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STATUS REPORT ON STANFORD'S SUPERCONDUCTING HEAVY ION LINAC PROJECT[*]

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Summary

Two superconducting niobium reentrant cavities resonating at 430 MHz were phase locked to within ± 0.05 rad. A quarter-wavelength resonator, operated at 215 MHz to chop the ion beam at the frequency of the accelerating cavities, was built and tested. Beam chops of less than 185 ps FWHM were obtained from a continuous 2 MeV proton beam. A double cavity structure, having the same separation between cavities and the same design details as planned for a many-cavity accelerator section, has been constructed. An assembly of two such double cavities, with associated tuners and electronics for each of the four cavities, is currently under test.

Introduction

Stanford's superconducting heavy ion linac project aims at the construction of a booster to enhance the energy of ions from a tandem Van de Graaff accelerator. The basic element of such a booster is a superconducting reentrant niobium cavity which resonates at 430 MHz.[1] A booster consisting of 100 such cavities (1 W/cavity) will more than double the energy of the ions, even without second stripping. The cavities will be grouped in rigid structures containing 10-12 cavities each. The distance between the centers of two adjacent cavities will be 10 cm. The single-gap structure of the reentrant cavity has the advantage of allowing individual control of each acceleration gap, thus enabling efficient acceleration of ions with different velocity profiles.

The acceleration of a beam by a single cavity,[2] as well as the use of such a cavity as a buncher,[3] have been previously reported. This paper describes phase locking of two cavities, assembly of an acceleration section consisting of four cavities, and the construction and testing of a beam chopper.

Phase Locking

Two cavities were phase locked. One of these cavities, with its tuning devices, is shown in Fig. 1. The following procedure was used for phase locking:

1. One of the cavities was driven to free-run at its resonant frequency. The second cavity was then tuned to within 100 Hz of that frequency with the aid of an electromechanical tuner,[3] which had a range of 2 MHz. This tuner is a motor driven caliper, which squeezes the cavity in its gap region.

Fig. 1. A reentrant niobium cavity with its tuners. The cavity is 35 cm in diameter.

2. The pressure in the helium bath was stabilized by a throttle valve in the helium gas return path.[3] This valve was controlled by a circuit detecting the frequency difference between the first cavity and a reference oscillator.

3. Cavity 2 was then locked to cavity 1 employing a piezoelectric tuner[4] having a 300 Hz range. This tuner was mounted on a cavity rib and exerted a force between the rib and the cavity surface in its gap region. The control signal driving the piezoelectric tuner was obtained by comparing the phases of the signals sampled from the two cavities. The same control signal was fed into an electronic phase shifter, in order to handle small phase variations.

Due to the extremely noisy environment in which our dewar happened to be situated, accoustical resonances in the dewar were a major problem when trying to phase lock the two cavities. These resonances were damped by partially filling the helium bath with

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styrene foam beans.

The two cavities were thus phase locked to within ± 0.05 rad. Work is in progress to obtain better phase locking by eliminating some of the noise sources in the vicinity of the dewar and by improving the electronic control unit.

Figure 2 is a block diagram of the setup used for phase locking. The cavity control unit shown in this diagram powers the cavity and controls the amplitude and the phase of the oscillations.[3]

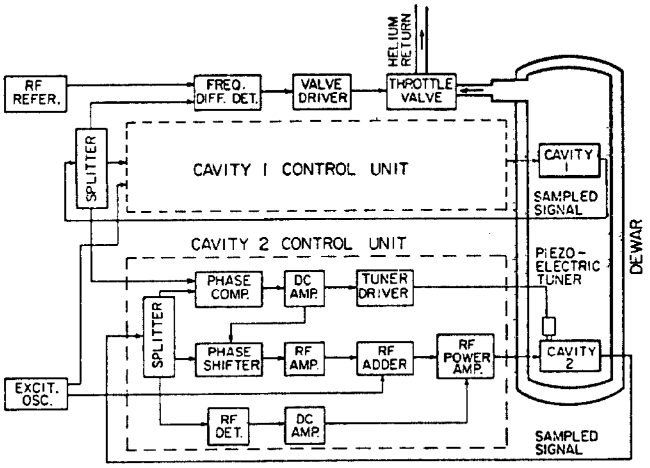

Fig. 2. Block diagram of the setup used for phase locking.

Beam Chopper

It is essential for a booster following a tandem Van de Graaff accelerator to preserve the low energy spread of the incoming beam with minimum intensity loss. In the case of a linac booster this implies that a high portion of the incoming beam be compressed into short bunches to be exclusively injected into the linac. This can be achieved by the use of a chopper-buncher combination. The assembly and testing of a 430 MHz post-Van de Graaff buncher, using a single superconducting niobium reentrant cavity, was previously reported.[3] Recently we have built and tested a post-Van de Graaff beam chopper, producing beam bursts at the same frequency.

A 215 MHz room-temperature quarter-wavelength resonator (Fig. 3) produces an electric field across a pair of deflection plates (4.7 cm long, 1.3 cm wide and 0.5 cm apart). This field sweeps the beam across a slit situated 2 m away from the deflection plates. Beam bursts with a repetition rate of 430 MHz are thus obtained. The resonator has a plunger type tuner, a unity coupled inductive feeding probe, and a capacitive sampling probe. The bandwidth between -3 dB points is 220 kHz.

The frequency of the signal sampled from an accelerating cavity is divided by two, using a fast flip-flop. The output of the flip-flop drives an RF power amplifier which feeds the resonator. RF power of 10 W fed into the resonator produces a peak voltage of 2 kV across the deflection plates.

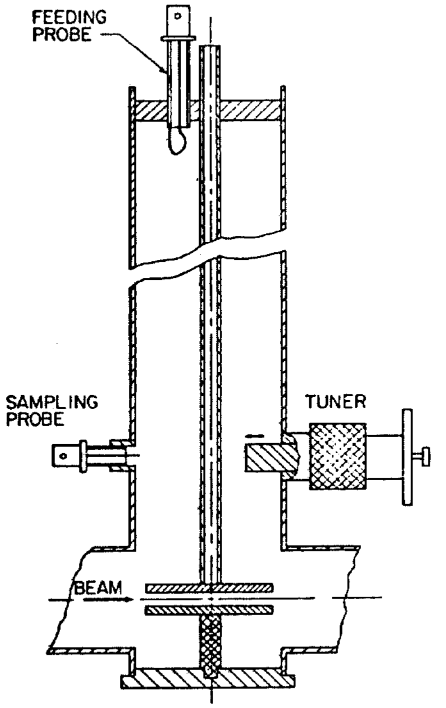

Fig. 3. Beam chopper resonator.

Figure 4 shows the time distribution of a 2 MeV proton beam obtained with 10 W applied to the resonator. A doublet of quadrupole lenses was used to focus the beam on the slit. The width of the slit was 0.8 mm, allowing approximately 80% of the beam to pass through it when the RF power was turned off. The method used for measuring the time distribution is described in Ref. 3.

It should be noted that the actual FWHM of the proton beam bursts was considerably smaller than the 185 ps indicated in Fig. 4, since the time resolution of the measuring system was approximately 100 ps.

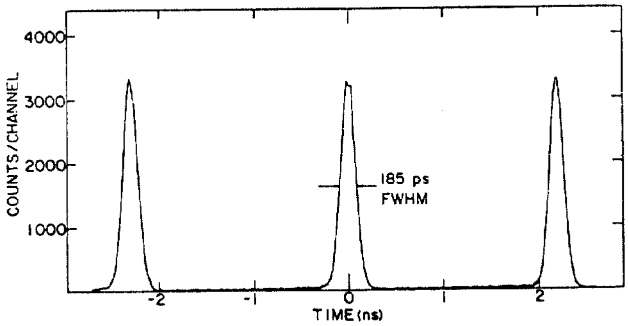

Fig. 4. Time distribution of a chopped 2 MeV proton beam (resonator powered with 10 W).

For a heavy ion beam from an 8.5 MV tandem accelerator, the same chopper arrangement, with 10 W RF power applied to the resonator, will produce bursts of approximately 500 ps FWHM. Hence, this beam chopper can be used in a post-tandem chopper-buncher combination.

Four-Cavity Test Section

A double cavity structure has been designed, and two such units have been manufactured. Each double cavity is a rigid structure consisting of two cavities, having 10 cm separation between their centers. The design features of a double cavity, including the separation between adjacent cavities, are the same as those planned for a many-cavity structure. The inner surfaces of the cavities were treated in a manner similar to that described in Ref. 1. An experimental section of two double cavities (Fig. 5) has been assembled. Each of the four cavities is equipped with an electromechanical tuner and a piezoelectirc tuner. Four cavity control units have been built, each contained in a NIM bin plug-in unit.

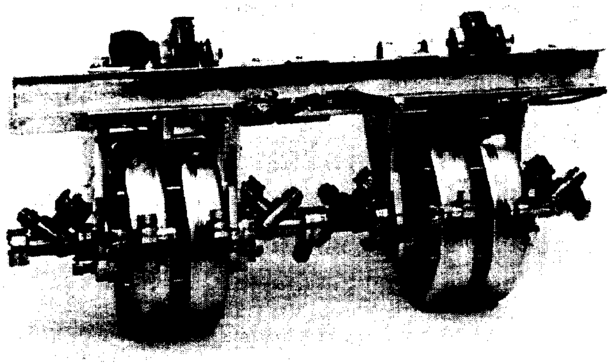

Fig. 5. Assembly of two double cavities.

The performance of this four-cavity assembly as an accelerating section will soon be tested with a chopped 2 MeV proton beam.

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