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SUPERCONDUCTING CAVITIES FOR A LARGE e^+e^- COLLIDING BEAM ACCELERATOR* H. Padamsee, J. Kirchgessner, J. Mioduszewski, R. Sundelin and M. Tigner Cornell University, Ithaca, N.Y. 14853

Abstract

An L-band cavity accelerator assembly suitable for large storage ring service is being developed. Design criteria are presented and development status is detailed.

Introduction

The potential advantage of application of superconducting cavities to high energy e⁺e⁻ storage rings is widely recognized¹. Recently a design study proposal² has been made for a 50 GeV x 50 GeV machine (CESR II) using 500 meters of superconducting rf structure. Testing a small section of superconducting cavity in an operational storage ring such as CESR is crucial to assessing the feasibility of the proposed design.

Design Parameters

Some of the relevant design parameters of CESR II are reproduced in Table I along with parameters for the small section test in CESR. In addition to reaching the design gradient at the design Q_0 , the l meter section in CESR must support single beam currents 3 times higher than the design current for CESR II in order that comparable power and peak voltages be induced in the higher order modes. By operating the superconducting section in conjunction with the normal CESR rf system³ (500 MHz) in a "bunch shortening mode" it should also be possible to achieve bunch lengths comparable with those expected in CESR II.

TABLE I. Proposed design parameters for CESR II and for small section test in CESR.

	CESR II	CESR Test
Beam energy	2x50 GeV	4 GeV
Beam current	2x3.7 mA	13 mA (single beam)
Number of bunches per		,
beam	2	1
Bunch length	~1 cm	~1 cm (see text)
Circumference	5485 m	768 m
RF frequency	1500 MHz	1500 MHz
Operating temperature	2°K	2 ⁰K
Cavity length	500 m] m
Unloaded Q	3x10 ⁹	3x10 ⁹
Accelerating gradient	3 MV/m	3 MV/m
Wall losses	2.5 watts/m	2.5 watts/m
Total losses	5 watts/m	5 watts/m
RF power	20 KW/m	20 KW/m
HOM power losses	2-4 KW/m	2-4 KW/m

CESR Test Cavity

Fig. 1 shows a sketch of the test section. The muffin-tin structure⁴ is adopted. The portion of the higher mode spectrum for this structure having the greatest overlap with the bunch spectrum has been investigated and coupling devices developed. These damp out longitudinal and transverse modes to the extent necessary to prevent beam instabilities in the CESR small section test as well as to limit the total power dissipated into liquid helium to a small fraction (<1 watt) of the beam induced HOM power. Details of the HOM coupling scheme and damping factors achieved have been given elsewhere⁵. The loaded Q's of the HOM's range from $5x10^2$ to $7x10^4$. Power is coupled to the fundamental mode through a large iris adjacent to one end-cell. The position of the short in the stub

opposite to the coupler is adjusted to achieve the desired coupling to the fundamental $(\sim 10^3)$.

A disadvantage of the muffin-tin structure is that it exhibits a transverse curvature in the longitudinal accelerating field. (Such a curvature is absent in a cylindrically symmetrical cavity over the entire beam aperture.) This curvature leads to a transverse gradient in the accelerating field if the bunch is off axis. The curvature and gradient could cause a number of problems: orbit distortion, synchrobetatron oscillations and, most seriously, coherent longitudinal instabilities⁶. To suppress the most serious effect requires a factor of 24 reduction in the curvature for application to CESR. Such a reduction is achieved by rotating successive cavity modules 90° about the beam axis relative to one another. A curvature cancellation occurs because the curvature in one transverse direction is equal and opposite to that in the orthogonal transverse direction. Furthermore, in order to maximize the horizontal aperture to accommodate the ribbon-like beam and the horizontally emitted synchrotron radiation, each cavity is rotated ±45° about its beam axis relative to its natural horizontal orientation. This provides sufficient aperture and field quality for both CESR and CESR II.

Niobium Cavity Tests

A 0.5 meter long Nb module with HOM couplers has been built and tested. The fundamental power coupler has been omitted in this first laboratory test module so that maximum possible field strengths may be reached with a low power source (20 watts). The HOM couplers were terminated in a short by placing Nb plates at the end of the Nb elbow sections.

Sheet metal fabrication techniques previously developed for higher frequency cavities were used and the standard chemical processing techniques (electropolishing and oxipolishing) were adopted. The cups with the HOM couplers were fired at 1800°C in the Brookhaven furnace. Tests with S-band cavities containing such couplers showed this to be essential to avoid thermal breakdown below 3 MeV/m. Fig. 2 shows the 5-cell halves after electropolishing and the assembly prior to final welding.

The cavity was tested in a vertical cryostat and excited by an adjustable electric probe along the beam axis. An unloaded Q_0 of 4.2×10^9 was achieved at 2° K. The maximum accelerating field obtained was 2.1 MV/m, limited by 4th order one-surface multipacting.

Prior to this cavity, 2 two-cell 1500 MHz cavities were also fabricated.⁵ The first cavity showed several orders of multipacting but processed through them up to the 4.5 MV/m, 2nd order barrier. The second cavity, which had grooves electro-discharge machined into the cup bottoms showed no multipacting but thermal break-down at 2.8 MV/m at the cup bottom. The breakdown spot was in the vicinity of the grooves as determined by a network of carbon thermometers placed close to the walls of the cavity.

In the next module, we plan to include the fundamental power coupler. However, in order to permit a low power laboratory test, the feed waveguide will be shorted at a location selected to give the same field strength at the coupling iris as would result if the feed guide were terminated. The cup bottoms will also have grooves machined (EDM) to avoid multipacting.

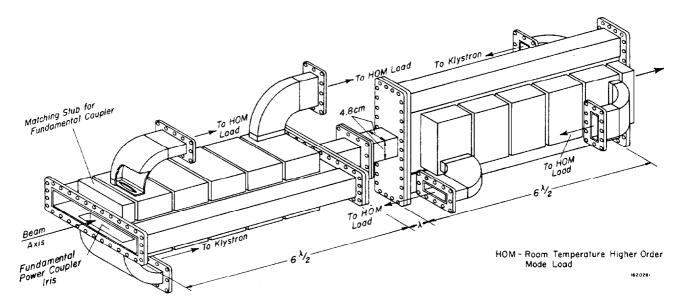


Fig. 1: Sketch of a 1-meter section for CESR beam test. The assembly will be rotated 45° about the beam axis to maximize the aperture.

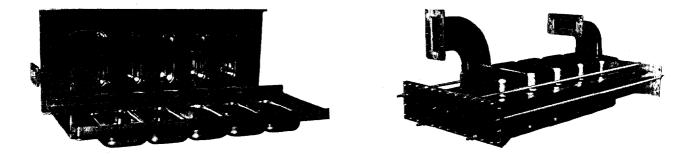


Fig. 2: 5-cell cavity with HOM couplers. A: Halves after electropolishing, B: assembly prior to welding.

Conclusion:

The first full scale module at L-band with HOM couplers reached the design $\boldsymbol{Q}_{0},$ but was limited by one-surface multipacting to 2.1 MV/m.

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