Superconducting Single Cell Cavity Test for Neutron Science Project at JAERI

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Abstract

JAERI has been proposing a high intensity proton linear accelerator for the Neutron Science Project exploring basic researches and nuclear waste transmutation technology based on a next generation spallation neutron source.

Superconducting (SC) cavity is a main option for high energy portion of the accelerator. The SC cavity development has been started since 1996 with an installation of test stand, design of cavity shape and fabrication of single cell cavities of β=0.5 in collaboration with the KEK. This report describes the performance of the SC cavity test facility at JAERI and the result of the first SC cavity vertical test.

1. Introduction

In these years, JAERI has been planning the Neutron Science Project (NSP) for exploring basic researches combined with the OMEGA program in JAERI based on a next generation spallation neutron source driven by the high intensity proton linac[1]. The design concept of the high intensity proton accelerator has been considered to achieve the various beam operation modes in the NSP.

A conceptual layout of the NSP accelerator is shown in Figure 1 and preliminary parameters for the accelerator are given in Table 1. The development of superconducting rf cavity system has newly started for a design study of the system and for a cavity test facility installation.

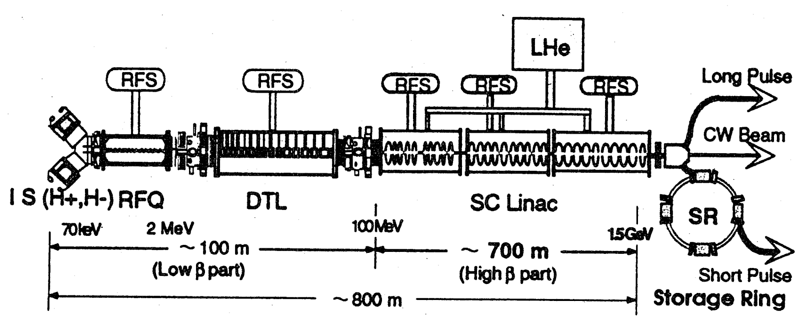

Fig. 1 Conceptual Layout of NSP Linac

Table 1 A preliminary specification of the JAERI NSPLinac

Energy :	1.5 GeV
Accelerated particle :	H^+, H^-
Average current :	1st stage : 1 mA
	2nd stage : 5.33 mA maximum
Peak current :	Nominal 30 mA
Low energy part :	Normalconducting linac:200 MHz
High energy part :	Superconducting linac : 600 MHz
Beam operation mode :	1st stage: Pulse mode operation
	2nd stage: CW / Pulse operation
Repetition rate :	50Hz
Macro-pulse width :	2 ms (at 1mA operation) to CW
Chopped-pulse width :	400 ns (interval 270 ns)
Chopping factor :	60 %

2. Superconducting rf cavity

Superconducting (SC) rf cavity is a main option for high energy portion of the NSP accelerator. Resulting with basic studies for the structure of high energy part of the accelerator, several favorable characteristics were pointed out with SC option in comparison with normal conducting cavity option. There are 1) a high electrical field gradient for beam acceleration which conducts a short length of the accelerator, 2) high quality factor of ~10^9 which gives a low operation cost and 3) acceptable wide beam tube aperture of 100 to 180 mm in diameter which introduces a low beam loss rate operation.

In the CW electron accelerator, technologies of SC accelerators are established. The experiences of design, manufacturing and operation for the electron SC accelerator are accumulated for years such as KEK-TRISTAN and other many laboratories[2]. The electron SC accelerator has single velocity of light speed (β=1). This condition leads uniform cavity shape and uniform cryomodule design for all accelerating cavity structures. In the proton accelerator, however, velocity varies sequentially from 100MeV to 1.5GeV ($0.43 < \beta < 0.92$). Accordingly, the length of the cavity also changes by $\beta\lambda$ in each region. Main concern is the mechanical strength of the cavity under the vacuum load for the energy range of 100 to 200MeV because of the more flatter shape than that of the electron accelerator.

3. The R&D work

The R&D work for SC accelerator has been started since middle of 1995 in collaboration with the KEK SC group to make a design and demonstrate the cavity characteristics and to establish a cavity test facility.

Design study of SC cavities

The mechanical structure calculations with the ABAQUS code have been done to determine the cavity shape parameters as well as electromagnetic ones with the SUPERFISH code[3]. To adjust the changes of proton velocity, energy range of 100 MeV to 1500 MeV, eight different cavity lengths are proposed. In the preliminary design of the SC system, one cavity consists five cells and one cryomodule composes two cavities. The schematic drawing of the JAERI SC accelerator cryomodule is shown in Fig. 2. The design concept for the major part of the cryomodule is followed from the experience of the KEK-TRISTAN .

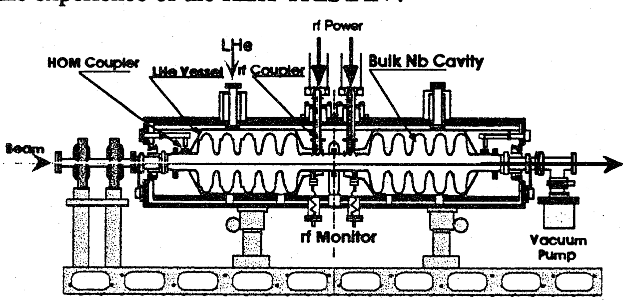

Fig. 2 Schematic drawing of the JAERI SC cryomodule

Test facility for SC cavities

A test stand for the vertical tests of 600MHz cavities has been installed at the JAERI Tokai site to examine the SC cavity performances for variable energy range. The SC cavity requires a pure material of niobium, ultra clean and smooth cavity surface and clean handling area[4]. The major process of the cavity examination is shown in Fig. 3.

The test stand installed is consists 1) an ultra pure water generating system(UPW), 2) a high pressure rinsing system(HPR), 3) an ultra high vacuum pumping system(UHV) and 4) a cryostat for vertical test. Additionary, a large furnace with clean vacuum is installed at the test stand which can be used since September 1997. The layout of the test stand is illustrated in Fig. 4. The summarized characteristics of the test facilities are shown in Table 2.

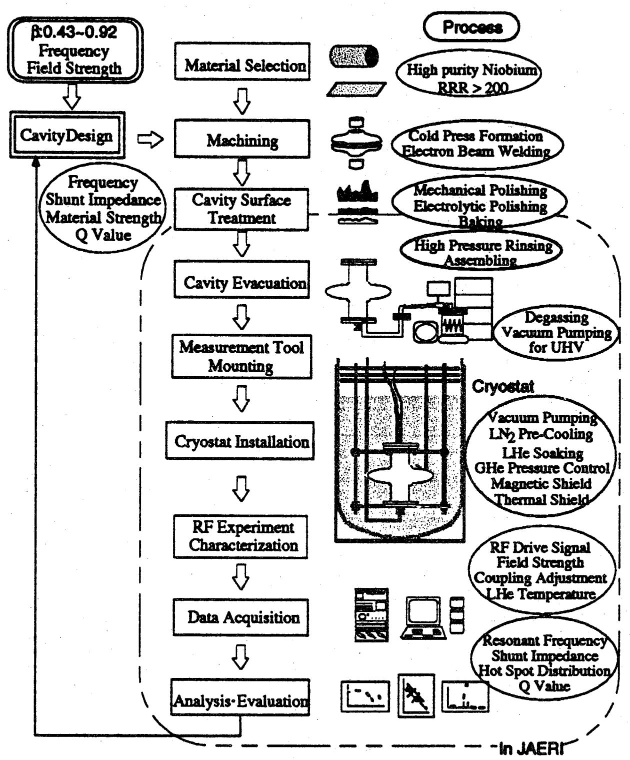

Fig. 3 The major process flow of the cavity examination

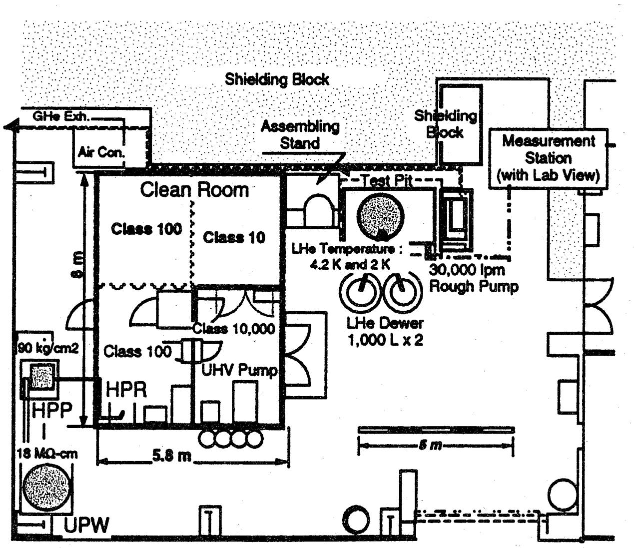

Fig. 4 The layout of the JAERI SC cavity test stand

Table 2 Characteristics of the JAERI SC cavity test stand

Cryostat :	
Test Area Dimension:	
Diameter:	800 mm
Hight:	1,500 mm
Residual Mag. Field:	< 10 mGauss
Thermal Permiation:	2.2 W
Cooling Speed(RT to 4.2K):	2 h
Ultimated Temperature:	1.90 K
LHe Feed Speed :	2.5 LPM
Cavity Baking Furnace :	
Effective Baking Area :	830W x 830H x 1,800L
Baking Temperature :	900 °C
Vacuum Pressure :	1 x 10^{-4} Pa (at 900°C)
Clean Room :	
Clean Level(Class 10):	< 10 p/ft^3 (> 0.3 μm)
High Pressure Rinsing :	
UPW Pressure:	90 kgf / cm^2
UPW Resistivity:	> 17.6 MΩ-cm
TOC Level:	70 to 300 ppb
Cavity Evacuation System :	
Ultimated Vaccum Pressure:	5 x 10^{-11} Torr

First SC cavity test

Bulk niobium superconducting test cavity of single cell for the region of 150MeV is fabricated according to the preliminary cavity design. The major dimension of the test cavity is shown in Fig. 5. The pure niobium sheets of 3 mm thick, RRR > 200, were pressed and trimmed to make the half cells and the beam pipes. Two half cells and beam pipes were connected by EBW at the equator area and the iris area, respectively. After the forming, the cavity surface was polished by mechanical polishing (BP) and electropolishing (EP).The average removal thicknesses are51 μm by BP and 23 μm(1st) + 33 μm(2nd) by EP, respectively. To eliminate the adsorbed hydrogen gas caused by EP process, the baking of the cavity was done for 750 °C and 3 hours. The final cleaning of the cavity surface was made by 90 kgf/cm^2 HPR with ultra pure water of 1.2 m^3. To prevent a cavity collapse at the vacuum loading on the flatter shape cavity, the support rods were mounted between the beam pipe flanges.The measurements were done for the Ep-Qo characteristics at 4.2 K and 2.1 K. The peak surface electrical field gradient (Ep(max.)) = 30 MV/m and quality factor (Qo) = 2 x 10^{10} at 2.1 K were measured. " Field emission " was observed at the high field measurement. The rusult of the measurement is shown in Fig. 6. The residual resistivity of 5.5 nΩ of the test cavity was obtained.

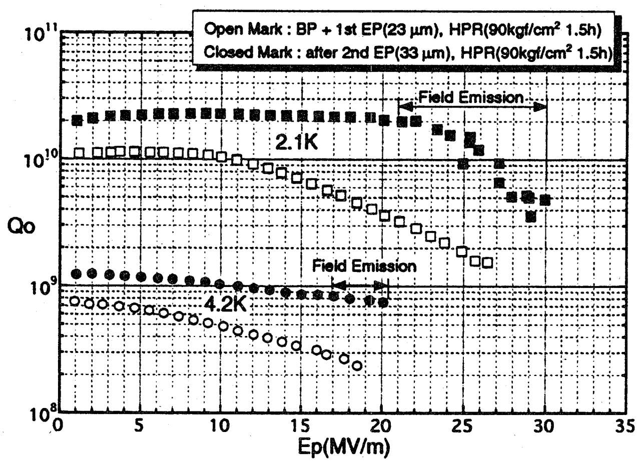

Fig. 6 Performance of 600 MHz single cell cavity (β = 0.5)

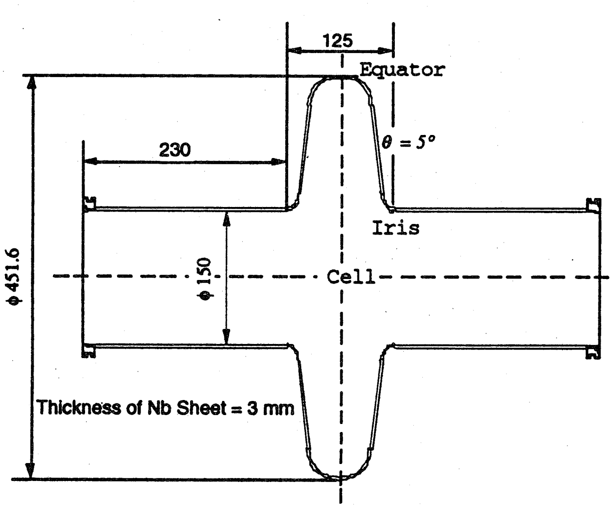

Fig. 5 The dimension of 600MHz single cell cavity (β = 0.5)

4. Summary

JAERI has started the R&D of the SC cavity to be appied in the NSP proton linac. A test stand was constructed to examine the cavity characteristics. First vertical test of a single cell cavity was performed for bulk niobium cavity of β= 0.5. Many of the cavity characteristics show in good agreement with the design values at the first SC cavity test.

References

[1] M. Mizumoto et al., "A High Intensity Proton Linac Development for Neutron Science Research Program", Proc. of the1996 Intn. Linac Conf. Geneva, (1996) 662

[2] Y. Kojima, et al., "Upgrading of TRISTAN by Superconducting RF System", Proc. of Particle Accelerator Conf. Chicago, p1789-1791 (1989)

[3] N. Ito et al., "Present status of the Development for the Superconducting Proton Linac in JAERI" Proc. of the 21st Linear Acc. Meeting in Japan, Tokyo(1996) 328

[4] K. Saito et al., "R&D of Superconducting Cavities at KEK" Proc. of the 4th Workshop on RF Superconductivity, Tsukuba, (1989) 635