

# MEASUREMENT OF SOME BEAM PARAMETERS USING TUNE MEASUREMENT SYSTEM FOR HLS \*

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## Abstract

The paper introduces the measurement of some beam parameters using tune measurement system for Hefei Light Source (HLS), which include the betatron tune, average beta function, natural chromaticity, corrected chromaticity, and central frequency. Additionally, the measurement of the influence on the betatron tune shift by DC clearing electrodes is also described. Some measurement results are given. The measurement results are compared with the theoretical values and shown to be in good agreement.

## 1 INTRODUCTION

The Hefei Light Source (HLS) consists of an 800MeV electron storage ring and a 200MeV Linac injector. To commission the 800MeV storage ring expediently, and to know more of the storage ring for improving it, it is very important to measure some beam parameters of electron storage ring such as the betatron tune, beta function, natural chromaticity, corrected chromaticity, central frequency, and the influence on the betatron tune shift by DC clearing electrodes. These parameters were measured by frequency domain technique.

The swept frequency excitation method was used to measure betatron tune. The beta function is given by the betatron tune shift with quadrupole strength. The dispersion is inferred from the orbit change induced by a shift in the RF frequency. The natural chromaticity is obtained by detecting the variation of the betatron tune as a function the main dipole field strength. The corrected chromaticity is given by the betatron tune shift with RF frequency. The central frequency is obtained by measuring the chromaticity for different sextupole strengths.

## 2 TUNE MEASUREMENT SYSTEM

Because the beam betatron motion is weak, it is very difficult to measure the beam betatron motion immediately. So, the swept frequency excitation method was used to measure betatron tune[1]. The tune measurement system is shown as Fig.1. This system

consists of a stripline BPM, an 180° hybrid, a BPF amplifier, a mixer, a spectrum analyzer with tracking generator, a power amplifier, an excitation electrode, a PC computer, and a GP-IB card.

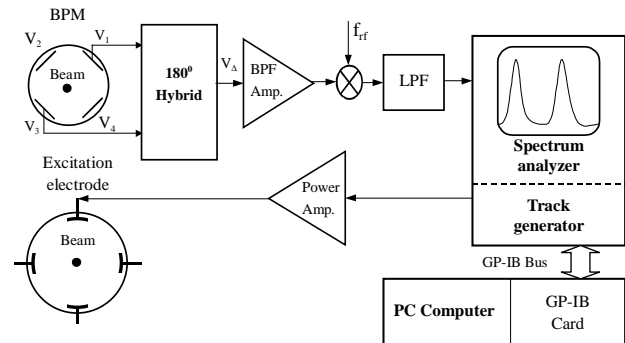


Figure 1: Block diagram of tune measurement system

The difference signal from the stripline electrodes is demodulated by AM detector. The signal will be analyzed by the spectrum analyzer with tracking generator. The output signal of the tracking generator is amplified by a power amplifier. The excitation electrode is driven by the amplified tracking signal to excite betatron oscillation. The PC computer and GP-IB card are used to acquire data from the spectrum analyzer so that the betatron tune can automatically be measured. The program is written by HP VEE.

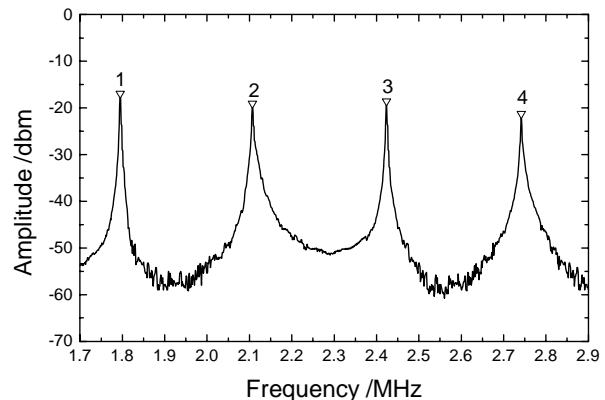


Figure2: Frequency spectrum of the beam betatron signal on Spectrum Analyzer

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### 3 MEASUREMENT OF TUNE

#### 3.1 Measurement result of betatron tune

Fig.2 shows the typical tune signal on the spectrum analyzer, in which the point 2 and 3 show the frequencies of the horizontal  $\beta$  sideband, and the point 1 and 4 show the frequencies of the vertical  $\beta$  sideband. We may get that the horizontal tune  $\nu_x$  and vertical tune  $\nu_y$  is respectively 3.5346 and 2.6047. The measurement accuracy is about  $1 \times 10^{-4}$ .

#### 3.2 Measurement of the influence on the tune shift by DC clearing electrodes

In HLS, there are some DC clearing electrodes with -800V in order to eliminate the ion trapping[2]. We calculate the electric field produced by DC clearing electrodes as[3]

$$\begin{cases} E_x = \frac{V_{Clear}}{\ln(r_w/R_w)} \left[ \frac{x}{x^2 + (y+c)^2} - \frac{x}{x^2 + (y+b)^2} \right] \\ E_y = \frac{V_{Clear}}{\ln(r_w/R_w)} \left[ \frac{y+c}{x^2 + (y+c)^2} - \frac{y+b}{x^2 + (y+b)^2} \right] \end{cases} \quad (1)$$

Here,  $b \approx 37.75\text{mm}$ ,  $c \approx 48.98\text{mm}$ ,  $R_w \approx 1.14$ ,  $r_w \approx 4$ ,  $V_{clear}$  is voltage of DC clearing electrodes.

The quadrupoles are

$$\begin{cases} K_x = \frac{e}{E_0} \frac{\partial E_x}{\partial x} \Big|_{0,0} = \frac{0.8eV_{Clear}}{E_0} \left( \frac{1}{c^2} - \frac{1}{b^2} \right) \\ K_y = \frac{e}{E_0} \frac{\partial E_y}{\partial y} \Big|_{0,0} = -K_x \end{cases} \quad (2)$$

The tune shifts calculated with above focus strength are

$$\begin{cases} \Delta\nu_x = -3.12 \times 10^{-6} V_{Clear} \\ \Delta\nu_y = 2.42 \times 10^{-6} V_{Clear} \end{cases} \quad (3)$$

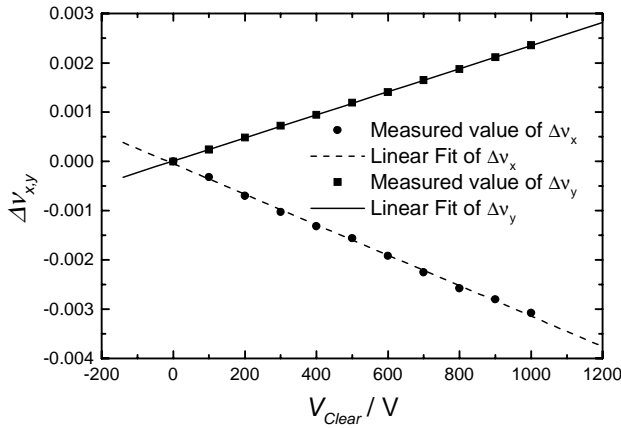


Figure 3: The tune shift as a function of the change in  $V_{Clear}$

Fig.3 shows the tune shift as a function of the change in voltage of DC clearing electrodes. According to the experimental results, we get

$$\begin{cases} \Delta\nu_x = -3.09 \times 10^{-6} V_{Clear} \\ \Delta\nu_y = 2.34 \times 10^{-6} V_{Clear} \end{cases} \quad (4)$$

Comparing equation (4) with equation (3), the measured results are fit close to the calculated results.

### 4 MEASUREMENT OF $\beta$ FUNCTION

The simplest beta function measurement is to detect the shift in the betatron tune as the strength of an individual quadrupole magnet is varied. In HLS, four magnets are connected to the same power supply, and then the strengths  $K_i$  ( $i=1, \dots, 4$ ) of four quadrupoles must be changed simultaneously, all by the same amount  $\Delta K$ . In this case, the induced betatron tune change is related to the average beta function at the four quadrupoles as[4]

$$\langle \beta_{x,y} \rangle_m \approx \pm 4\pi \frac{\Delta\nu_{x,y}}{m\Delta K l} \quad (5)$$

Here,  $l$  is the length of the quadrupole,  $m=4$ .

Fig.4 shows the average beta function measured by above method as compared with the theoretical beta function.

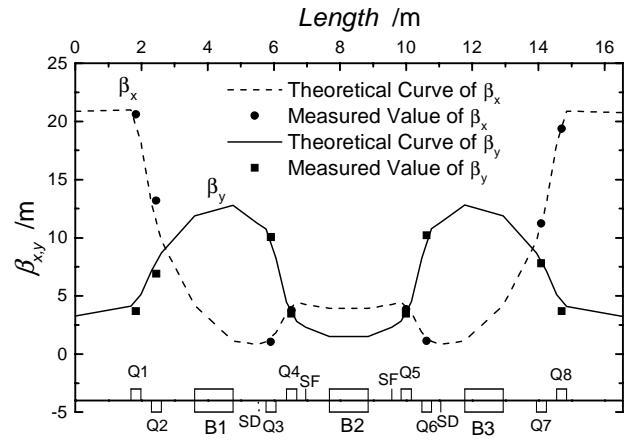


Figure4: Comparing the measured average beta function with the theoretic beta function

Additionally, we also measured the beta functions at Q7W and Q8N by the beam-based alignment system[5]. Comparing the measured beta functions at Q7W and Q8N with the theoretic value is shown by table 1. According to the experimental results, the measured beta functions are close to the theoretic curve in HLS.

Table 1 Comparing the measured beta functions at Q7W and Q8N with the theoretic value

	$\beta_x$ (m)		$\beta_y$ (m)	
	Theoretic value	Measured value	Theoretic value	Measured value
Q7W	9.69	7.91	9.88	7.55
Q8N	20.75	22.09	3.24	3.57

## 5 MEASUREMENT OF CHROMATICITY

In an electron storage ring, the chromaticity is characterized by the energy dependence of the tune, which is denoted  $\xi$ . Without the chromaticity correction, the natural chromaticity is a negative value, the head-tail instability<sup>[2]</sup> will occur. The natural chromaticity is usually corrected by means of two or more sextupole families. The corrected chromaticity should be slightly positive to avoid the head-tail instability.

### 5.1 Natural chromaticity

The natural chromaticity is obtained by detecting the variation of the betatron tune as a function the main dipole field strength, it is given by[4]

$$(\xi_{x,y})_{nat} \approx \frac{\Delta v_{x,y}}{\Delta I / I} \quad (6)$$

Fig.5 shows the variation of the tune as a function of the main dipole field strength.

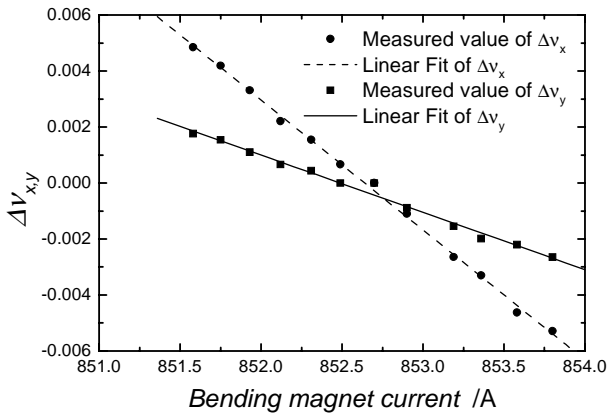


Figure5: Tune variation as a function of the change in bending magnet current

According to equation (6), the natural chromaticity in horizontal and vertical is respectively  $-6.059$  and  $-2.634$ , whereas the design value is respectively  $-6.13$  and  $-2.41$ . The measured results are fit close to the design values.

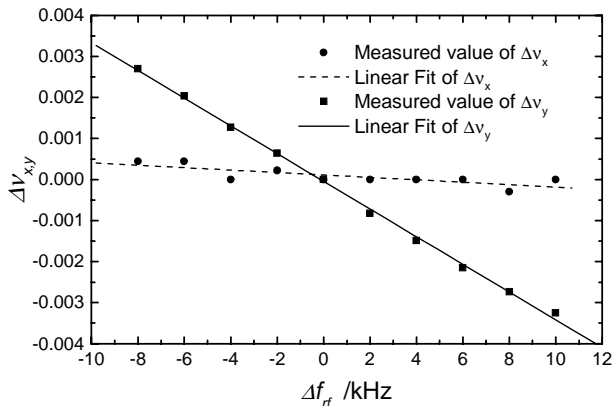


Figure6: Tune variation as a function of the change in RF frequency

### 5.2 Corrected chromaticity

The corrected chromaticity can be determined by measuring the tune shift as a function of the RF frequency[4]

$$(\xi_{x,y})_{corr} \approx -\alpha_c \frac{\Delta v_{x,y}}{\Delta f_{rf} / f_{rf}} \quad (7)$$

Fig.6 shows the variation of the tune as a function of the RF frequency change. According to equation (7), the corrected chromaticity in horizontal and vertical is respectively  $0.268$  and  $3.057$ .

### 5.3 Central frequency

The central frequency can be determined by Measuring the chromaticity for different sexupole strengths. When the beam passes (on average) through the center of the sextupoles and quadrupoles at the central frequency, the tune doesn't vary as the change of sexupole strength. The measurement result of the central frequency is shown in Fig.7. Here, the central frequency is about  $204.03225 \pm 0.00089$  MHz.

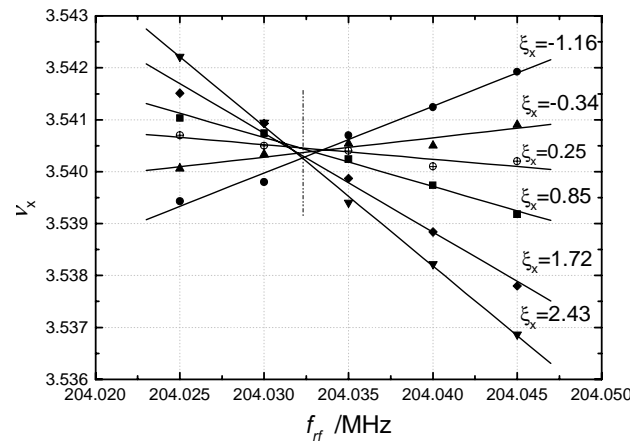


Figure7: The measurement of the central frequency

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