DEVELOPMENT OF AN S-BAND RF DEFLECTOR AT IHEP *

J.P. Dai #, J.R. Zhang, G.X. Pei, M. Hou, IHEP, Beijing, China
Q. Gu, M.H. Zhao, S.P.Zhong, SINAP, Shanghai, China

Abstract

We have measured the bunch length of a photo-cathode RF gun using a transverse RF deflector. This is the first time in China that such a transverse RF deflector has been developed and used to measure the picosecond bunch length. Potential applications include the ability of reliable measurement of sub-ps bunch length and observation of the variable electron beam characteristics, such as emittance and peak current, within the length of the bunch.

INTRODUCTION

The development of future free electron lasers and linear colliders requires high brightness electron beams with bunch lengths on the order of ps or sub-ps. Reliable measurement of such a short bunch is not trivial problem. A simple way to measure bunch length and possible unfold beam quality variations over the bunch length is to ‘streak’ the bunch using a transverse RF deflector at its zero-crossing phase.

The principle of this method is shown in Fig. 1. The deflector is able to deliver very high and very fast changing transverse deflecting field and is used to sweep the beam transverse to the direction of propagation. It operates at zero-crossing phase of the field, where the time derivative is the maximum, so that the bunch is “titled”, or in other words, is given a strong correlation between longitudinal z-coordinate and transverse position. Measurement of the beam size downstream on a profile monitor is used to measure the bunch length. It is possible to deliver a large amount of power to such a device to give the beam an extremely strong kick and thereby obtain sub-ps bunch length resolution.

This method has already been demonstrated at SLAC [1] and DESY [2][3]. The experiment results show that using RF deflector to measure the micro-bunch lengths in future FELs and ILC is quite promising. It is an advanced, reliable and economical method.

As the R&D work of the XFEL in China, we have developed an RF deflector and used it to measure the bunch length of a photo-cathode RF gun located at Shanghai Institute of Applied Physics (SINAP).

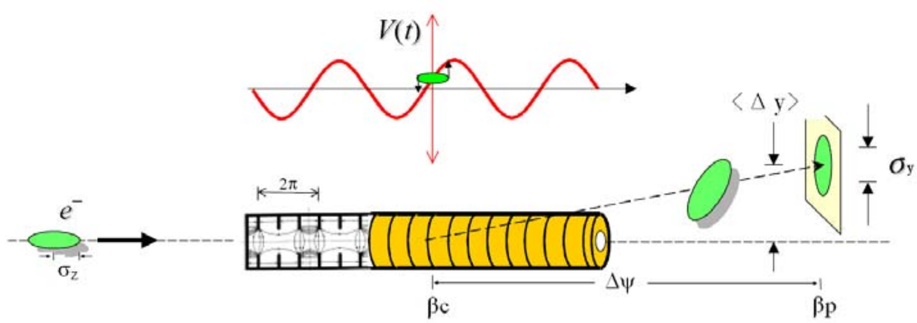

Figure 1: Principle of operation of the TM11 transverse RF deflector

DEVELOPMENT OF RF DEFLECTOR

The transverse RF deflector is an iris-loaded waveguide structure [4]. We choose the travelling wave structure simply because we understand it well. It operates at 2856MHz because high power klystrons and other equipments are readily available in our lab. Compared with other modes, 2π/3 mode gives the largest deflecting efficiency, so a 2π/3 phase shift per cell has been chosen. It works in backward-wave type mode. The deflecting mode in the iris-loaded cylindrical waveguides is HEM11 or TM11-like mode. For the polarization degeneration, minor imperfections in the structure could cause the mode to rotate, so two additional holes are provided to stabilize the mode and prevent rotations.

Shown in Fig. 2 is our developed RF deflector and Table 1 describes its main parameters.

The deflecting voltage given by the shunt impedance of the structure is

$$V_t \approx 1.6MV/m/MW^{0.5} \cdot L \cdot \sqrt{P_{in}} \qquad (1)$$

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jpdai@ihep.ac.cn

Table 1: Main Parameters of the RF Deflector

Parameters	Value
Type of structure	Constant impedance structure
Mode type	TM11 (Hybrid mode)
Frequency	2.856 GHz
Number of cell	10
Phase shift/cell	$2\pi/3$ (120^o)
Cell length	35 mm
Wavelength, λ	105 mm
Relative group velocity	-0.0189
Transverse impedance	~16Mohm/m

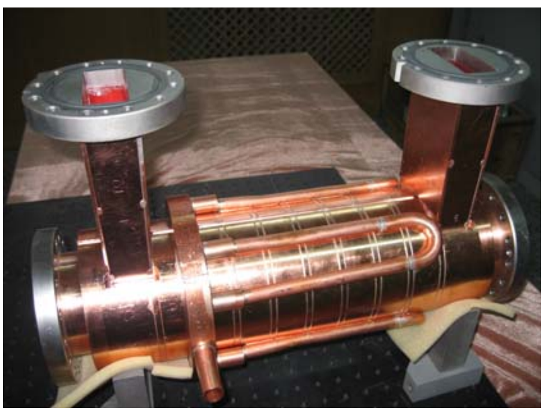

Figure 2: Picture of the RF deflector

So, for the deflector of L= 0.35m, we get about 177kV with an input power, Pin=100kW.

BUNCH LENGTH MEASUREMENT

The RF gun test bench located at SINAP could produce high brightness electron beam with the RMS length of about 4~6 ps, and it was suitable to be used to research and demonstrate the bunch length measurement with the above RF deflector.

Fig. 3 is the layout of the measurement setup. Not shown are the driven laser system and the 30MW RF power system shared by the deflector and the RF gun. The phase and amplitude of RF power inputted in the deflector may be adjusted with the dedicated phase shifter and attenuator. Since the cavity BPM did not work well at this moment, both the beam position and size were measured with a YAG screen. The beam trajectory may be tuned by the triplet magnets and the quadrupole magnet.

Regarding the beam is relativistic, the transverse centroid offset at the screen, $<\Delta y>$, and the deflected length, $\sqrt{\sigma_y^2-\sigma_{y0}^2}$ due to a deflecting voltage, V_t, may be written approximately as:

$$<\Delta y> = -C\cdot V_t \cdot \sin(\varphi-\varphi_0) \quad (2)$$

$$\sqrt{\sigma_y^2-\sigma_{y0}^2} = C\cdot V_t \cdot \beta_L \cdot \sigma_z \cdot \cos(\varphi-\varphi_0) \quad (3)$$

Where C is a constant related with the beam energy and the lattice of the beam transport line

$$C = \frac{e}{E_0}\cdot\sqrt{\beta_c\cdot\beta_p}\cdot\sin\Delta\Psi \quad (4)$$

φ_0 is the RF phase of zero-crossing of the field phase, φ is the RF phase, σ_{y0} is the original transverse beam size when the deflection is zero, β_L is the phase constant of the deflector, $\beta_L=2\pi/\lambda$. σ_z is the bunch length needed to be determined

In the measurement, we first determined the zero-crossing phase and calibrated the constant C. The most direct calibration way was to observe the beam position, $<y>$, on the YAG screen while the RF phase of the deflector is varied, as shown in Fig. 4.

From Fig. 4, we got the zero-crossing phase, φ_0=155 degree, and $C\cdot V_t$=4.6mm at this voltage whose input power is 2.7kW.

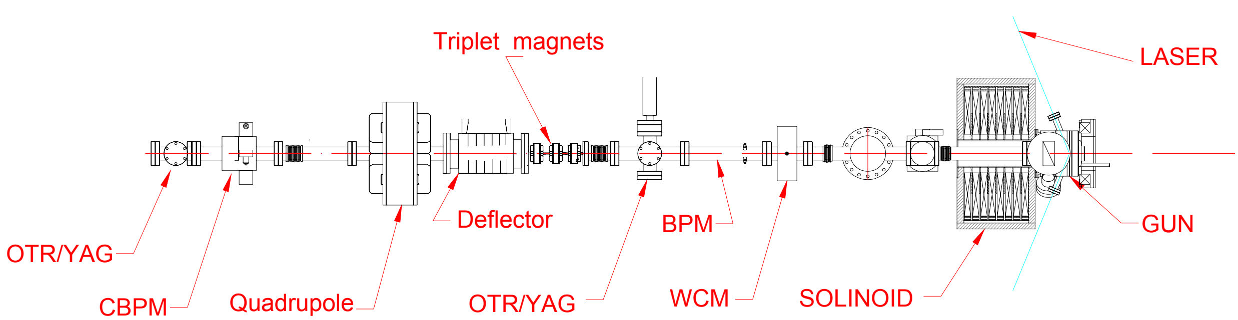

Figure 3: Layout of the bunch length measurement setup

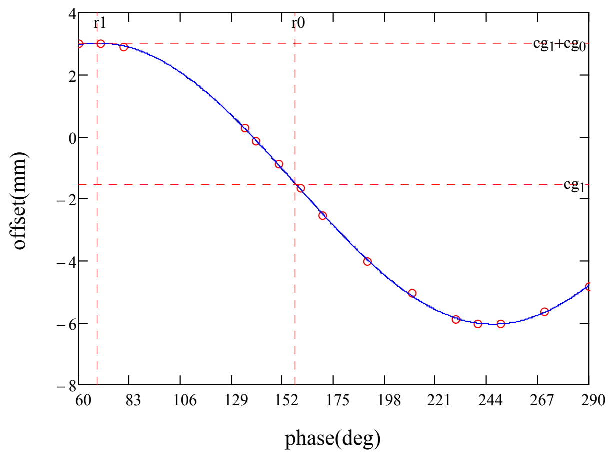

Figure 4: Beam centroid offset as the function of the RF phase of the deflector

Then, we got the deflected length by measuring the RMS beam sizes at zero-crossing phase to get σ_y and 90 degree to get σ_{y0} while the different deflecting voltage was varied, as shown in Fig. 5.

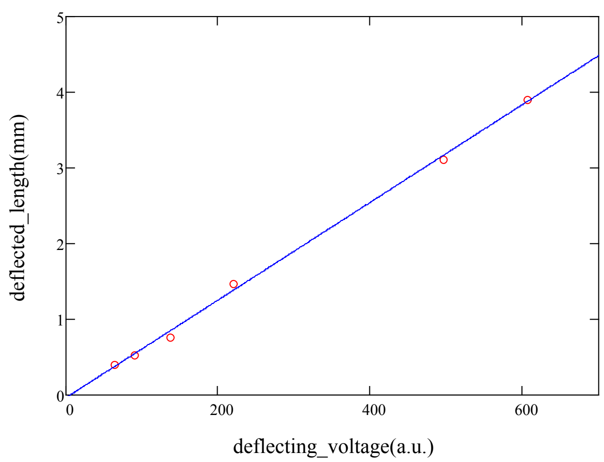

Figure 5: Beam deflected length as the function of the voltage of the deflector

From Fig. 4 and Fig 5, we got the RMS bunch length of the RF gun, which is 5.1ps. This agrees with the prediction from the driver laser parameter of the RF gun.

CONCLUSION

We have demonstrated the bunch length measurement of the RF gun located at SINAP using a RF deflector. Next, we will use the Cavity BPM (CBPM) to measure the beam position instead of the YAG screen so as to improve the measurement precision.

ACKNOWLEDGEMENT

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