# EXPERIMENTAL CHARACTERIZATION OF ATF BEAM POSITION MONITOR

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***ABSTRACT***

Performance of the stripline beam positiopn monitor (BPM) at Brookhaven Accelerator Test Facility (ATF) was experimentally characterized. The design of the BPM and its local receive were discussed briefly. The dynamic range of the BPM was measred from a few pC to an 0.5 nC charge without saturation. The resolution of the BPM was measured to be 150 μm for a 200 pC charge electron bunch. The BPM sum signal was also used to investigate the timing jitter between the RF gun driving laser system and the ATF linac RF system, the sensitivity for timing jitter measurement was measured to be 6mV/ps.

## 1 INTRODUCTION

The Brookhaven Accelerator Test Facility (ATF) is a user's facility for physics of beams, equipped to study the interaction between high power electromagnetic fields and bright electron beams. The ATF's experimental program requires electron beam parameters that range widely in charge, pulse length and pulse train length. The single bunch charge can be varied from pC to nC, with a normalized rms emittance from 10 mm-mrad to 0.02 mm-mrad. The electron beam bunch length can be varied (by adjusting the relative phase between the laser and RF gun) from 10 ps to 500 fs. The number of bunched in a macropulse can be varied continuously from one to a few hundred micropulses. The electron beam diagnostics system at ATF were designed in such a way that both transverse and longitudinal emittance of electron beam can be characterized. The main components of the ATF electron diagnostics system are beam profile monitors [1] and stripline beam position monitors (BPM). The design of the ATF BPM and experimental characterization of its performance were presnet in this paper.

## 2 ATF BEAM POSITION MONITOR

The ATF stripline BPM and its local receiver design was described in the previous report[2]. The ATF beam position monitor consists of a beam pick-up element with four stripline electrodes in a 1.5" diameter stainless steel pipe mounted with 2 3/4" diameter Con-flat flanges, and a local receiver. This device is shown in Fig.1.

The stripline type BPM was chosen over the capacitive button electrodes because of its high sensitivity and wide bandwidth. The length of the the electrodes was selected so that the ATF linac RF frequency (2856 MHz) is the second-order quarter wave resonance frequency; and shortening the downstream end of the electrode is cost effective and without sacrificeing its performance. The transvese dimension of the electrode was optimized for 50 Ω character impendence, the angular width of the electrode was chosen to be $\pi/4$ to maximize the signal without introducing significant coupling among the neighbouring electrodes.

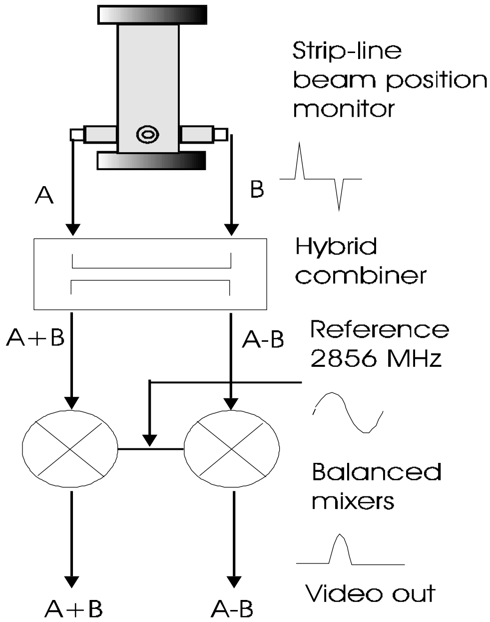


**Figure 1.** The stripline beam position monitor system.

The local receiver of the ATF BPM is made up of a frequency down converter and an amplifer. The signals of an opposing pair of electrodes are combined in a 180° hybrid to produce sum and difference signals. The sum and difference signals were followed by one GHz high-pass filters to increase the saturation level of the mixers followed. These signals were mixed with 2856 MHz RF reference signal derived from ATF linac RF system. The video outputs (IF) were passed through 100 MHz low-pass filters before entering high-bandwidth amplifier. The bandwidth of the amplifer is 60 MHz so it can distinguish individiual pulse for a pulse train with separation of 12.5 ns. The gain of the amplifier is about 25 dB. The amplified signals were digitalized by charge sensitive ADCs.

The frequency down converter and amplifer borad were housed in two separate metal cases. To reduce the noise from the klystron modulator, the amplifier was installed inside a cast aluminum box with an isolated DC power input.

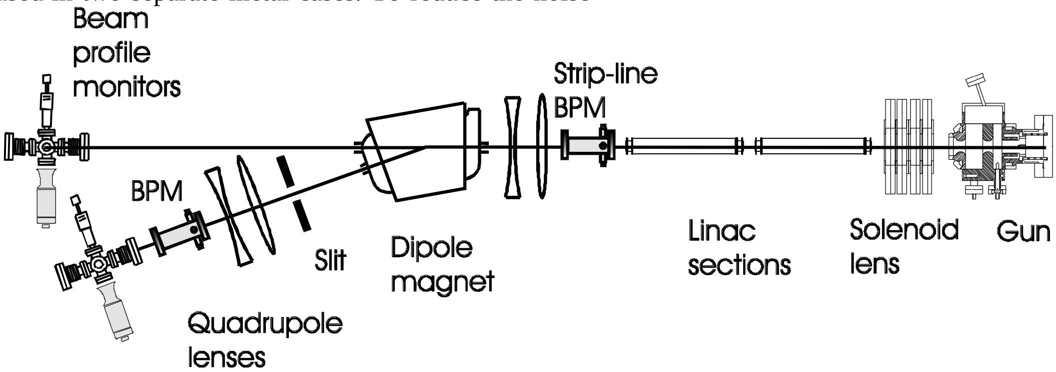


**Figure 2.** The schematic of ATF accelerator system.

## 3 EXPERIMENTAL CHARACTERIZATION OF THE BPM

The ATF accelerator system consists a 2856 MHz one-and-half cell photocathode RF gun and two sections of SLAC type traveling wave linac (Fig.2). A frequency quadrupled Nd:Yag laser system is used to drive the RF gun. The accelerator RF and laser system are synchronized through a 81.6 MHz master oscillator. The stripline BPM after the linac was used for the measurement.

The ATF BPMs were characterized extensively before installation[2]. It was found that the ratio of the difference to the sum signals deviates less than 1% if the displacement less than 3.5 mm from electrodes mechanical center. It was also measured that the rms deviation of electric center of the electrodes to its mechanical center is about 60 µm.

There are 14 BPMs installed at the ATF. The dynamic range and resolution of the BPM were experimentalled investigated using a 40 MeV electron beam. Fig.2 is the schematic of the ATF photocathode RF gun injector and linac system. The BPM used for the study locate half meter upstream a beam profile monitor. And there is a Faraday cup locate down stream of the BPM. The dynamic range of the BPM was investigated by simultaneously measure the stripline sum signal and the charge reach the Faraday cup. The charge in the beam varied as we changed the laser energy for the photocathode RF gun.The experimental results were plotted in Fig.3. Fig.3 shows that the stripline saturated when the charge is over 0.5 nC, and 2 pC charge will produce about 5 mV stripline BPM sum signal.

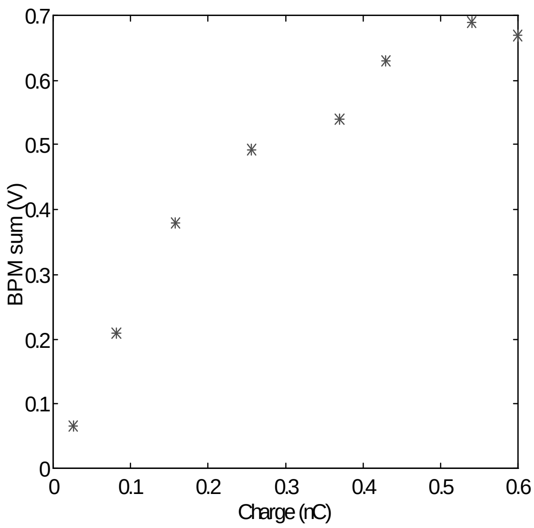


**Figure 3.** The BPM dynamics range characterization.

The resolution of the BPM was characterized for a 200 pC charge electron beam. The electron beam was moved using an upstream steering magnet. The stripline BPM difference signal and centroid position of the electron beam on the downstream beam profile monitor were recorded for each steering magnet current setting. The largest displacement of the beam centroid is about ±4 mm without beam loss. Fig.4 shows the centroid position as function of the stripline difference signal. A 100 µm displacement of beam centroid on the beam profile monitor produced 3 mV BPM different signal. The β function at stripline is about 20% bigger than at beam profile monitor, so it was estimated that 150 µm displacemet at BPM will produce at least 4 mV difference signal. Considering the noise level and ADC resolution, we concluded that resolution of the ATF BPM is about 150 µm for a 200 pC charge. For higher charge, 100 µm resolution can be achieved.

mV/ps. Using this technique, we have measured the rms timing jitter between the laser and RF system is 0.5±0.25 ps.

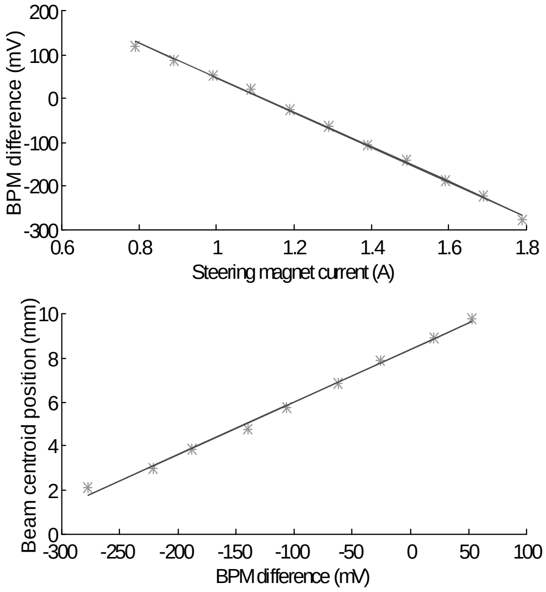


**Figure 4.** The BPM resolution measurement.

## 4 TIMING JITTER MEASUREMENT

Maintaining the timing stability between the RF system of the photocathode RF gun and its driving laser system is crucial for the performance of the photocathode RF gun. Since the pulse length of the laser is on the order of a few picoseconds, the timing jitter is required to be on the order of sub-picosecond. We have developed a new technique [3] of measuring the sub-ps timing jitter between the RF and laser using stripline beam position monitor (BPM). As we discussed earlier, one of the resonant frequency of the BPM is ATF RF system frequency 2856 MHz. Using the ATF low level RF signal as local oscillator, the output from the mixer with stripline sum signal contained both intensity and phase information relative to the RF system of the photoelectron beam. The output of mixer is plotted in Fig.5 as a function of local oscillator phase, near the zero crossing, the output is almost linearly proportional to the relative phase between the RF system and electron beam. The sensitivity of our system was measured to be 6.5 mV/ps. Using this technique, we have measured the rms timing jitter between the laser and RF system is 0.5±0.25 ps.

## 5 ACKNOWLEDGEMENTS

Many people has made contribution to the ATF stripline beam position monitor, specially K. Batchelor, R. Malone, J. Rogers, and J. Sheehan, The technical support of W. Cahill, M. Montemagno and R. Harrington is appreciated.

This work is supported by the U.S. department of Energy under contract No. DE-AC02-76CH00016.

## 6. REFERENCES

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**2.** J.T. Rogers et al, STRIPLINE BEAM POSITION MONOTORS FOR THE ATF, BNL - 47145 (1992).

**3.** X.J. Wang, Z. Segalov and I. Ben-Zvi, to be published.

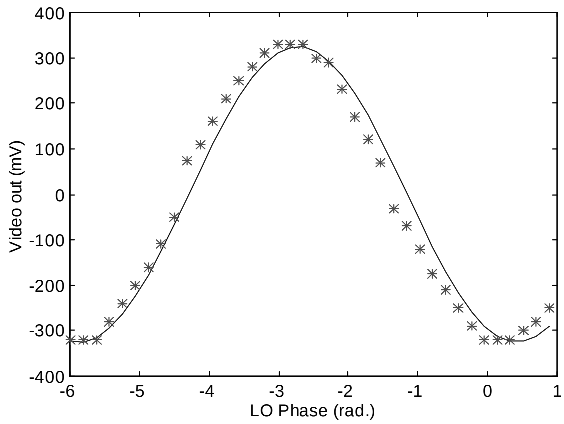


**Figure 5.** Stripline BPM sum video out vs. Local oscillator phase.