DEVELOPMENT OF JAERI-TANDEM SUPERCONDUCTING BOOSTER

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ABSTRACT

A superconducting heavy ion linac has been proposed for the JAERI tandem booster. The linac will be composed of superconducting quarter-wave resonaters. Present status of the development work on the superconducting resonators as well as the linac system is presented.

1. Introduction

JAERI has a plan of a superconducting booster to multiply by 2 to 4 the energy of heavy ions from the JAERI tandem acceleretor. The booster will be a linac composed of superconducting quarter-wave resonators, which will accelerate ions of carbon to bismuth from the tandem. The linac needs as many as forty resonators in order to obtain an accelerating voltage of 24 - 28 MV, if the maximum accelerating field level is assumed to be in 4.0 - 4.7 MV/m for the resonators.

The development work on the superconducting resonators began in 1984. A prototype resonator was successfully fabricated in 1986. In its performance tests, maximum accelerating field levels of 4.6 MV/m and 5 MV/m have been obtained.

2. Linac

The construction site will be on the east side of the tandem. The linac units will be lined up in the direction of 0-degree beam line from the tandem switching magnet. Ions from the tandem will be bunched by a superconducting buncher, electron-stripped at the entrance of the linac or at the object point of the tandem energy analyzing magnet, accelerated by 40 quarter-wave resonators housed in 10(or 5) cryostats(linac units) and focused by 10 lenses in the linac. The accelerated ion beams will be de/re-bunched by a couple of superconducting quarter-wave resonators, analyzed by a 90 degree magnet and transported to a new target area by three beam lines. A 350 watts helium liquefying system and an RF control system will be placed by the linac.

3. Prototype Resonator

We have devoted much of our development time to the work on superconducting resonators so far. A prototype resonator is shown in fig. 1. The center conductor terminated with a drift tube is made of pure niobium and is hollow for cooling with liquid helium. The outer conductor is an oval cylinder made of niobium-clad-copper plates and is cooled via the thermally conductive copper layer. The accelerating length is 15 cm and the optimum ion velocity is 0.1 c.

The fabrication of the prototype resonator began in the fall of 1985 at Mitsubishi Electric Company in Kobe. Parts of the center conductor and other niobium parts were made by machine processing from niobium rods or thick plates and two halves of the outer conductor cylinder by sheet processing. Electron beam welding was used to weld them together. Niobium surfaces of the center and outer conductors were electropolished by about 150 μm in JAERI. The center conductor was annealed at 1000 C in vacuum of 1×10^{-6} Torr for 6 hours before and after the electropolishing. Then, the center conductor and the outer one were welded together. The niobium surface was electropolished several times by 10 - 20 μm each in order to remove a number of small spots on the drift tube and the base plate of the center conductor. The spots happened to be brought in by the second annealing.

The prototype resonator was successfully fabricated for the first trial of fabrication in spite of some mistakes. The mistake which should be mentioned in addition to the spots above is the accidental creation of cracks and holes at the upper ends of two welded lines in the outer conductor of niobium by excessive penetration of electron beams through copper in the welding process of a copper part. It was too difficult to repair them perfectly. It was fortunate that they were located where the electromagnetic fields are not so strong.

The performance test began in August of 1986. At the first test, we had a maximum field level of 3.6 MV/m. The resonant frequency at 4.2K was 129.6 MHz. After several tests and surface treatments, we had 4.6 MV/m with 1.6 watts rf dissipation and a Q-factor of 5×10^{8}. The performance got worse by a further surface treatment of electropolishing and rinse, although we wished a higher Q with the treatment. Recently, a field level of 5 MV/m was obtained with a low Q as low as 1.4×10^8, after mechanical polishing with #400 to #1200 polishing papers and electropolishing. Large rf dissipation, a cause of the low Q, seemed to be occur at the cracks and holes mentioned above or in the base plate of the center conductor from the thermometry of the outer conductor during the test.

We learned that all the welds of niobium should be perfect and that too much electroplishing might be harmful. We had good prospect that this type of quarter wave resonators will provide enough accelerating field levels for the booster.

4. Superconducting Buncher

During the performance test of the prototype resonator, a couple of quarter-wave resonators, a cryostat to house them, rf phase control circuits and associated equipments for the buncher were being fabricated. Some of them were already delivered. The resonators were changed at several points from the prototype one in order to introduce frequency tuning capability into the outer conductor and to meet the requirements of the high pressure gas regulation. Frequency tuner and rf phase stabilizing controller are under development.

5. Hereafter

We will make a same thing as the buncher in 1987-1988. This will be used for the acceleration test of heavy ions with the resonators, combined with the buncher.
In future, it will be used as a de/re-buncher in the booster. We hope to start the construction of the main linac units in 1988.

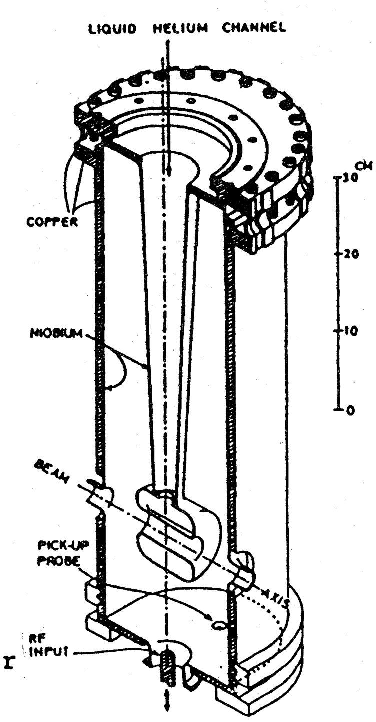

Fig. 1. Cut away view of a superconducting quarter wave resonator.