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HLS RF cavity development in NSRL phase II project

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Abstract

Hefei light source (HLS) is mainly composed of an 800 MeV electron storage ring and a 200 MeV Linac functioning as its injector. A new RF cavity has been developed successfully for the HLS storage ring in NSRL phase II project. In this paper, the design, fabrication and measurement of the cavity are described in detail. The results and some analyses are presented.

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Keywords: RF cavity; Input coupler; Frequency tuner; Electron storage ring

1. Introduction

Hefei light source (HLS) is mainly composed of an 800 MeV electron storage ring and a 200 MeV Linac functioning as its injector. On the machine side, the goals of the NSRL phase II project upgrading plans are (1) regular operation of general purpose light source (GPLS) mode with typically 300 mA accumulated current in every fill, with more than 8 h lifetime and (2) alternatively, regular high brightness light source (HBLS) mode operation with 150 mA current of 4 h lifetime [1]. The HLS RF cavity must fulfill the following requirements:

- A new copper cavity, with an operating frequency of 204 MHz and a power handling capability up to 20 kW, is needed to establish a sufficient RF gap-voltage of cavity for accelerating beam current from 200 MeV to 800 MeV and maintaining acceptable quantum lifetime and suitable bunch length.
- The loop type input coupler with suitable coupling factor can transfer a CW power of 20 kW and maintain a match between the final RF amplifier and cavity in operation with a

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larger beam current so as to insure the stability of the beam–cavity system.

- The tuning loop can compensate frequency error effectively for either detuning by the beam or temperature effects to keep the cavity tuned status.
- High-order modes are calculated first and the dampers will be added to the RF cavity in following works so as to acquire an appropriate low-impedance environment for the beam and to reduce the high coupled bunch instability growth rates at high beam current.

The RF cavity has been developed successfully for the HLS storage ring. In this paper, the design, fabrication and measurement of the cavity are described in detail. The results and some analyses are presented.

2. HLS cavity development

2.1. Cavity-shape selection and fabrication

HLS is a light source with a beam energy of 800 MeV and a beam current of 200–300 mA. Besides compensating for the synchrotron radiation power loss and providing sufficient beam lifetime, the RF system of the storage ring is used to accelerate the beam from 200 MeV to 800 MeV. In the phase II project, the ring was designed to operate in both GPLS and HBLS modes. The RF system is required to provide a cavity gap-voltage of 250 kV and a beam power of 5 kW.

A new cavity has been designed [2] and manufactured. To point at the problems appearing in the original cavity (made in phase I project), the choice of the cavity material, the selection of the cavity shape and the improvement of cooling type were given special attention in design. The shape optimization, RF parameters calculation and power density distribution on the cavity wall were numerically simulated with SUPERFISH-Code [3]. HOMs were computed with URMEL-T [4]. The result is shown in Tables 1 and 2, respectively.

A re-entrant type cavity is adopted. It consists of five parts: a center-body-section, two end caps and two noses with beam pipes. In the center-body-section, there are ten openings: a coupler port, a vacuum pumping port, an observation port, a vacuum measurement port, two pick-up ports, two tuner ports and two ports for the HOMs restrainers. There are another four ports on the end cap for the antenna-type and loop-type HOMs dampers. The geometry construction of the cavity is shown in Fig. 1.

Table 1
Main design parameters of HLS cavity

Parameters	HLS cavity
Frequency (f)	204 MHz
Max. voltage (V_c)	250 kV
Shunt impedance cal. ($R_{sCal.}$)	3.9 MΩ
Unloaded Q value cal. ($Q_{0Cal.}$)	33 000
Coupling factor (β)	2.0
Tuning range (Δf)	>300 kHz
Temperature (T)	42.5 °C

Table 2
Main HOMs of HLS cavity

Monopole	Freq. (MHz)	R/Q (Ω)	Q
0-E-3	796	16.4	58 519
0-E-4	1101	2.6	48 457
0-E-6	1338	10.4	69 419
0-E-8	1713	3.1	81 615
Dipole		$R_{\perp}/Q$ (Ω/m)	
1-E-1	579	56.3	51 687
1-E-3	935	26.2	59 384
1-E-5	1139	2.6	49 311
1-E-7	1475	0.45	80 704

The most critical aspects of fabricating the shell were surface finish, dimensional control of the capacitance loading plates (noses), welding and ultra-high vacuum cleanliness. The main fabrication technology of HLS cavity is described as follows:

- Oxygen-free high-conductivity copper (OFHC copper) was chosen as the cavity material for its electrical, vacuum and mechanical properties.
- Each end cap was formed by hot spinning a copper plate in the steel model. The center-body-section-ring was specially forged in order to make the material more compact for