Superconducting RF Activities at JAERI

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Abstract

A JAERI's project of constructing a heavy ion booster is in a period of progressive fabrication of superconducting resonators and cryostats. Its another project of developping a free electron laser has stepped forward in fabricating a superconducting linac. Study on rf superconductivity of high T_c metal-oxides has been continued. This paper outlines the status of these three activities.

1. Superconducting heavy ion booster

1.1 Superconducting resonators

A superconducting heavy ion booster for a tandem accelerator is under construction at JAERI. The booster employs 44 superconducting quarter wave resonators of β_o = 0.1 and f = 129.8 MHz, which are made of niobium and niobium-clad copper[1,2,3,4]. Four of them were made for bunching and de-bunching units in the early part of the project. Their maximum accelerating field levels were 7 MV/m[1,4]. Later, these values were increased to 8-9 MV/m by additional surface treatments which ended up with vacuum drying[5,6].

The linac is composed of 40 resonators. Sixteen of them have been fabricated. Their surface treatments, resonator tests and assembling to their cryostats are being done in JAERI. A linac unit is shown in Fig. 1. The resonator performances obtained so far are shown in Fig. 2.a) and Fig. 2.b). The accelerating field levels obtained with well treated resonators were about 7 MV/m at an rf input of 4 watts. At such field levels, one resonator provides an acceleration of about 1 MV for incident particles of β = 0.1; The acceleration length is 0.15 m. The

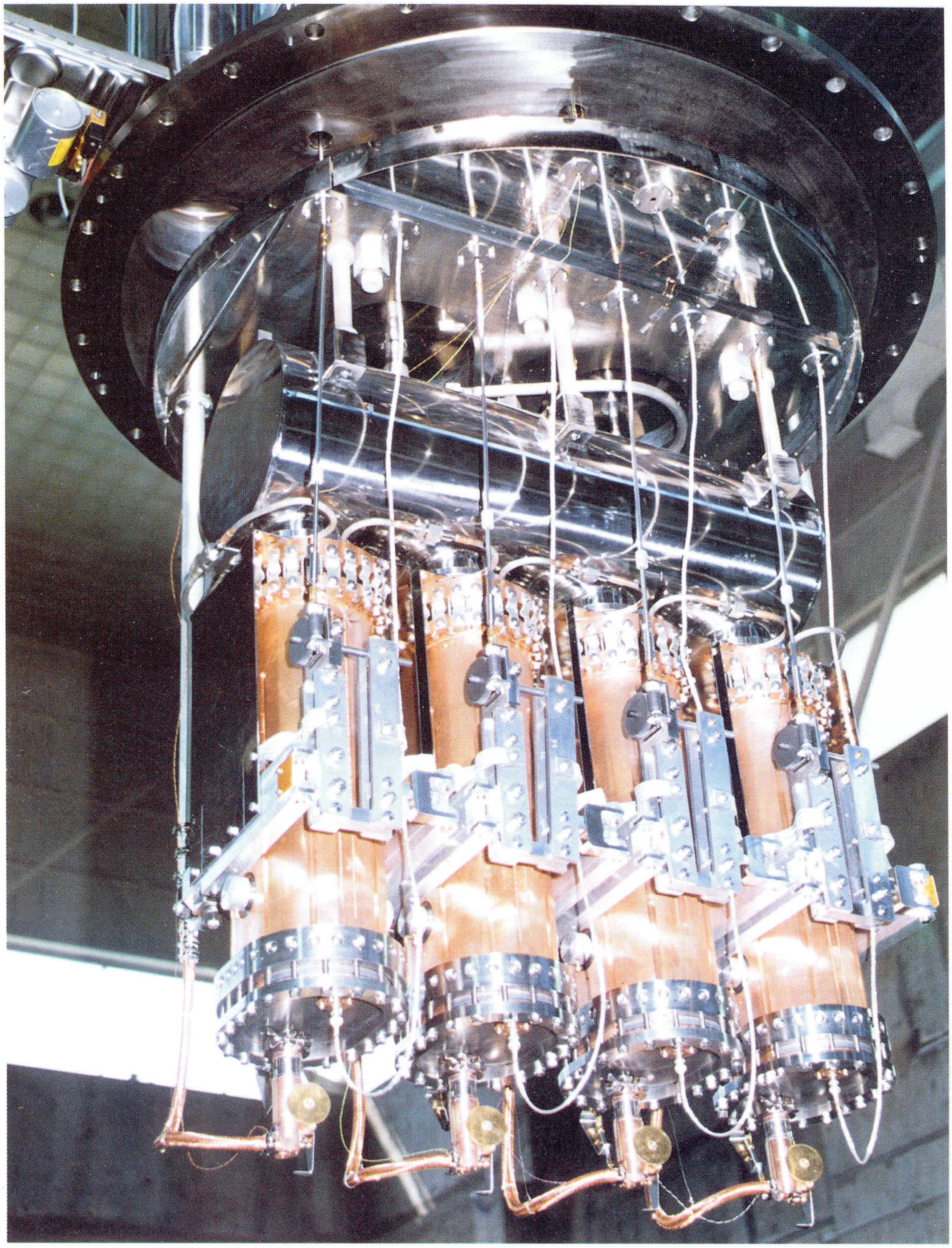

Fig. 1. A heavy ion booster linac unit composed of four superconducting quarter wave resonators of $\beta_o = 0.1$ and $f_o = 129.8$ MHz.

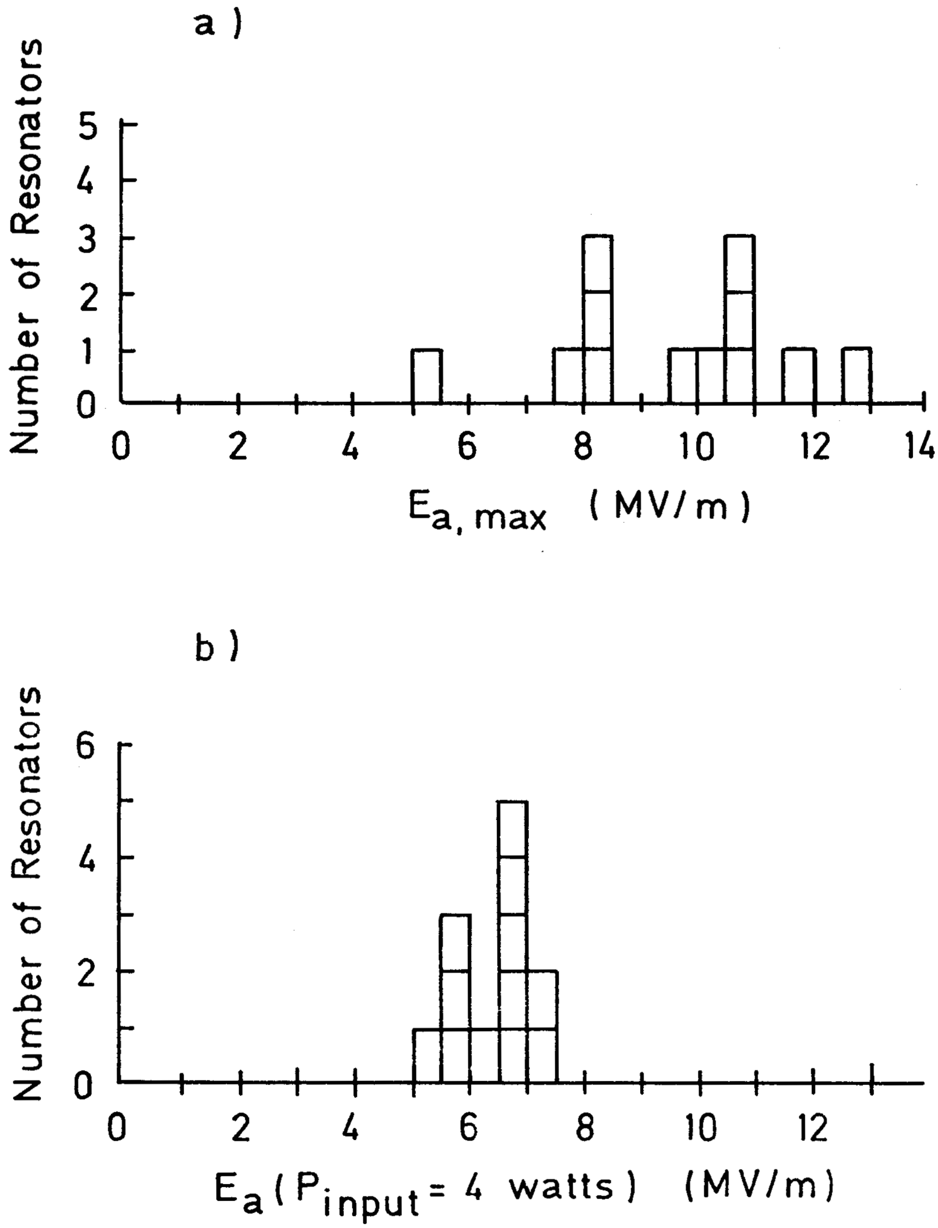

Fig. 2. Resonator performances at 4.2 K.
a) Maximum accelerating field levels.
b) Accelerating field levels at an rf loss of 4 watts.

maximum of the accelerating field levels was 12.6 MV/m, which corresponded to the peak surface electric field of 58 MV/m or the peak magnetic field of 950 G.

Our design value of operating field levels was set at 5 MV/m for an RF loss of 4 watts from the initially obtained resonator performances [1,3]. The resonators examined so far satisfied this demand. If the off-line resonator performances can be maintained in on-line operation, one may expect that the total acceleration voltage of the linac can exceed 30 MV[1,3] and extend toward 40 MV.

1.2 Cryostats

The booster linac will be lined up with ten cryostats. Four of them have been completed. Each one houses 4 resonators as is shown in Fig. 1. The vacuum chambers are 1.3 m in diameter and 1.6 m high. They are made of pure iron for the purpose of shielding the resonators from the terrestorial magnetic field which degrades Q. They worked well as a magnetic shield. The magnatic field levels in the chamber were well below 50 mG. In our experience with a high mu metal box in side a stainless steal vacuum chamber, the field levels could not be suppressed below 150 mG because of its incomplete closeness. The iron chamber walls are plated with nickel. A 1000 l/s turbo-molecular pump of which rotor is suspended with magnetic bearings is put at the top. The pressure inside the wall was 8 x 10^{-7} Torr when the inside is warm and 3 x 10^{-8} Torr when the resonators were cooled. Between the chamber wall and the radiation shield, a high mu metal box is inserted as a supplementary magnetic shielding and is thermally insulated for doubling the effect of radiation shielding from the chamber wall.

The radiation shields will be cooled with 60-80 K gaseous helium from a refrigerator. Liquid helium lines pass through heat exchangers of the resonators before they enter into the dewar. One can expect continuous sequence from precooling of the resonators to liquid transfer into the dewars.

1.3 Refrigerators

Two identical refrigerators with refrigerating powers of 250 watts for 4.5 K liquid helium and 1.5 kilo-watts for 60 K helium gas will be employed for the booster. They need not be assisted with liquid nitrogen. Each of them will have a screw compressor of 1340 Nm^3/h driven by a motors with an output power of 310 kilo-watts. One of the two refrigerators is to be used with the buncher units and 5 linac units and the other with the rest 5 linac units and the de-buncher unit. The 60 K loops are for the radiation shields. The liquid flows into the cryostats in parallel. Every line into a cryostat has a flow control valve. The flow is continuous so that some liquid may return to the refrigerator, mixed with gas. Heat load stabilizing heaters are to be set in the liquid helium dewars for a stable operation against a quick change of rf dissipation.

The quiescent heat flow into all the resonators, helium dewars and liquid transfer lines was estimated to be about 120 watts[7]. Forty-six resonators can share the rest refrigeration power of about 380 watts in operation. In operation at the design rf loss of 4 watts for each resonator, power of about 180 watts will be dissipated and 200 watts will remain for extra power. The heat flow into the 60 K loops was estimated to be about 2500 watts.

The system has been ordered and will be installed in the beginning of 1992 together with the linac components.

1.4 Further work

The rest 24 resonators are being completed at the industry. They will be delivered to JAERI at the end of 1991. We plan to treat them after the refrigerating system is installed and confirmed to work with all the resonators and cryostats.

For harmonic double drift bunching of incident heavy ion beams, we have started the development of 260 MHz quarter wave resonators made of niobium and copper and shown in Fig. 3. It is in a beginning stage of fabrication.

2. Free Electron Project at JAERI

JAERI is developping a FEL which incorporates a superconducting linac to realize high quality acceleration and quasi-CW operation[8]. The newest layout plan of the FEL is shown in Fig. 4. The layout was

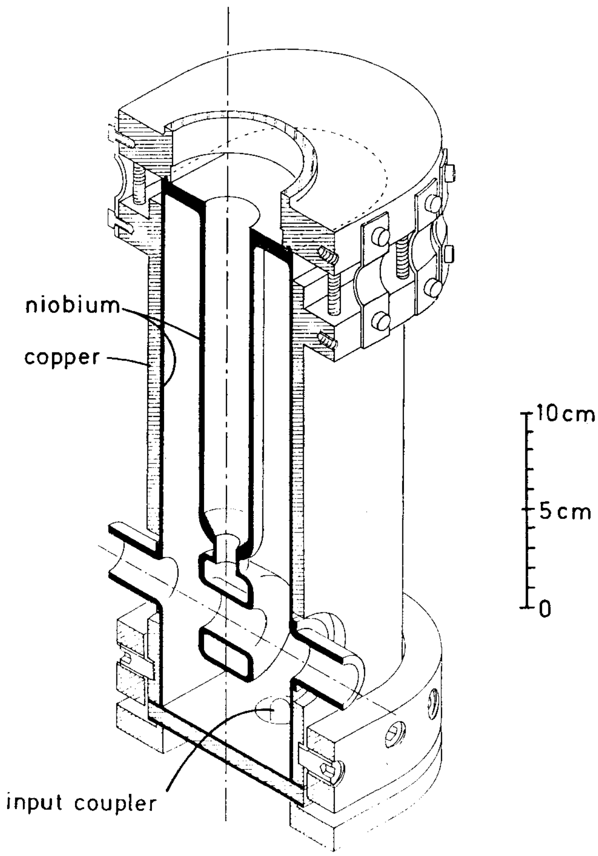

Fig. 3. A 260 MHz superconducting quarter wave resonator of $\beta_o = 0.1$.

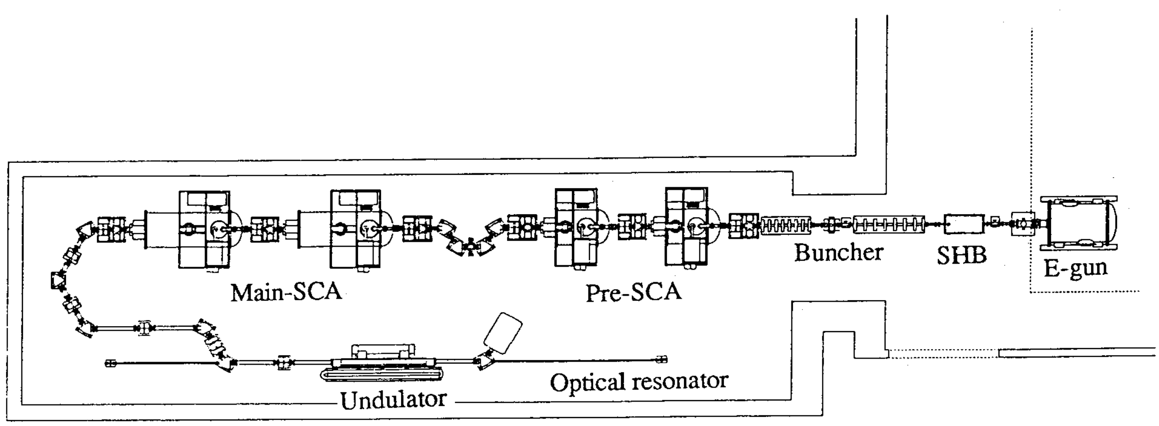

Fig. 4. Layout plan of a free electron laser incorporating a superconducting linac.

changed from the previous L-shaped placement[3] to J-shaped one because of a change of installation place. A 90° bending magnet is, then, replaced with a momentum analyzer composed of 4 bending magnets. Electron beams are bent back with a tripple-bend achromat before entering into the undulator. Up to now, the injector gun and the subharmonic bunching system have been developed.

The acceleration system will consist of two 500 MHz single cell cavities for pre-acceleration and two 500 MHz 5-cell cavities for main acceleration. Order for the superconducting cavities with their cryostats have been placed with a foreign industry.

Every cavity and its radiation shields are to be independently cooled with small refrigerators which have cold heads in closed gas loops[9]. Liquid helium in the cavity dewar is supplied from liquid helium containers. The liquid level is maintained by heat exchange between the gas and the cold head in the dewer. The refrigeration power for 4.3 K liquid is 10 watts. For radiation shields, they are thermally connected to cold heads with copper braids.

All the accelerator components will be delivered in 1992.

3. RF properties of metal-oxide superconductors

As a program of JAERI on high T_c metal-oxide superconductors, a group has been measuring RF properties of various polycrystalline superconductors[10]. In the last Workshop, cavity construction with various high T_c superconductors and their Q values were reported[3]. In recent years, surface resistance of various polycrystalline superconductor wires has been measured by putting them in a coaxial-line half-wave cavity, as was done at Argonne National Laboratory[11,12]. The wires were prepared by a doctor blade method. Typical surface resistance of YBCO superconductors at 2-3 GHz was around 100 μ ohm at about 4 K and approximately 400 μ ohm at 20 K.

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