6 - 47 Design and Test of Automatic Tuning System for SSC-LINAC RFQ

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This paper introduces the structure of the RFQ cavity tuner and the influence of the tuner on the Cavity field. According to the actual condition of cavity tuner, automatic tuning system is developed. The system was tested online and the phase difference between the cavity input signal and the cavity sampled signal is less than |5°|, which meets our requirements.

The cavity tuner system is one of the major part of the SSCLINAC RFQ. Its function is to complete the tuning of the cavity to ensure that the cavity is in better working condition. The tuning system has two main parts, the cavity tuner and the automatic tuning control system. The cavity tuner consists of four sets of tuning poles, which are driven by step motors. The automatic tuning control system is based on the full digital system of FPGA and DSP. The system consists FPGA main board and stepper motor control board.

1. The principle of cavity tuning

RFQ cavity is four bar type linear accelerator cavity. We can adjust the inductance and capacitance distribution of each unit to change the frequency of the cavity and the field distribution. For this, it can add the tuning pad and tuning bar in some units, as shown in Fig. 1. The effect of the block is to shorten the current circuit of the resonant unit, which reduces the inductance, according to $\omega^{-2} = LC$, thus the local frequency of the unit will increase, then the whole cavity through the coupling effect between unit frequency increase. Four tuning bars are installed into the cavity from the side of cavity, as shown in Fig. 2. It is equivalent to change inductance of the unit, and change the frequency.

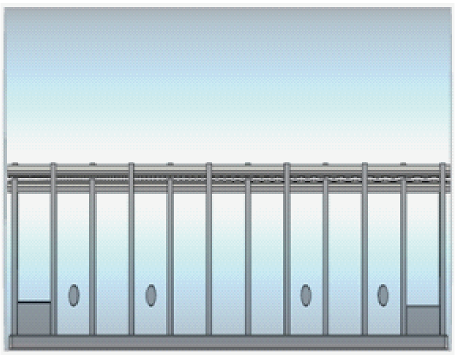

Fig. 1 (color online) Tuning block and positions of tuning pole.

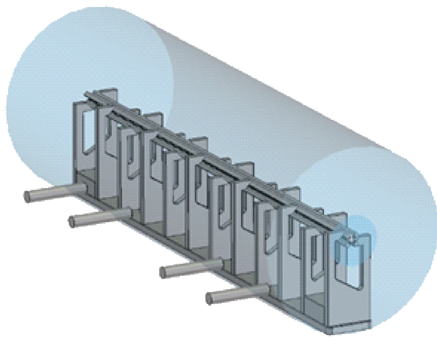

Fig. 2 (color online) Tuning bars installed into the Cavity.

When the height of the left block is 86 mm, the height of the right block is 76 mm, the frequency can reach 53.667 MHz. As for the tuning lever, its range is designed to be 0∼350 mm. In order to avoid field shape distortion, movement of four tuning bars will be synchronized, their tuned mass as shown in Fig. 3(a), can make the biggest cavity frequency increase of 120 kHz, without change of the field distribution as shown in Fig. 3(b).

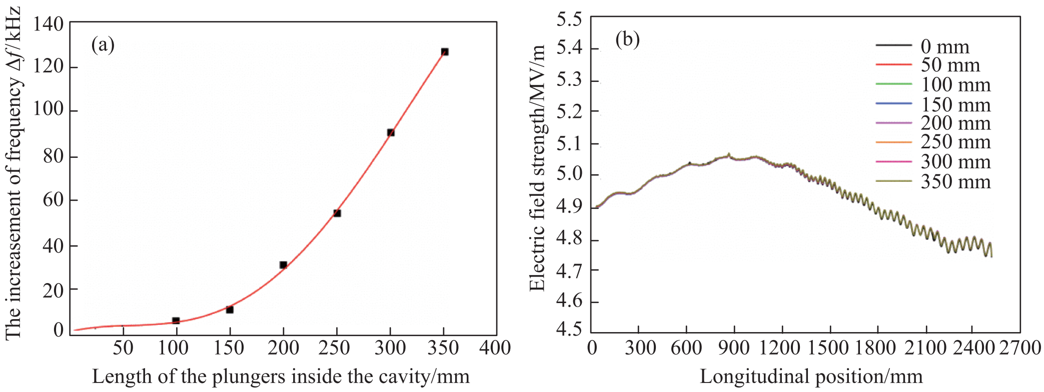

Fig. 3 The tuning amount of cavity frequency (a) and the field distribution (b) to the position of tuning bars inside the cavity.

2. Automatic tuning principle and system composition

2.1 Working principle

The working principle of frequency stabilization system is to use the single tuned filter characteristic of resonant cavity. When the cavity detuning input and output phase shift changes. We can use the frequency detection unit detects cavity of input and output phase shift changes (phase error), frequency control unit control cavity to reduce phase shift change direction, eventually eliminate the detuning of the resonant cavity frequency.

2.2 System composition

Cavity frequency stability of the system is consisted of frequency detection unit frequency control unit, as shown in Fig. 4. The frequency detecting unit is used to detect phase difference between the input signal and cavity sampling signal. The main function of the frequency control unit is to control stepping motor to move in the corresponding direction to achieve the goal of tuning cavity depending on the output phase difference of frequency detection unit.

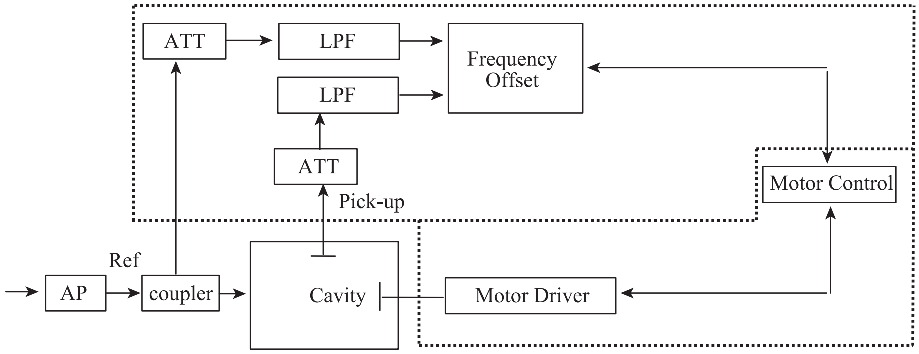

Fig. 4 Automatic frequency stabilization system.

3. Design of frequency detection unit

The frequency detection unit is shown by Fig. 5.

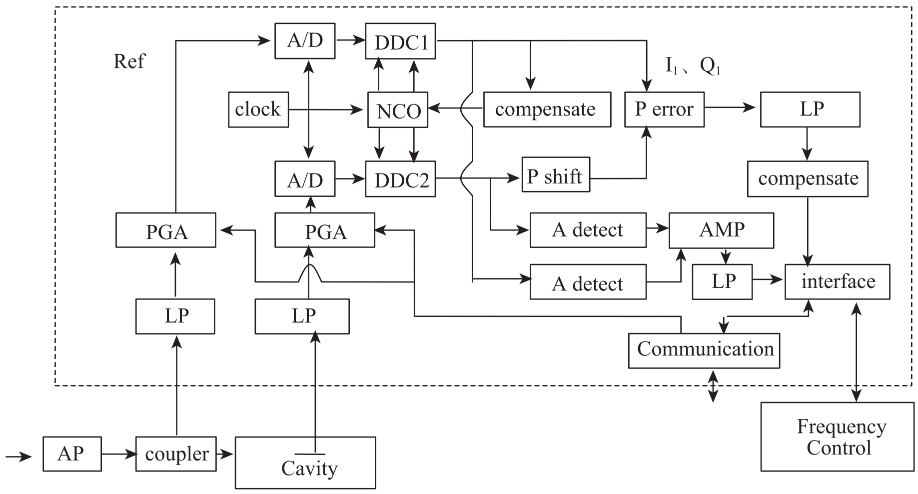

Fig. 5 Frequency test unit principle design diagram.

4. Step motor control

Signal from the frequency detection unit is sent to the frequency control unit through McBSP (multi-channel buffer serial port) after calculating the angle of cavity dissonance. The core of the frequency control unit is DSP2812, which function is output pulse, direction, and enable signal. The frequency control unit detects the dissonance phase value according to certain frequency, and the direction of the step motor is controlled according to the dissonance phase value. The adjustable parameters in the system mainly have phase dead zones, phase discrimination frequency, step motor input pulse frequency. These three parameters can be combined with the loss harmonic speed and the torque of the motor.

5. The test results

The system has a long-term power test on RFQ cavity. In cavity power 10 kw, 20 kw and 30 kw the system works normally under the condition of the phase of the dead zone $|1.5°|$, $|3.5°|$ and $|5°|$. with the increase of the power of the cavity, the Cavity detuning is accelerated, and the greater area of the dead zone is required to ensure that the system is working properly. The problem needs to be solved by modifying the control of the step motor.