R&D STATUS OF A 3.5MEV RFQ ACCELERATOR FOR ADS STUDY IN CHINA

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Abstract

ADS technology is under study in China for the purpose to provide a new option for the development of nuclear power station, which is going to play a more important role in our newly increased power resources to meet the demand of the rapid economy growth. In an ADS basic research program supported by Chinese government, a long-pulse intense-beam RFQ accelerator will be built at IHEP, Beijing, as the means to master the key technology in a CW RFQ. At present we have finished the design of the RFQ with pulse beam current of 50mA, output energy of 3.5MeV and length of 4.7m with two segments coupled by a resonant coupling cell. A technological copper model cavity of 1.2m long has been machined. The RF power supply of 352.2MHz, 1.2 MW is now under installation. In this paper, we will report the R&D activities on the RFQ, including the beam dynamics design, 3-D cavity modeling, the copper model manufacture and the RF power supply.

1 INTRODUCTION

Energy resource is a key issue for China's further economic development. To meet the needs of our economic growth in the new century, the contribution of nuclear energy in the total newly increased power supply must become larger. However, the present nuclear power stations dominated by the PWR in the world are facing some troubles which obstacle the development of nuclear power. ADS (accelerator driven subcritical system) is hopefully capable of avoiding these troubles and it is recognized as a prospective power system for fission energy. Nuclear energy development in China is just at the starting stage and it is worthwhile to exploit this novel option while developing the traditional nuclear power plants. A program for preliminary ADS study was lunched in 2000 supported by the Ministry of Science and Technology. Scientists from Institute of High Energy Physics (IHEP), China Institute of Atomic Energy (CIAE) and Peking University join in this program to conduct high-current proton linac study. Our major task in this five-year program is to build a high-duty factor front-end linac, which consists of an ECR ion source and an RFQ accelerator, as an intermediate step toward a CW front-end.

The long-pulse intense-beam RFQ accelerator will be built at IHEP. At present we have finished the design of the RFQ. A technological copper model cavity of 1.2m long has been machined. The RF power supply of 352.2MHz, 1.2 MW (decommissioned from LEPII) has been moved to IHEP from CERN and is now under installation. In this paper, we will report the R&D activities on the RFQ, including the beam dynamics design, 3-D cavity modeling, the copper model manufacture and the RF power supply.

2 RFQ DESIGN STUDY

The major parameter of the RFQ is listed in Table 1. This four-vane type RFQ consists of two sections, coupled with a resonant coupling cell. Each section has two technological segments.

Table 1 RFQ major parameters

Input Energy	75keV
Output Energy	3.5MeV
Peak Current	50mA
Duty Factor	6%
RF Frequency	352.2MHz
Maximum E_s	33MV/m
Beam power	210kW
Structure power	420kW
Total power	630kW
Total length	4.75 m

2.1 Beam dynamics design

Two codes (PARMTEQM[1] and LIDOS.RFQ[2]) were applied in the beam dynamics design to take the advantages of each one. We used LIDOS.RFQ code for the RFQ parameter design. As a result, there is no distinct division of gentle bunching and accelerating sections, as given by CURLI and RFQUIK. To consider the multi-pole effect, PARI was used to modify the designed parameters, and the beam dynamics simulation was done by PARMTEQM with the RFQ channel generated by PARI. Figure 1 plots the major parameters, including the focusing strength B, the synchronous phase Φ , the modulation factor m, the aperture radius a and the synchronous energy W, along the RFQ. PARMTEQM simulation shows the beam transmission rate is 98.1%, which is close to the result of 99.5% from LIDOS.RFQ. To simplify machining of the cavity and vane, a constant vane-tip radius of curvature ρ and a constant average aperture radius R_0 are chosen, and the ratio ρ/R_0=1 along all the length of the RFQ. Consequently, the cavity inner wall shape keeps the same along the RFQ and vane-tip can be milled with a single type of cutter throughout all the length of the RFQ.

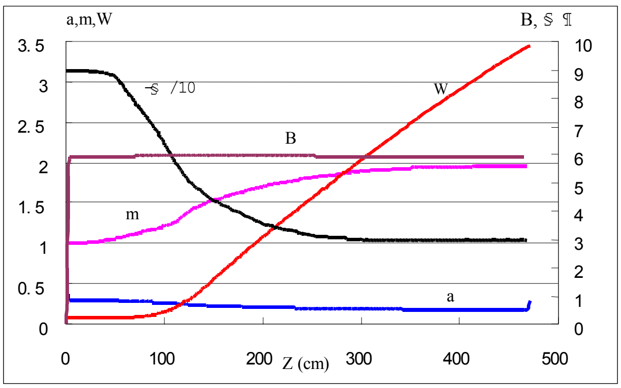

Fig. 1 RFQ major parameters along RFQ length

To separate the long RFQ into two sections at the right longitudinal position, LIDOS.RFQ code was applied again to the modified design version from PARI. At the middle cell of the RFQ, LIDOS.RFQ determines a dividing location where both the transverse and the longitudinal forces acting on the reference particle are zero, so that the particle feels no existence of the coupling gap. Figure 2 shows the beam bunch just ahead of the gap.

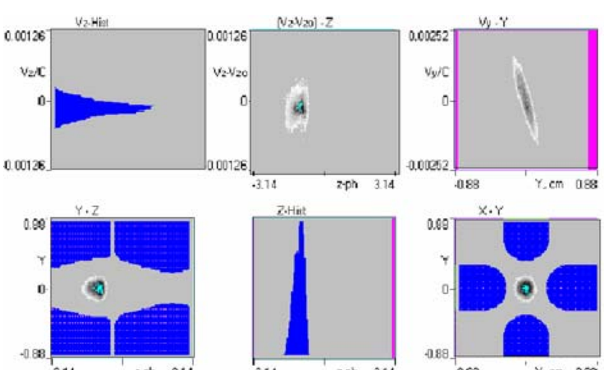

Fig.2 LIDOS.RFQ simulation of beam bunch just ahead of the coupling gap.

2.2 Error study

Various error effects have been simulated with LIDOS.RFQ. These errors include systematical variation of beam parameters or RFQ parameters and random deviation of the RFQ cell parameters. Figure 3, as an example, shows transmission rate dependence on the random aperture variation from cell to cell along the RFQ. The results indicate when the aperture error is less than ± 25μm there is a probability of 90% that the transmission rate is higher than 94%. According to this result, we set the machining tolerance less than ±25μm.

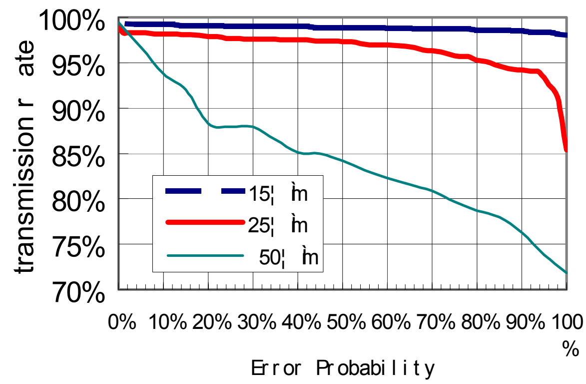

Fig.3 The transmission rate dependence on the probability of random aperture errors.

2.3 Cavity RF design

Computer simulations are carried out for calculating the electromagnetic field distribution and frequency of the RFQ cavity in 2-D coordinates (by SUPERFISH) and 3-D coordinates (by MAFIA). The MAFIA runs are dedicated for the design of the tuners, the end cells, the coupling cells and other 3D components of the RFQ. The designing principle is that the E-field longitudinal distribution and the local quadrupole cut-off frequency should be kept as constant as possible. Figure 4 is a modeling of the magnetic field distribution around the coupling cell.

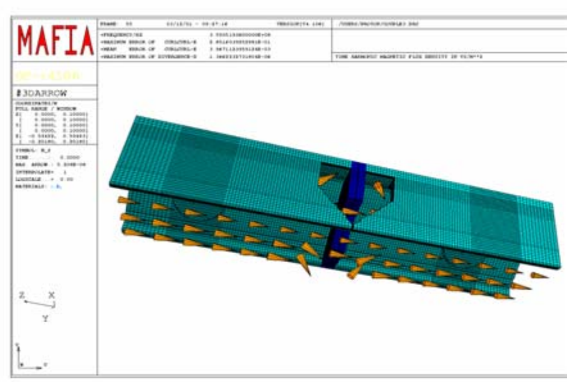

Fig. 4 MAFIA modeling of the coupling cell

2.4 The thermal & structure analysis

The RF power dissipation is a serious issue for the high-power and high-duty RFQ cavity. Water cooling channels are necessarily distributed on both the cavity wall and the vanes, according to the power distribution calculated from SUPERFISH. ANSYS code is applied in the analysis of the thermal deformation of the cavity and the cooling channel design, as well as cooling water temperature design, in order to control the frequency shift less than 20kHz. In this work we assume the cavity is run under the CW mode because the RFQ may be upgraded to CW mode in future with the present RF power source described in section 4.

3 MODEL CAVITY MANUFACTURE

The manufacture of copper cold-model cavity is now underway according to the design described in last section. It is meant to search for a manufacture technology to ensure the tight allowance in machining and brazing processes. A 1.2 m long model cavity made of OFHC has been machined, as shown in Fig. 5.

Fig. 5 The copper cold-model RFQ cavity of 1.2 meter long.

A series of brazing tests have been done on some small OFHC pieces with different brazing grooves and different shapes. Figure 6 shows one test piece just before vertical brazing. It consists of three blocks with the same size near the brazing region as the real cavity Vacuum leakage check of the brazed pieces suggested us one successful option. More tests on a larger scale are planed in the next step, as we have realized that brazing is a very difficult key point in the RFQ manufacture.

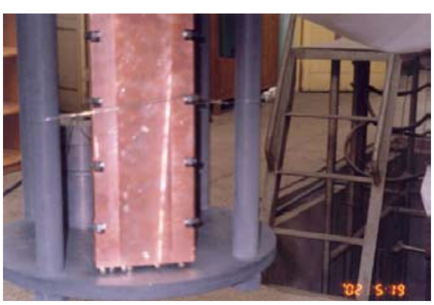

Fig. 6 The Vertical brazing test piece just before to be put into the hydrogen furnace

4 RF POWER SOURCE

Thank to the kind support from CERN, we obtained the CW RF power source of 352.2MHz/1.2MW, dismounted from LEPII. The TH2089 klystron, DC high power supply, HV interface, RF power distribution system and RF control system have been transported to IHEP successively in recent months. Figure 7 is the klystron in our laboratory. It also shows the water-cooling system we prepared. Installation, connection and test operation are scheduled in our next work. Afterwards, we will develop the modulator of square pulse to meet our pulse operation mode (the modulator from CERN is operated in ramp mode).

Fig. 7 The 352.2MHz/1.2MW CW klystron from CERN has been moved to IHEP, Beijing.

5 CONCLUSIONS

The RFQ for ADS basic research program has been designed. The fabrication technology is now under development. Its RF power source has been moved to IHEP from CERN. We will make use of the tunnel of the 35MeV BPL for this RFQ. Some facilities have been added to the existing water-cooling system of BPL to satisfy our RF source and RFQ operation. An intense-beam ECR proton source is now under development at China Institute of Atomic Energy, and will be moved to IHEP together with the LEBT in future.

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