STATUS OF THE PEFP SUPERCONDUCTING RF PROJECT*

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Abstract

Superconducting RF project of the Proton Engineering Frontier Project (PEFP) aims to develop a superconducting RF linac to accelerate a proton beam above 80 MeV at 700 MHz. In the past two and a half years, the preliminary design of a low-beta cryomodule has been completed. A low-beta (β_g=0.42) cavity, a HOM coupler, a fundamental power coupler for the PEFP cavities have been designed, and their copper prototypes have been fabricated and tested successfully. The tuning system of the PEFP cavities has been set up and tested successfully. The measurement and testing results of the prototypes, the status of the SRF project and an overview of the RF superconductivity activities of PEFP in the coming two years are presented in this paper.

INTRODUCTION

A superconducting RF linac (SCL) is being considered for accelerating a proton beam at 700 MHz in the PEFP linac and its post-project [1,2]. PEFP superconducting RF (SRF) project started from September, 2005. In the past two and a half years, a preliminary design of the PEFP low-beta cryomodule has been completed [3], a low-beta cavity has been designed [4]. The higher-order modes (HOMs) have been analyzed, and the HOM damping requirements for the PEFP low-beta linac have been presented [5]. The dies and fixtures for the low-beta cavity fabrication have been fabricated and tested.

One low-beta copper prototype cavity (Cavity A) has been fabricated and tested. A cavity tuning system (dumbbell tuning system and cavity field flatness system) has been designed, fabricated and tested.

A new HOM coupler has been designed for the PEFP cavities [6], and its prototype has been tested. The PEFP fundamental power coupler (FPC) has been designed [7]. The inner conductor penetration depths of the Field Probe and FPC have been tested and decided on the Cavity A. And a design of the PEFP FPC baking system has been completed [8].

In this paper, the preliminary design of the PEFP low-beta cryomodule is introduced briefly. The cavity design and production, and the testing and measurement results of the prototype copper Cavity A are described; the design of the new HOM coupler and the FPC, and the testing results of their prototypes are presented. The R&D works at present and future plan are described.

PEFP LOW-BETA CRYOMODULE

The design of the PEFP low beta cryomodule, such as its cooling system and its magnetic shielding, is largely based on the successful design, construction and commissioning experiences of the SNS project at JLab and ORNL. The comprehensive and competent analysis has been done for the fundamental electromagnetic and mechanical designs [3]. Figure 1 shows a PEFP low-beta cryomodule.

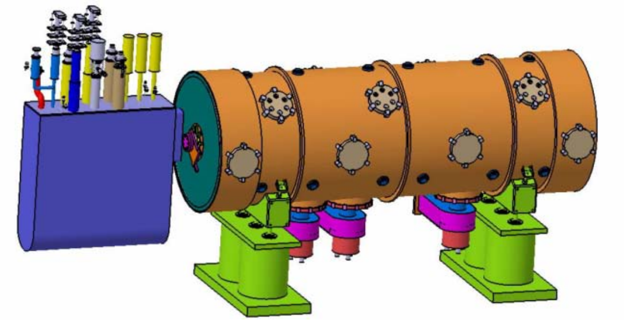

Figure 1: PEFP low-beta cryomodule.

PEFP LOW-BETA CAVITY AND PROTOTYPING COPPER CAVITY

After the optimization of the cavity shape in the RF properties, the cavity mechanical analysis, the cavity HOM analysis, a PEFP low-beta elliptical cavity with double stiffening-ring has been designed [9].

In order to produce documentation for a procurement and quality control for an industrial manufacturing of the cavities, a prototype copper cavity A has been fabricated and tested. At this prototyping stage, we have verified the PEFP low-beta SRF cavity design and parameters, tested the PEFP dumbbell tuning system and cavity field flatness tuning system, set up dumbbell and cavity field flatness tuning procedures, and also produced a cavity production procedure. During the tuning of the PEFP low-beta dumbbell, a new method to measure an individual half-cell's frequency of a dumbbell has been developed [10]. This new method has been used to tuning PEFP dumbbell successfully [11].

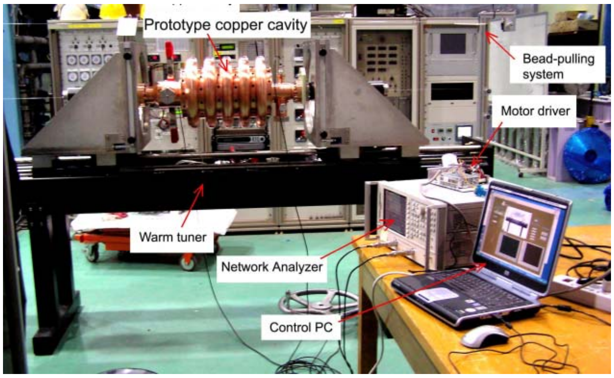

Figure 2: PEFP cavity's field flatness tuning system.

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Figure 2 shows the prototype copper cavity and the PEFP cavity field flatness tuning system. Using this tuning system, the field flatness of the prototype cavity with the double stiffening-rings has been tuned from 75.62% at 697.970 MHz to 1.43% at 700 MHz (the specification of the field flatness is less than 8.0% at 700 MHz), as shown in Fig. 3. The tuning of the cavity field flatness shows that the field flatness affects the passband, as shown in Fig. 4.

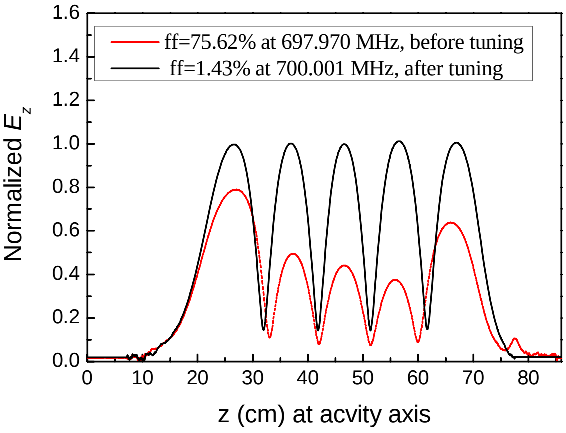

Figure 3: The initial and final field flatness of the PEFP low-beta copper prototype cavity.

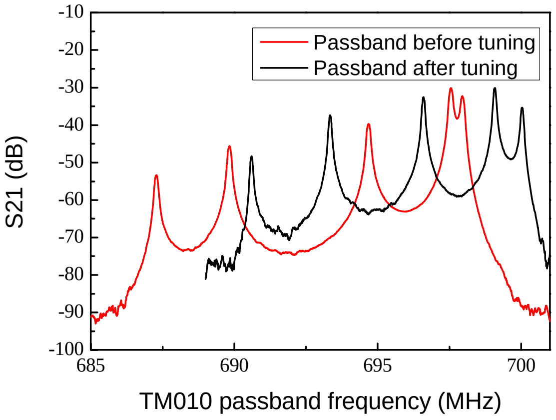

Figure 4: Cavity TM010 passband change before and after tuning.

PEFP HOM COUPLER

A new type of coaxial HOM coupler with one hook and two stubs has been designed for PEFP SRF cavities to satisfy the HOM damping requirements of the PEFP SCL, and to overcome the notch frequency shift and feed-through tip melting issues.

In order to test the RF parameters and to finalize the dimensions of the HOM coupler, two prototype HOM couplers have been fabricated, as shown in Fig. 5. The two prototype couplers have been installed on the cavity A and tested. The tested transfer curve of the PEFP HOM couplers on the low-beta cavity A is shown in Fig. 6.

HOM analysis has shown that, for the PEFP low-beta cavities, the HOM coupler's Q_{ext} is lower than 3×10^5, reducing the influence of dangerous modes on the beam instabilities and the HOM-induced power [5]. The testing results for the HOM damping display that the Q_{ext}s of the new HOM couplers for all the dangerous and potential dangerous HOMs are lower than 1.5×10^5, which can fully meet the PEFP HOM damping requirements. According to the testing results, the final angle of the hook and the final penetration depth of the inner conductor of the HOM coupler have been decided.

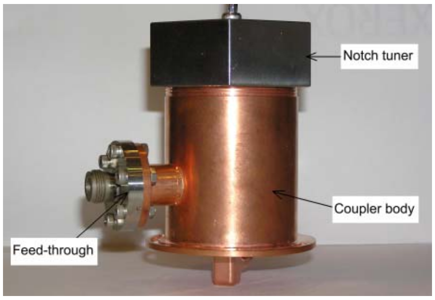

Figure 5: A PEFP prototype HOM coupler.

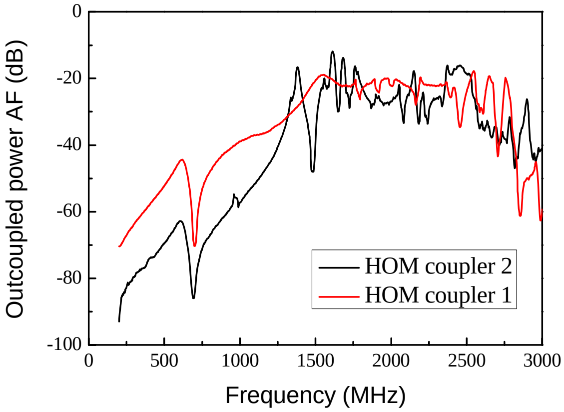

Figure 6: Tested transfer curve of the PEFP HOM couplers on the low-beta cavity A.

FPC AND FIELD PROBE

Each PEFP SRF cavity has one FPC to transfer a RF power from the klystron to the beam. A coaxial-type FPC is designed for the PEFP SRF cavities [7]. In order to confirm the PEFP FPC design and finalize the inner conductor length of the FPC, a FPC taper and a FPC window taper have been designed and fabricated to test the relation of the external Q versus the penetration depth of the FPC inner conductor, and the match between FPC window and coaxial transmission line. Based on the testing results, the FPC inner conductor penetration has been decided.

Each PEFP cavity has one Field Probe to detect a cavity's accelerating gradient and resonant frequency. The specification of the PEFP Field Probe is $1\text{mW}/(\text{MV/m})^2$ with a tolerance of ±2 dB. In order to meet this specification, a prototype Field Probe has been fabricated and tested, as shown in Fig. 7. According to the testing results for the Cavity A, the final length of the Field Probe has been decided.

Figure 7: A PEFP Field Probe.

HELIUM VESSEL

In order to save on the material costs and to be easy to fabricate, the FPFP helium vessel is going to be made of stainless steel. Based on JLab's experiences, additional benefits of this design include the elimination of stainless steel to titanium explosion bonded joints which is both a cost savings and reliability improvement [12]. The added complication of a brazed niobium to a stainless joint has been evaluated at JLab with test pieces and cavity assemblies. After a mechanical analysis and considering the final assembly, a helium vessel for a PEFP low-beta cavity has been designed, as shown in Fig. 8.

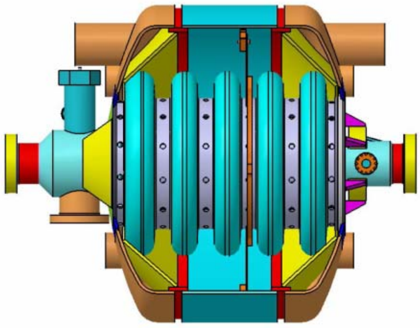

Figure 8: PEFP helium vessel for a low-beta cavity.

PRESENT AND FUTURE OF THE PEFP SRF PROJECT

At present, copper Cavity B is under fabrication, and will be tested soon. All the parts and production procedure of Cavity B are the same as that of the niobium cavities. After a fabrication and testing of Cavity B, Nb cavity will be fabricated. The helium vessel design has been completed. A new PEFP tuner is under design. The PEFP FPC conditioning system and cavity vertical testing system are under design. The drawings of the cryomodule assembly tools are under production.

In the future, in the coming two years, we are going to complete the FPC production and its conditioning, and a two-cryomodule production, testing and conditioning. Also a cavity vertical test system, the cryomodule assembly equipments and test system will be constructed.

SUMMARY

In the past two and a half years, many R&D works for the PEFP SRF project have been completed, and prototyping copper cavity A, a Field Probe and a HOM coupler have been completed. The FPC key-part prototypes have been fabricated and tested. The results of the testing and measurements of the cavity, Field Probe, HOM coupler and FPC prototypes show that the SRF design is successful at present. In the coming two years, PEFP is going to complete the Nb cavity testing, the FPC production and its conditioning, two-cryomodule production, testing and conditioning.

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