Strip line beam position monitor for HLS LINAC

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Abstract The parameters of beam transverse positions at HLS 200 MeV LINAC are very important to injection efficiency. We have designed a new non-interceptive strip line beam position monitor (BPM) as a substitution for the original interceptive fluorescent target. This paper gives out the theoretical analysis and bench test result of the strip line BPM. The BPM has a characteristic impedance of (50±5)Ω, a reflection coefficient of less than –4 dB, a bandwidth of 400 MHz, a coupling coefficient of less than -15 dB, and a sensitivity of 1.16 dB/mm. Additionally, the strip line BPM has a good linearity.

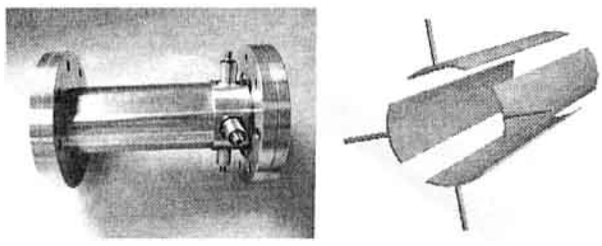
Keywords Beam position monitor, Strip line, Reflection, Coupling, Sensitivity

CLC number TL506

1 Introduction

Beam position monitors at HLS LINAC and transfer line will deliver the information about the transverse positions and phases of beam passing by. Typical requirement for position resolution is within 1mm within 1/3 of half aperture r_b (r_b of HLS LINAC is 25mm). The HLS LINAC BPMs will also serve as beam phase detectors, which require a tough broadband frequency response and impedance match for the BPMs. Additionally, space available for the BPMs at the HLS LINAC also imposes a restriction on BPM design.

Based on these requirements, we design a strip line electrode structure, which is 60 degrees in azimuthal angle with an inner radius of 19mm[1] and a length of 183.8mm (7/4 wavelength according to HLS LINAC RF frequency 2.856GHz). Fig.1 (a) gives out the machined strip line BPM. Fig.1 (b) shows the strip line electrode shape excluding vacuum house. The electrodes are shorted at the end of vacuum house for structural firmness.



(a) (b)

Fig.1 HLS LINAC strip line BPM.
(a) Machined strip line BPM; (b) 60 degrees strip line electrode structure.

2 Analysis

2.1 Characteristic impedance

According to Ref.[2], signal modes induced on the electrodes can be classified as sum mode, dipole mode, and quadrupole mode by relative polarities of electrodes. All four electrodes have the same polarities in sum mode; opposite electrodes have reverse polarities in dipole mode; and adjacent electrodes have reverse polarities in quadrupole mode. Based on CST Microwave Studio[3], we get the simulated result of the BPM characteristic impedance, which is 59.7Ω in sum mode, 47.6Ω in dipole mode and 42.8Ω in quadrupole mode. The discrepancy of characteristic impedance among different modes is larger because of the stronger coupling between the electrodes of the new BPM.

Fig.2 gives out the bench-test result of the BPM

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characteristic impedance. The characteristic impedance is between 45Ω and 55Ω within the frequency range of 3GHz. We expect that the BPM can match 50Ω cables well.

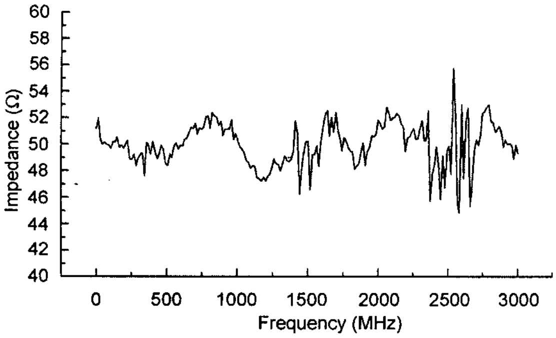

Fig.2 Characteristic impedance of the strip line BPM.

Fig.3 is the reflection coefficient of the strip line BPM. The reflection coefficient is quite flat from DC up to 1 GHz and within 4 dB in the whole frequency range of 3 GHz.

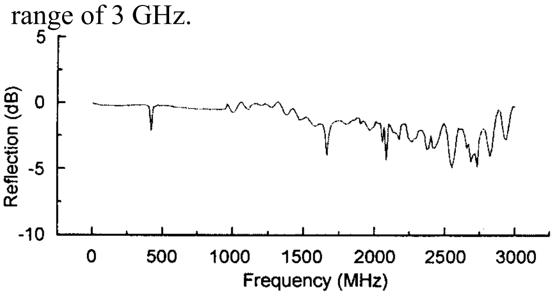

Fig.3 Reflection coefficient of the strip line BPM.

2.2 Time domain and frequency domain response

The time domain transmission functions of the BPMs are simulated by Mafia[4]. In T3 module of Mafia, we take a Gaussian longitudinal charge distribution of the bunch with the total charge Q=0.1nC, β=1 and the rms length σ=5mm to simulate 40 mA beam for HLS LINAC. Fig.4(a) is the time domain signals on the strip line electrodes with a transversely displaced beam passing by. The oscillation of electrode signals shows that feedthroughs and strip line electrodes do not match so well. Fig.4(b) is the corresponding spectra of Fig.4(a). The increase of electrode response with increase of frequency is caused by coupling between electrodes, which is stronger with frequency increasing. In Fig.4(b), the bandwidth of signals is approximately 400MHz, which promises a good broadband response for the beam phase detecting.

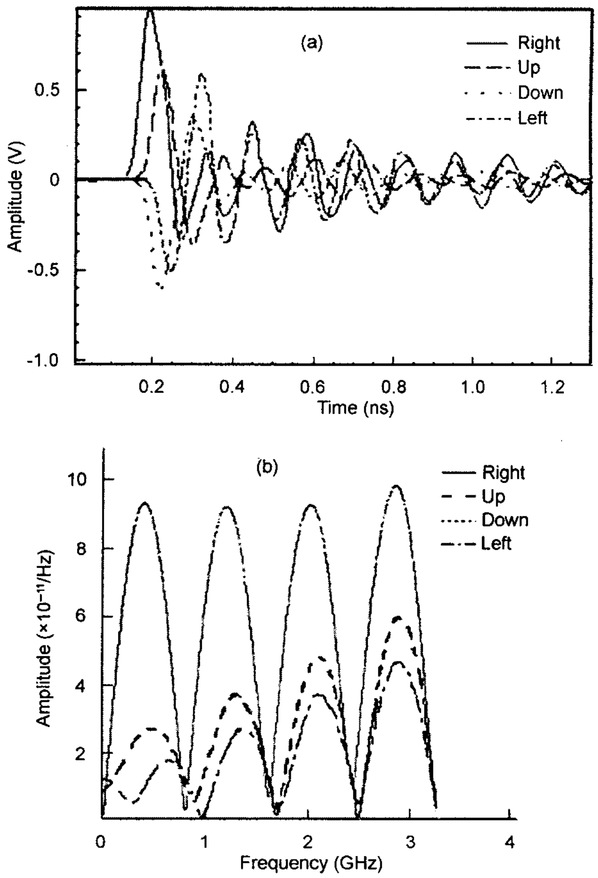

Fig.4 Signals on the new designed stripline electrodes.
(a) Currents versus time for a passing transversely displaced (β=1, x=0.5r_b, y=0) bunch; (b) Fourier transformation of the signals in (a).

The time resolution is defined by the bandwidth of the signal as [5]

$$\tau = \frac{1}{\pi \cdot \mathrm{BW}} \tag{1}$$

With BW approximately equal to 400MHz, the time resolution of the new designed BPM structure is 0. 8 ns, which is applicable in HLS LINAC and transfer line.

2.3 Coupling between electrodes

Fig.5 gives out the coupling coefficients between adjacent electrodes and opposite ones of BPM. The coupling coefficient is no more than –15 dB from DC up to 2.9 GHz.We can also find that the coupling between adjacent electrodes is prone to be larger than that between opposite ones within the range of 3 GHz.

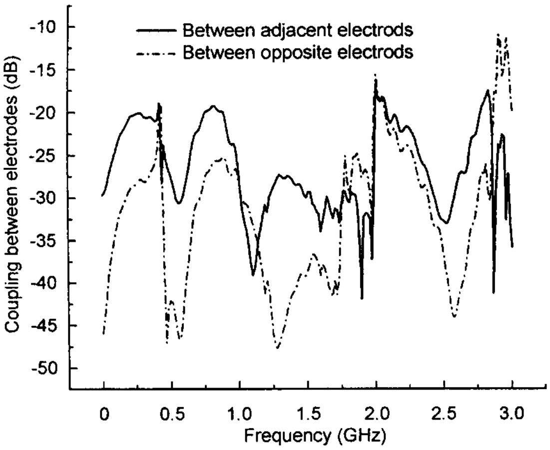

Fig.5 Coupling between electrodes of BPM.

2.4 Sensitivity and linearity

Fig.6 gives the BPM linearity results simulated by Mafia, which are signal logarithmic ratio ln(R/L)/2 and difference-over-sum (R–L)/(R+L). From Fig.5, we can conclude that signal logarithmic ratio has a better performance in linearity than difference-over-sum.

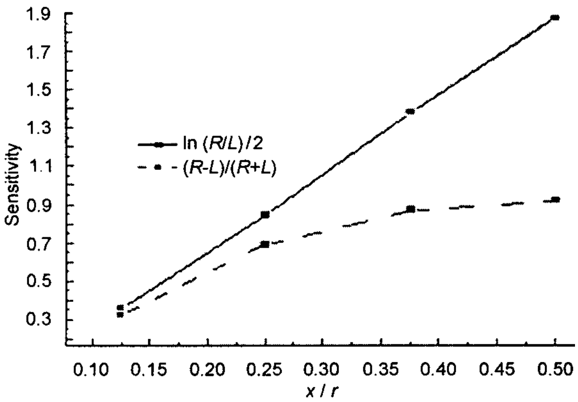

Fig.6 Sensitivity versus the beam horizontal offset x/r with the beam vertical offset y=0.

The sensitivity of strip line BPM for logarithmic ratio can be expressed as[1]

$$S=\frac{80}{(\ln 10)b}\times\frac{\sin(\phi/2)}{\phi/2} \tag{2}$$

Taking b=25mm and $\phi=\pi/3$ into Eq.(2), we get the theoretical position sensitivity value of the new designed BPM structure equal to 1.33 dB/mm for logarithmic ratio. From Fig.6, we can calculate the position sensitivity 20lg(R/L)/x[6] of the new designed BPM, which is 1.16 dB/mm. The difference between the two values is mainly attributed to the coupling between strip line electrodes.

3 Conclusion

In order to improve injecting efficiency of HLS 200 MeV LINAC, we design a new non-interceptive strip line beam position monitor (BPM) as a substitution for the original interceptive fluorescent target. The theoretical analysis and bench test result show that the BPM has a characteristic impedance of (50±5)Ω, a reflection coefficient of less than –4 dB, a bandwidth of 400 MHz, a coupling coefficient of less than –15 dB, and a sensitivity of 1.16 dB/mm. Additionally, the strip line BPM has a good linearity. And we expect a beam based test after installment of the strip line BPM on HLS LINAC in future.

References

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