SRF SYSTEM IN THE JAERI – KEK JOINT PROJECT

Shuichi Noguchi[†]
KEK, High Energy Accelerator Research Organization
1-1 Oho, Tsukuba, Ibaraki, 305-0801, Japan

Abstract

Japan Atomic Energy Research Institute (JAERI) and High Energy Accelerator Research Organization (KEK) have been collaborating to develop the superconducting LINAC for high intensity proton acceleration since several years ago. Also, the effort to construct the high intensity proton facility in JAPAN was continued, and in 2000 the joint project was approved as the collaborative project of JAERI and KEK. The facility is constructed in the JAERI Tokai site, and the superconducting LINAC of 200 MeV will be constructed to increase the energy of proton from 400 to 600 MeV in the phase 2.

1 INTRODUCTION

Since about ten years ago, JAERI had been proposing the Neutron Science Facility and KEK the Japan Hadron Facility project. In 2000, two institutes agreed to combine two projects to save budget, man power and to construct the facility as soon as possible.

The accelerator complex consists of a 400MeV Linac, a 3GeV rapid cycling synchrotron (RCS) and a 50GeV synchrotron. The 3GeV beams are used for the neutron and the muon science facility, and a part of them are injected to 50 GeV synchrotron. The 50 GeV beams are used for nuclear, high energy and neutrino physics. The linac energy will be increased to 600 MeV with a superconducting linac (SCL) for the basic research of the nuclear waste transmutation system (ADS).

A baseline design of the SCL is reported by K. Hasegawa [1]. Figure 1 shows a block diagram of the linac. The basic features of the SCL are summarized as followes.

1: Doublet + two 9-cell cavities in one cryostat.
2: Matching of cavity geometrical β to proton β averaged in a lattice period.
3: Constant surface peak electric field (Epk) of ~30MV/m.
4: Two cavities are driven by one klystron.

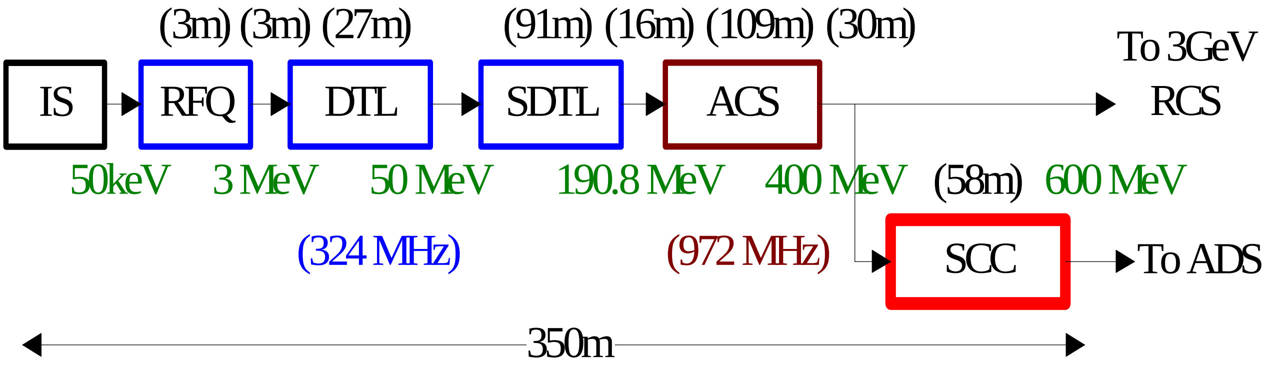

Figure 1. Block diagram of the linac
IS: Ion Source, RFQ: Radio Frequency Quadrupole Linac, DTL: Drift Tube Linac,
SDTL: Separated-type Drift Tube Linac, ACS: Annular Coupled Structure Linac,
SCC: Supercnducting Cavity Linac

[†] shuichi.noguchi@kek.jp

The basic parameters of the SCL are summarized in Table 1.

Table 1. Basic parameters of the SCL

Beam Energy	400 – 600 MeV
Macropulse Beam current	30 mA
Macropulese beam pulse width	~1 msec
Repetition rate	25 Hz
RF frequency	972 MHz
Accelerating Gradient	9~11 MV/m
RF power per coupler	300 kW
Operating temperature	2 K
Capacity of He refrigerator	2.5 kW at 4K
Number of cryomodules	11
Total length	58 m

The key issues of the SCL are the RF control in the pulse operation and the reliability of hardware. R&D have been concentrated on these points, and the status is summarized as follows.

1: Structure shape, which is free from higher order modes trapping, is optimized [2].
2: The first single cell cavity (β=0.725) achieved Eacc of 13 MV/m.
3: The dynamic Lorentz detuning has been extensively studied and an effective way to suppress the oscillation of field gradient vector was found [3].
4: The prototype 9-cell cavity is under fabrication at KEK.
5: The input and the HOM couplers have been designed.
6: Design of the prototype cryostat has been completed.
7: 2K helium system has been designed.

Figure 2 shows the cross section of the tunnel.

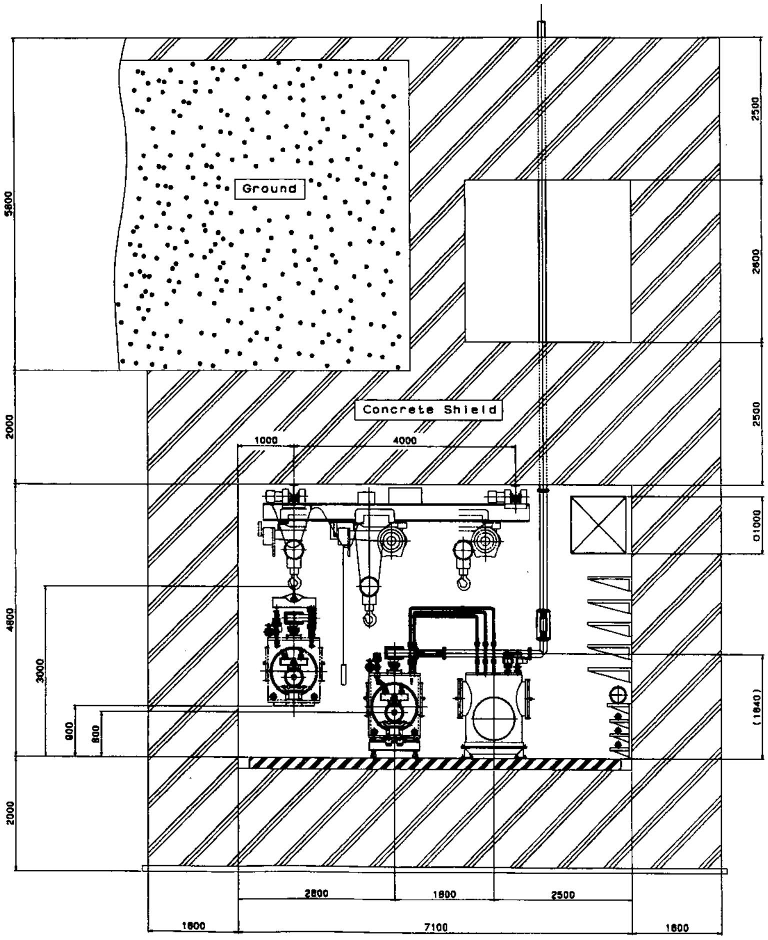

Figure 2. Cross section of the tunnel

2 LORENTZ DETUNING

In order to keep the beam loss below the hands-on-maintenance possible level, the errors of accelerating gradient are required to be less than 1 deg. and 1 %. If one power source drives one cavity, or the pulse modulation is slow, the accelerating gradient could be stabilized by either RF feedback control, or the frequency tuning system. But the present case is not this case and requires stiff cavity. The mechanical analysis of the cavity deformation by the Lorentz force has been extensively performed and we have decided to make the thick (4mm) cavity without stiffener. Figure 3 shows a stationary Lorentz deformation under the fixed length constraint of 4 mm thick and β=0.725 cavity. The Lorentz deformation constant is 1 Hz/(MV/m)^2. Figure 4 shows an example of the dynamic Lorentz detuning in the pulsed excitation of 9-cell β=0.556 cavity, and frequency analysis at the flattop region is shown in Figure 5. The peak at 1660Hz is such a mode in which iris position dose not move, and the modes below 500Hz are modes irises move. These modes can be excited even if the cavity length is fixed. On the other hand, in the mode at 830 Hz the cavity shrinks axially because of finite stiffness of the tuning system. The phase modulation at the flat top is suppressed below the required level. Moreover if we control the rise and fall part of the Lorentz force not to excite higher mechanical frequency modes, the phase error could be improved further. The simulation with sinusoidal rise and fall of the Lorentz force shows nice results. In the 1msec case (500Hz), the phase error becomes a half.

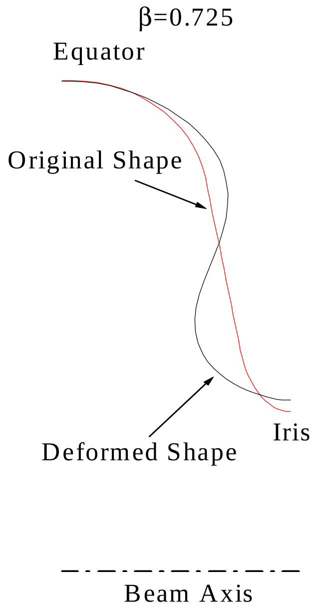

Figure 3. Cavity deformation

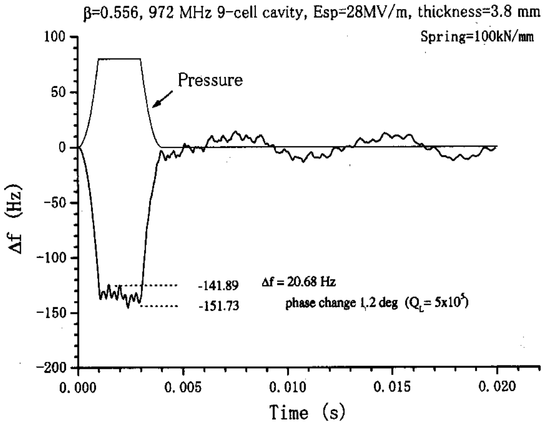

Figure 4. Dynamic Lorentz detuning in the pulsed excitation

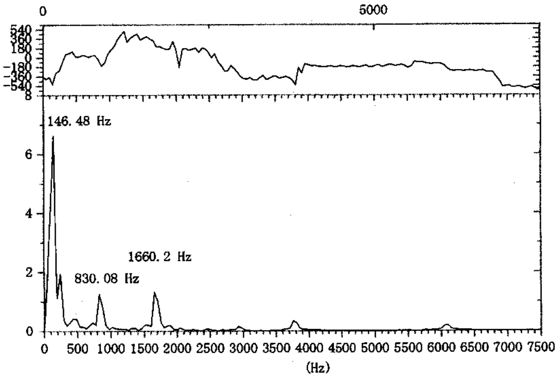

Figure 5. Frequency analysis at the flattop region

3 CAVITY

The prototype 9-cell cavity under fabrication at KEK is shown in Figure 6. Parameters of the cavity are summarized in Table 2. There are no trapped modes below 2.5GHz. The dominant higher order modes are TM011-5π/9 (2.3GHz, R/Q=7Ω) for longitudinal and TM110-7π/9 (1.3GHz, Rt/Q=950Ω/m) for transverse modes. The real cavity will be equipped with a input coupler port, two HOM coupler ports and a monitor port on the beam pipes. All the flanges will be stainless steel bonded to Nb pipes by HIP (Hot Isostatic Press) technique [4].

The first single cell cavity has been already tested, and the first test result is shown in Figure 7.

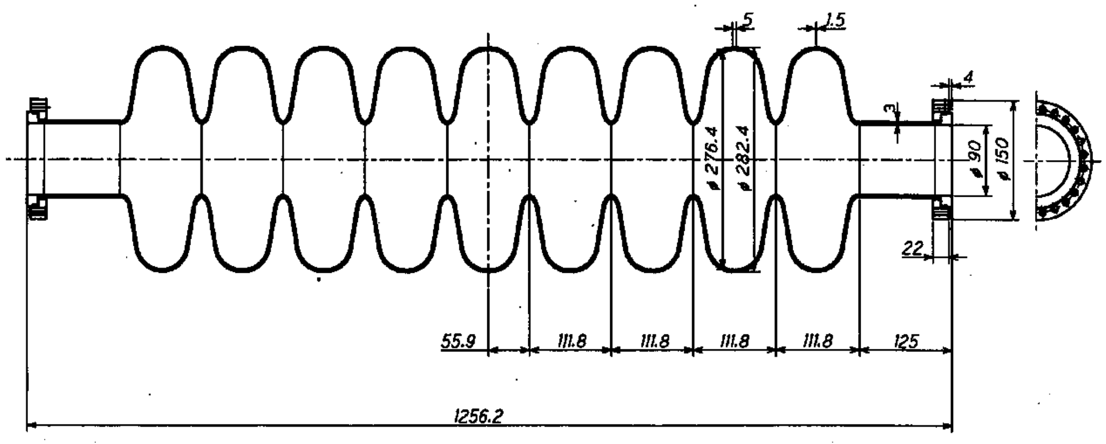

Figure 6. A prototype 972MHz, β=0.725, 9-cell superconducting cavity

Table 2.
Main cavity parameters of the TM010 accelerating mode (by SUPERFISH)

Esp/Eacc	3.04	
Hsp/Eacc	55.0	Oe/MV/m
R/Q	523.	Ω
Geometrical factor	206.	Ω
Cell to cell coupling	2.8	%
Transit time factor	0.73	

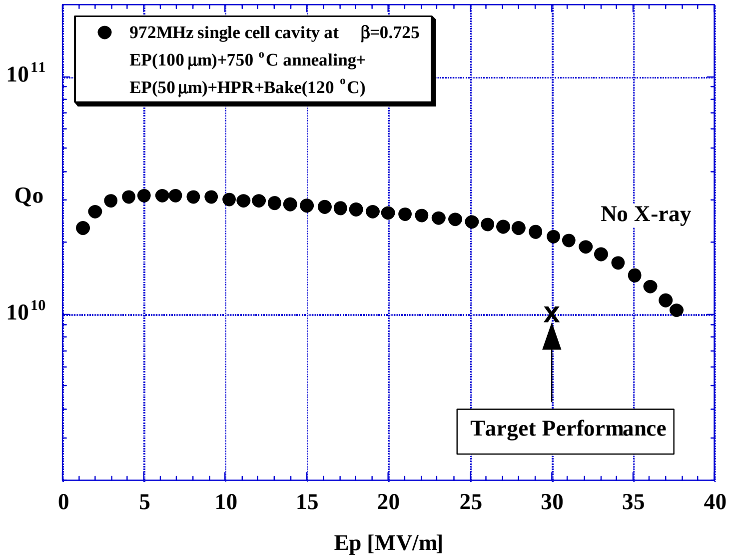

Figure 7. The first test result of 972MHz single-cell cavity (β=0.725)

4 COUPLERS

The required input RF power for the acceleration of 30mA beam with a gradient of 10MV/m is about 300kW. The matched external Q value is about 7x10^5, but a stronger coupling is preferable to reduce the effect of the Lorentz detuning. The design of coupling port was done using HFSS and a single cell cavity shown in Figure 8. The external Q value of 5x10^5 can be achieved with this configuration for a 9-cell cavity of β=0.725. The RF window and the doorknob transformer are scaled from the TRISTAN 508MHz coupler [5] and optimized with HFSS. The size of ceramic disk is ID=32mm, OD=136mm and t=7mm. A high power test stand for coupler processing is under preparation and the test will be started next year. A DESY type HOM coupler has been designed and tested. It has a two-post high pass filter and a λ/4 notch filter.

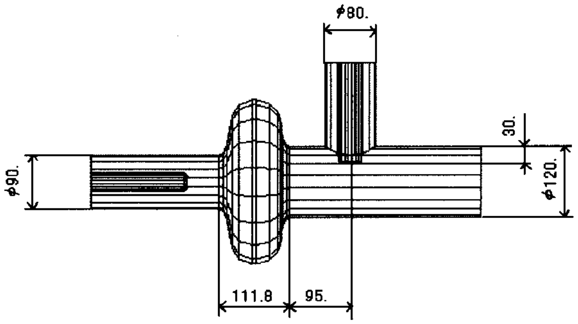

Figure 8. Model cavity for calculation by HFSS

5 CRYOMODULE

Figure 9 shows the cross section of the cryostat. Two 9-cell cavities with their own Ti jackets are connected at the center through RF decoupling beam pipes. Each cavity has an RF input, a field monitor and two HOM damping couplers. The Ti jacket base-plates having a stiffness of 200kN/mm are EB welded to beam pipes. The frequency tuning is done mechanically using two flanges at the Ti bellow of the jacket. Tuning force is transferred through two coaxial rods from outside of the cryostat. In order to reduce the effect of Lorentz detuning, each coaxial rod has been designed to have a stiffness of 50kN/mm. Thus the stiffness of the tuning system becomes 50kN/mm with a stiffness of 100kN/mm of the Ti jacket. He supply and gas recovery are done through a reservoir box connected to two jackets. A heat exchanger is contained in a valve box beside the cryostat, but a J-T valve is in the cryostat. Alignment, paring and assembling of monitor and HOM couplers are done in the class-10 clean room. Then the cavity pair is installed into the cryostat. Assembly of input couplers and gate valves are done in the class-100 area. Estimated static heat losses per cryomodule are 8W, 20W, 50W for 2K, 4.4K and 80K, respectively.

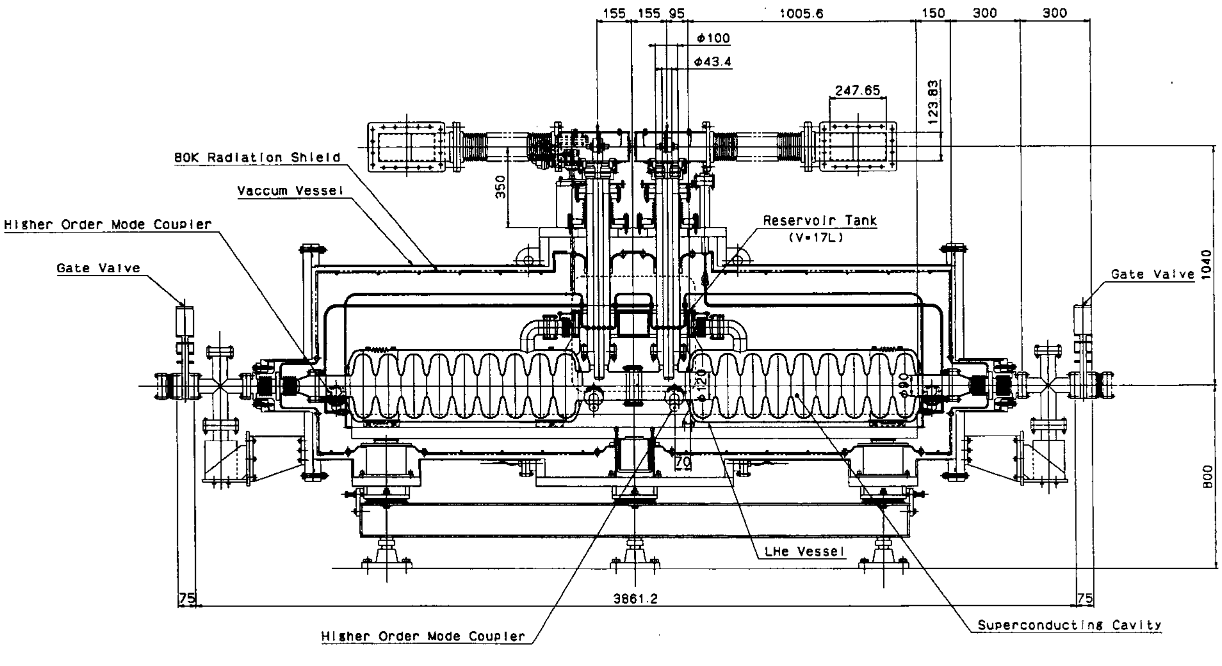

Figure 9. A 972MHz prototype cryomodule

6 REFERENCES

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