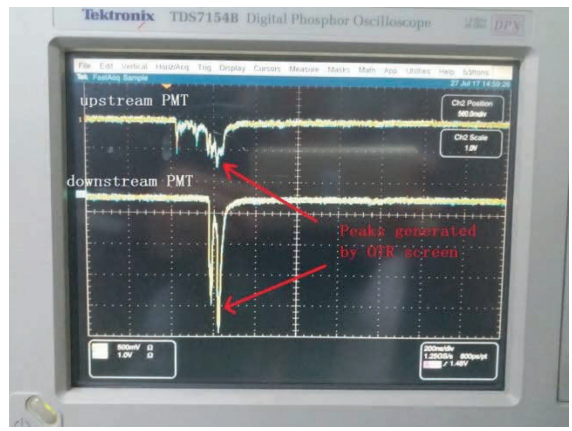

Figure 5: Peaks generated by No .1 OTR screen.

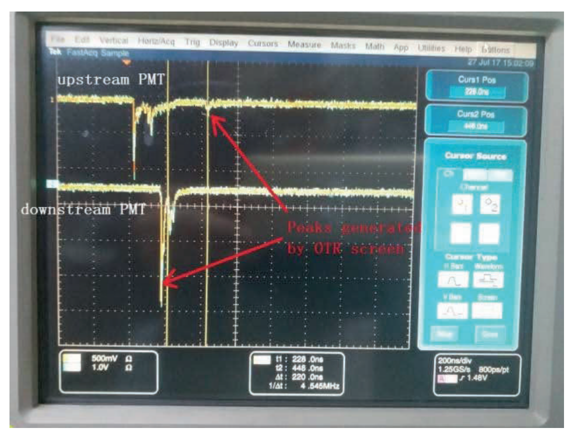

Figure 6: Peaks generated by No. 2 OTR screen.

We calculated the position of No. 1 and No. 2 OTR screen. Unfortunately, compared with their actual location, there were a few meters error in the calculation results. This may be caused by the interference of the linac natural beam losses during routine operation. If the location of the natural beam loss is near the OTR screen, the signals generated by the beam loss may overlap on the oscilloscope, and caused the error in the calculation results.

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BEAM PROFILE MONITOR

Beam profile measurement is an essential part of the beam diagnostic. A new beam profile monitor was constructed by combining a wire scanner (WS) type beam scraper and CBLMs. The length of fiber used here is 20m. The type of fiber and PMT are the same as mentioned in Table 1 and 2. By detecting the beam loss generated by wire Scanner(Fig. 7), the beam profile can be aquired. The advantage is that multiple wire scanners can share one CBLM. The beam profiles measured with the new monitor were shown in Fig. 8.

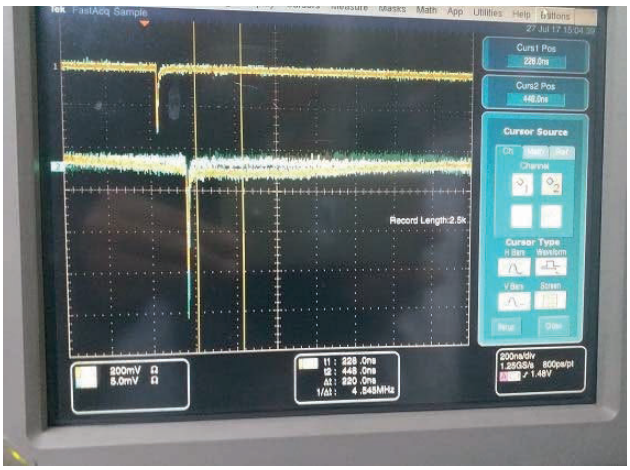

Figure 7: Beam loss generated by wire Scanner.

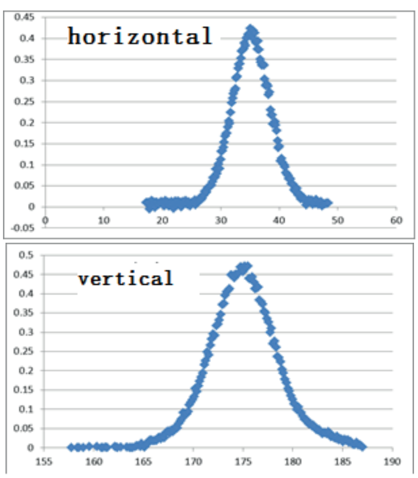

Figure 8: Beam profile measured with WS and CBLM.

SUMMARY

We have developed a fiber-based Cherenkov beam loss monitor (CBLM) in BEPC II linac. Using this CBLM, both natural beam losses and artificial beam loss can be detected. The locations of the OTR screens were calculated by the time difference between the maximum peak of the Cherenkov light on oscilloscope. But compared with their actual location, there were a few meters error in the calculation results. This may be caused by the interference of the linac natural beam losses during routine operation.

Besides, a new beam profile monitor was constructed by combining a wire scanner (WS) and CBLM. Beam profiles of different directions were measured successfully with the new monitor.

The performance of the CBLM system is not satisfactory in the experiment. In the future, we will repeat the beam loss detection experiment in other sections of the BEPC II linac and the storage ring. The CBLM system will be improved.

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