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Effect of the RF cavity temperature on low-energy injection at HLS

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The resonant frequency shift caused by the temperature of the RF cavity at the Hefei Light Source has been measured and the results analysed. The effect of this frequency shift on low-energy injection with a low cavity voltage is discussed, and a new injection mode is proposed.

Keywords: RF cavities; frequency shifts; injection modes.

1. Introduction

Hefei Light Source (HLS) is a dedicated synchrotron radiation light source which adopts a low-energy injection mode. The main parameters relating to the RF system are listed in Table 1.

During the operation of HLS, we found that the temperature and the frequency of the cavity shifted noticeably with a change of the cavity voltage, and sometimes the frequency shift would lead to loss of the beam. This is discussed in the following.

2. Frequency shift of the cavity

The HLS cavity (Fig. 1) is a re-entrant cavity made of a copper/stainless-steel compound material. Using code *URMELT* (DESY M-85-11), we calculated the normalization distribution of the power along the skin of the cavity; the results are shown in Fig. 2.

Since the cooling water of our cavity distributes poorly and its flow is not very large, the cavity temperature and its distribution will change noticeably when the cavity voltage, *i.e.* the power, changes. In addition, since our cavity is made of copper/stainless steel, it is relatively easily deformed as the temperature changes, leading to frequency shifts.

Table 1
Main parameters of HLS.

Beam energy, E	200 MeV (injection), 800 MeV (storage)
Momentum compact factor, α_p	0.044
RF frequency, $f_{\rm rf}$	204.035 MHz
Revolution frequency, f_0	4.53411 MHz
Bunch number, k_b	45
Cavity voltage, V_c	50–100 kV
Cavity shape	Re-entrant
Cavity material	Copper/stainless steel

For our cavity the relation between the frequency shift and the movement of the tuner is

$$\Delta f_r = 0.0043\Delta L. \quad (1)$$

We define the tuner position, L_R, as the position where the resonant frequency of the cavity is 204.035 MHz, *i.e.* the frequency of the RF source. By measuring the movement of L_R caused by the change of the cavity voltage, we may obtain the frequency shift quantitatively.

From Fig. 3, we know that when the cavity voltage increases to 100 kV from 42 kV, the movement of L_R is 7 mm, and this means that when the tuner is fixed the frequency of the cavity decreases by about 30 kHz.

3. Effect of frequency shift on injection

The RF system at HLS operates with no feedback system. In the injection procedure the cavity voltage changes greatly, and therefore the frequency also shifts greatly. Because the tuning angle, ψ, is defined in the following form,

$$\tan\psi = -[2Q_0/(1+\beta)](f_{\rm rf} - f_r)/f_{\rm rf}, \quad (2)$$

it has to be very large (near $-90°$) so that the ψ shift caused by the frequency shift is relatively small and the beam is far from the Robinson instability region. If the tuning angle was near the optimum tuning angle, ψ_m, then

$$\tan\psi_m = -I_0 R_s \sin\varphi/[V_c(1+\beta)], \quad (3)$$

and the frequency shift would easily lead to the Robinson instability and beam loss. This is injection mode I, shown in Fig. 4.

Although injection mode I is simple and the RF system may operate without any feedback system, the reflected power is

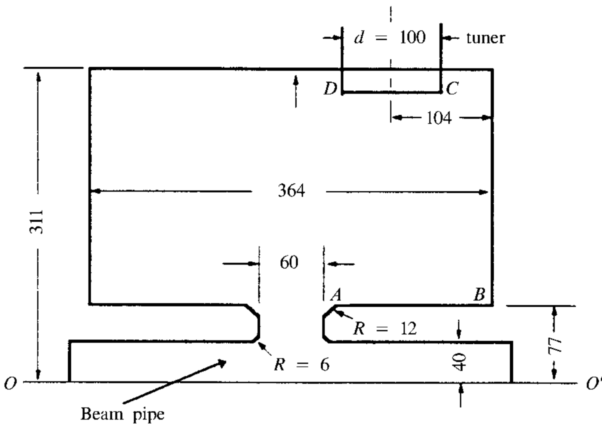

Figure 1
Shape of the RF cavity (dimensions in millimetres).

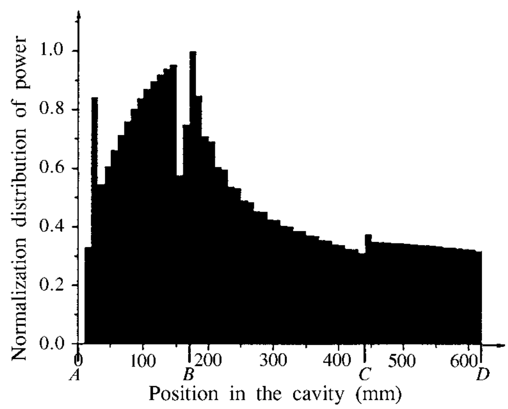

Figure 2
Distribution of the power of the HLS cavity.

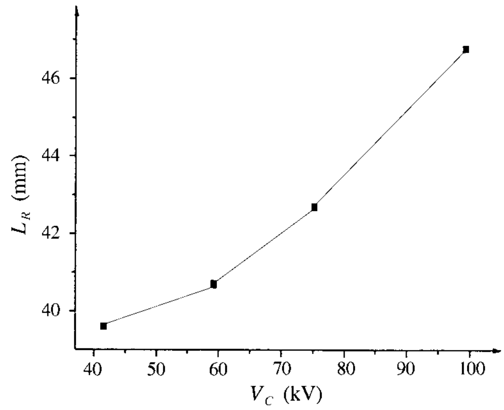

Figure 3
Movement of L_R with the change of cavity voltage.

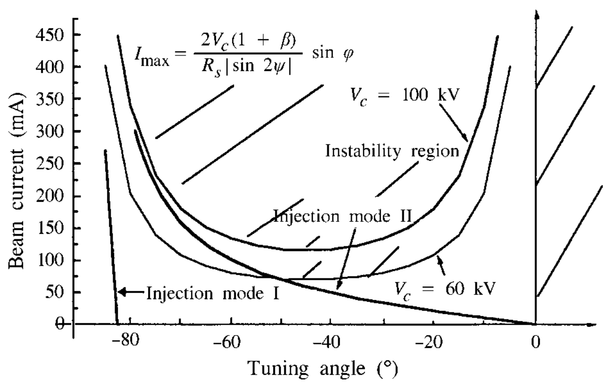

Figure 4
Threshold current determined by the Robinson instability.

extreme. Usually, more than 50% of the power is reflected, which often damages the circulator or the RF source.

4. Improvement of the injection mode

In order to decrease the reflected power, we will adopt a new injection mode, mode II (Fig. 4).

In this mode, the cavity voltage is increased to 100 kV and fixed by an amplitude loop, and the tuning angle, ψ, is the optimum angle, ψ_m, and is controlled by a tuning loop. The reasons for choosing the cavity voltage to be 100 kV are as follows.

(i) The tuning angle, ψ, is the optimum angle, ψ_m, and the movement of the tuner is adjusted by the tuning loop as

$$L - L_R = 6.1 \times 10^6 I_0/V_c. \tag{4}$$

If V_c = 100 kV, the tuner will move 18.3 mm altogether when the beam current accumulates to 300 mA from zero; however, if V_c = 40 kV or less, the tuner would move 45.6 mm or more, and it is impossible for our tuner to move such a long distance.

(ii) The threshold of the beam current, $I_{\max}$, determined by the Robinson instability, is

$$I_{\max} = 2V_c(1+\beta)\sin\varphi/R_s \sin|2\psi|. \tag{5}$$

If V_c is higher, the threshold of the beam current will be higher.

(iii) When the tuner is near the 25 mm position, the longitudinal multi-bunch instability driven by the TM_{012} mode of the cavity often leads to the difficulty of beam accumulation. If V_c is chosen as 100 kV, the tuner will be at 30–49 mm, and so this dangerous tuner position can be avoided.

5. Conclusions

A new injection mode has been tested successfully. Efforts to improve the water-cooling system of our cavity are continuing.

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