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SUPERCONDUCTING RF SYSTEM FOR THE CESR LUMINOSITY UPGRADE: DESIGN, STATUS, AND PLANS*

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1 INTRODUCTION

The CESR Luminosity Upgrade Plan consists of several consecutive steps, or phases [1]. At the present time, this program is in Phase II. The next step, Phase III, would yield a luminosity of $1x10^{33}cm^{-2}sec^{-1}$ with 45 bunches in each beam for a total current of 1 A. This plan utilizes four superconducting single-cell cavities with an accelerating gradient of 6 MV/m, which corresponds to a peak accelerating voltage of 1.8 MV per cell. The power transferred to the beam in each cavity would be 325 kW. Some machine and RF parameters are given in Table 1.

The use of only four superconducting RF (SRF) cells with more strongly damped higher-order modes (HOMs), as compared to the present twenty normal conducting (NRF) copper cells, decreases both the broad band and narrow band impedances sufficiently to allow stable operation at the high current levels.

The name BB1 has been assigned to the Cornell superconducting 500 MHz single-cell cavity shape. One can find a detailed description of the cavity elsewhere [2]. Two cavities have been manufactured to date: the first, BB1-1, by Dornier, and the second, BB1-2, by ACCEL.

The BB1-1 cavity and prototype RF window, cryostat, HOM loads and beam line components were subjected to a beam test in CESR in August 1994 [3]. This experience allowed us to complete the design of the SRF system, which is described in this paper.

2 SYSTEM DESCRIPTION

As mentioned earlier, the SRF system will consists of four single cell niobium cavities. Each cavity has its individual cryostat, input coupler and RF window, two ferrite HOM loads, taper transition(s) to the adjacent CESR beam tube, and some other beam-line components. A single cavity module is shown in Figure 1.

Table 1: Selected parameters for CESR Phase III.

Beam energy	5.3 GeV
Revolution frequency	390.14 kHz
Total current in two beams	1 A
SR energy loss per turn	1.16 MeV
Momentum compaction	0.0113
Bunch length	1.7 cm
Machine loss factor	5.2 pF^{-1}
RF harmonic number	1281
Beam power	1.3 MW
Number of bunches per beam	45
RF frequency	500 MHz
Total RF voltage	7.2 MV
Number of SRF cavities	4
R/Q per cell	89 Ω
Unloaded *Q*	$1x10^9$
External *Q*	$2x10^5$

Pairs of the SRF cavities will replace the present NRF cavities on the East and West side of the CLEO detector (Figure 2). A calculations [4, 5] indicate that two tapers provide a significant fraction of the assembly's total loss factor (26% at 1.7 cm bunch length and about 45% at 1.0 cm bunch length) and impedance. Therefore, in order to reduce the overall impedance of the system, there will be no tapers between the cavities in the pair. Each pair of cavities will be fed by one klystron with a magic T to split the RF power.

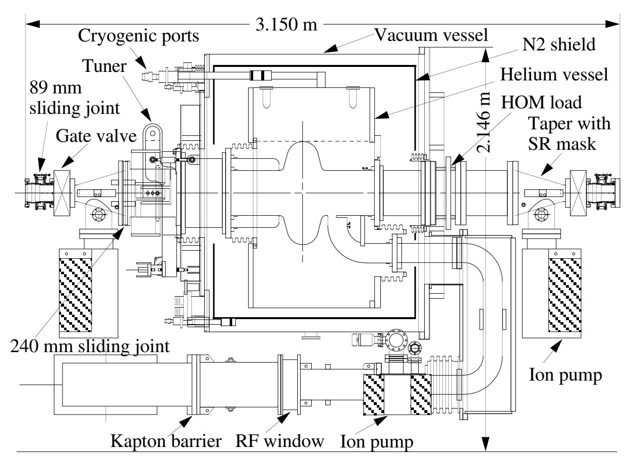

Figure 1: Layout of a single MARK II cavity-cryostat system to be installed in CESR.

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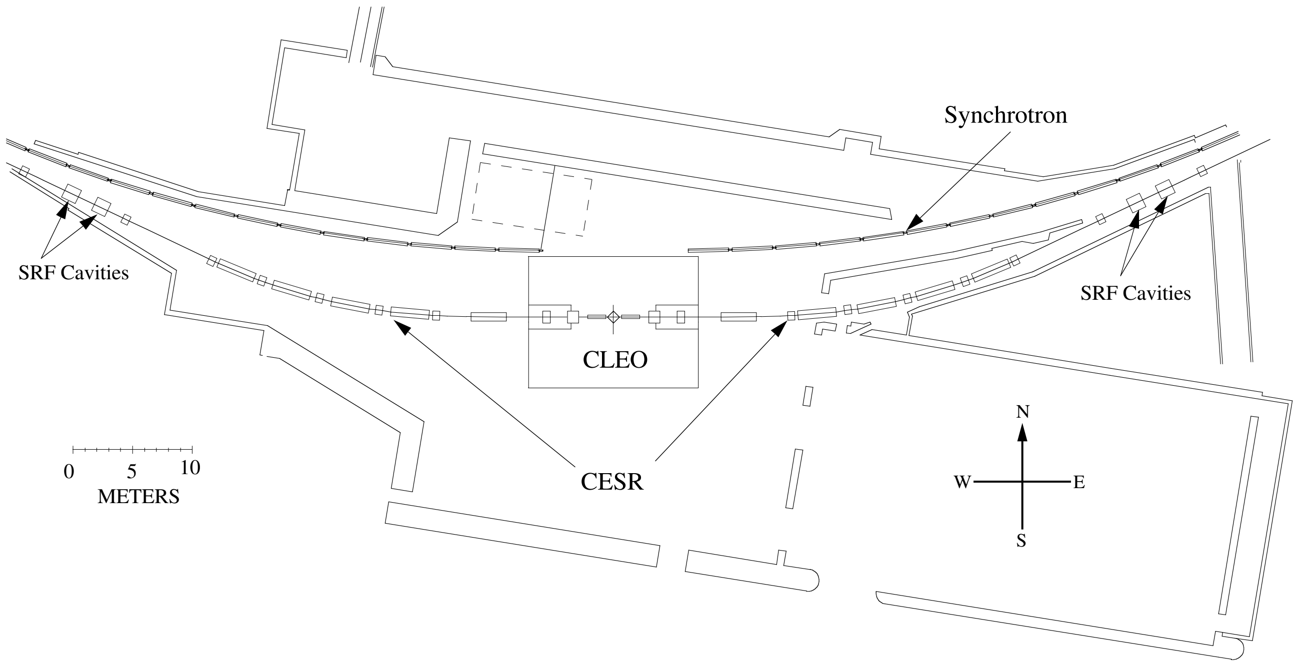

Figure 2: Layout of CESR near the interaction region.

2.1 Cavity

The BB1-1 cavity was exhaustively tested in a series of tests in a vertical and a horizontal cryostat [6, 3]. This cavity performed satisfactorily in all respects but was found to suffer from the "Q-virus" due to one of the chemical treatments. In the near future we plan to heat treat this cavity to remove hydrogen contamination.

The BB1-2 cavity differs from the BB1-1 only by the addition of two RF probes, one on the round beam tube and one on the waveguide just before the coupler. After mechanical measurements and final chemical cleaning, this cavity was tested in a vertical cryostat up to 6 MV/m accelerating gradient. A special slow cool-down test was performed to check for hydrogen contamination. There were no signs of the "Q-virus". The BB1-2 cavity will be used in the final assembly of the MARK II cryostat.

2.2 Cryostat

The MARK I cryostat [7] worked extremely well during the beam test [3]. This cryostat was very tall, as it was designed for installation in the high bay area near the CLEO detector. However, the final version of the cryostat must fit in the 2.44 m (8 foot) high accelerator tunnel where the RF straight sections are located.

The MARK II cryostat was designed to meet the tighter tunnel requirements. The cavity and beam line components are almost unchanged from the MARK I design, but the cryostat is turned upside down so that the waveguide feed is from the bottom, with the RF window lying beneath the cryostat. The cryostat vacuum vessel was reduced in width and increased in hight. This new cryostat is currently being manufactured and will be tested with the full size copper cavity model at Meyer Tool and Mfg.

In the first SRF installation in the CESR tunnel there will be only one SRF cavity, so small gate valves (89 mm dia.) and small sliding joints will be placed on both ends of the cavity next to the tapers. There will also be a 240 mm dia. sliding joint to accomodate the tuner motion.

2.3 Refrigerator and Distribution System

We have ordered a dedicated refrigerator system for Phase III. A 600 W unit is presently being installed and in a year or so another 600 W system will be added in parallel for the CLEO solenoid and the superconducting quadrupoles to be added near the interaction point in Phase III. Details of the refrigerator system are reported elsewhere [8].

The 2000 liter storage dewar, refrigerator output lines, transfer lines, and main and station distribution boxes are on order and will be installed this summer. Transfer line elbows are being manufactured in house.

2.4 HOM Loads

During the beam test, beam line HOM loads were installed at each end of the BB1-1 cavity [9]. The performance was entirely satisfactory with respect to both adequately damping HOMs and adequately handling the HOM power. This power level in the beam test was only 1 kW per load, much smaller than the Phase III requirements.

An additional test was done off line, with an HOM load under vacuum. In this test, 7 kW of power was dissipated under vacuum and 15 kW was dissipated in air. It was clear upon observation with an infrared camera that there were hot spots on the ferrite where the thermal bond to the copper cooling panel was poor.

New loads are being fabricated for the MARK II cryostat. The new cooling panels are made of Elkonite (a tungsten copper composite) instead of copper. This material matches the thermal expansion coefficient of the TT2-111R ferrite very closely and should therefore provide a more homogeneous solder bond and improve the load's power-handling capability. Also, the ferrite has been extended toward the cavity by an additional 3 cm on the fluted beam tube end in order to reduce the Q of one of the marginally troublesome transverse modes by a factor of 2 to put it well within the calculated requirements for the anticipated current levels.

2.5 RF Window

We have previously reported the test of the new high power RF vacuum window manufactured by Thomson [10]. CW power levels up to 300 kW were obtained. Pulsed power levels reached 430 kW in travelling-wave operation at 33% duty factor and 125 kW in standing wave operation (at all phases) with 50% duty factor. We plan to use this window design on the MARK II cavity/cryostat.

2.6 Sliding Joint

A life-time test of the 240 mm dia. bellows sliding joint was done in vacuum to test the reliability of the sliding joint under the repetitive motion required for the constant cavity tuning due to beam loading. We tested three different combinations of finger stock and stainless steel shell: i) BeCu finger stock against a freshly machined stainless steel surface; ii) BeCu finger stock against a polished surface; and iii) Ni finger stock against a polished surface. The last combination clearly was unacceptable due to a lot of dust collected in a short time. Although the second combination was the best in the short term, polishing the surface made very little difference in terms of long-term wear of the sliding joint.

3 BEAM-CAVITY INTERACTION

According to prediction [5], the total parasitic loss factor of the BB1-2 single cavity assembly is 0.374 pF^{-1} for a 1.7 cm long bunch; the corresponding dissipated power is 5.3 kW per HOM load for CESR Phase III conditions. This is well below the power level reached in off-line tests of the HOM loads used with the MARK I cryostat.

The beam test results [3] as well as preliminary studies of cavity HOMs [2, 11] indicate that all HOMs are sufficiently damped by ferrite and there will be no instabilities due to beam-HOM interaction. Recent studies of the direct interaction between the beam and the ferrite layer [12] indicate that there should be no problem for Phase III.

4 STATUS AND FUTURE PLANS

As a first step toward the upgrade of the RF system for CESR III, one of the NRF cavities will be replaced with an SRF cavity in a new cryostat for a long-term test. The new cavity, BB1-2, was tested in a vertical cryostat up to 6 MV/m accelerating gradient. The cryostat is being manufactured and will be tested in the near future. A new 1200 W refrigeration and distribution system is being fabricated and installed at this time. After testing at low RF power level in the horizontal MARK II cryostat, the cavity assembly will be processed with high power for the final off-line test of all the components (late summer 1996). The cavity module will then be installed in CESR for a long-term test.

According to the CESR luminosity upgrade plan, all four SRF cavity modules are anticipated to be installed in the ring in late '97 - early '98 assuming the project is funded at the expected level.

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