

## Accelerating Cavity Development for the Cornell B-Factory, CESR-B\*

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### ABSTRACT

To achieve luminosities of 30-100 times CESR, 1-2 amps of current must be stored. A CESR B-factory [1] parameter list calls for 50 MV for two rings, to be supplied by 16 cells operating at 10 MV/m gradient. With a new cell shape, the impedances of the dangerous higher order modes (HOM) are drastically reduced. All HOMs modes propagate out of the cavity via the beam pipe, which is specially shaped. This allows HOM power couplers to be placed completely outside the cryostat. A ferrite absorber on the beam pipe lowers all Qs to ~100, which is sufficient to avoid multi-bunch instabilities without feedback systems. A waveguide input coupler on the beam-pipe provides Qext as low as  $5 \times 10^4$ , with a C-slot shaped iris that has a negligible effect on the cavity loss parameter.

### THE CASE FOR SUPERCONDUCTING RF CAVITIES

To achieve the desired currents in a B-factory, it will be essential to lower the impedance of the ring. RF cavities are a chief source of impedance. The advantage of using SRF is that higher gradients are possible than with room temperature RF, allowing a substantial reduction in the number of cells and their corresponding impedance. There is a substantial savings in capital cost from the smaller RF installation which need only provide the beam power, the cavity dissipation being negligible. Corresponding savings in operating cost are realized. A quantitative comparison between a normal conducting RF system for a machine such as CESR-B and the SRF system envisioned is presented in Table 1.

Here we consider the use of single cell copper cavities with the same cell design as the superconducting cells, to properly compare the impedances presented. A maximum operating gradient of 1 MV/m for copper cavities is assumed, based on the need to keep the overall cell dissipation below 100 Kwatts/cell ( $10 \text{ watts/cm}^2$ ). NC cavities presently used in storage rings dissipate between 15-60 kWatts/cell [2]. The comparison shows that the SRF version has 10 times fewer cells (impedance), a 13 Mwatt RF power installation savings, and a 22 Mwatt wall plug power saving. The 2 Kwatt refrigerator needed in the

Table 1: Comparison between a normal conducting and superconducting RF system for the CESR-B factory

	LER	HER
Voltage (MV)	12	35
Beam Power (MW)	1.5	4.5
<u>Normal Conducting</u>		
Gradient (MV/m)	1	1
No. of cells	40	117
Cavity dissipation (MW)	3.4	9.8
<u>Superconducting</u>		
No. of cells	4	12
Gradient (MV/m)	10	10
Cavity dissipation (watts)	408	1224
( $Q = 1 \times 10^9$ )		

SRF version would absorb < 1/4 of transmitter capital cost savings, and consume < 1 Mwatt of wall plug power. Today superconducting structures for storage rings TRISTAN, HERA AND LEP reach average gradients over 10 MV/m in acceptance tests. Recently a 5-cell, 500 MHz cavity reached 16 MV/m accelerating gradient[3].

While this experience shows that the desired gradient of 10 MV/m is feasible, the maximum beam current stored has been less than 100 mA. Our design concept faces the challenges to advance the capability of SRF cavities to handle amps of current. A new cell shape has been chosen to reduce the impedances of higher order modes and to facilitate power extraction and damping. New fundamental power couplers are considered to increase the input power capability from the present-day maximum of 100 kwatt to at least 400 kwatts. New higher mode couplers are considered to increase the power handling capability from 100 watts to 10 kWatts. To avoid multi-bunch instabilities in face of the tight bunch spacing of 10 nanosecs, higher modes need to be heavily damped to Qs < 100.

### CELL SHAPE.

Fig. 1 compares the new cell shape with the normal conducting cell shape presently used in CESR, and with the superconducting cavity shape that will be used for LEP-II. A major advance provided by the new shape is that the impedance of the most dangerous HOMs have been reduced by factors much larger than the drop in fundamental R/Q. It should be noted that this shape is significantly more open than the existing superconducting cavity shapes.

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<sup>1</sup>Babcock and Wilcox, Lynchburg, Va.

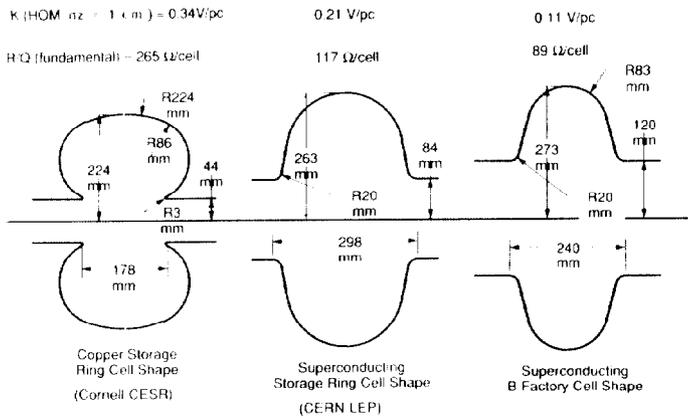


Fig. 1 Comparison of storage ring cell shapes

Table 2 lists the properties of the fundamental mode as computed by SUPERFISH.

Table 2 : Properties of the fundamental mode.

Frequency	500	Mhz
R/Q	89	Ohms/cell
k(fund.)	0.07	V/pC
E <sub>max</sub> /E <sub>acc</sub>	2.5	
H <sub>max</sub> /E <sub>acc</sub>	52	Oe/MV/m
Dissipation	102	Watts/cell
(Q = 1x10 <sup>9</sup> , E <sub>acc</sub> = 3 MV/cell)		

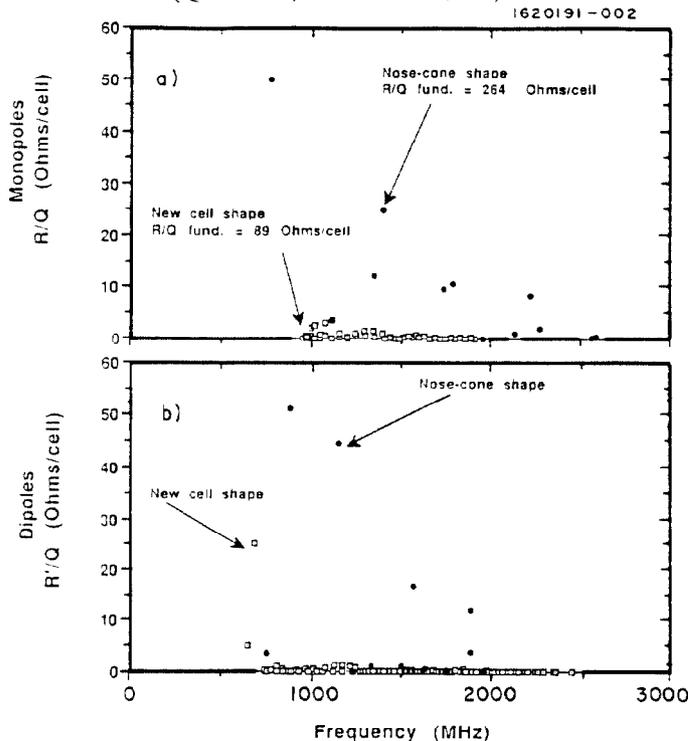


Fig. 2 Comparison of impedances of different cell shapes

Fig. 2 compares the R/Qs of CESR NC cell shape with the proposed CESR-B cell shape. For longitudinal HOMs (a), and all but two transverse modes (b), the highest impedance has been reduced by more than a factor of 10. Another major advance is that all longitudinal HOMs propagate out of the cavity via a round beam pipe. This allows all HOM coupling devices to be placed outside the cryostat, greatly simplifying power extraction and damping. All but the two lowest frequency transverse HOMs also propagate out the beam pipe. To extract the two "trapped" modes, we propose, following a new idea of Kagcyama[4], to use a fluted beam pipe of cross-section similar to that shown in Fig. 3. Both calculations and model measurements show that the rectangular waveguides formed by the flutes serve to guide out the troublesome transverse modes.

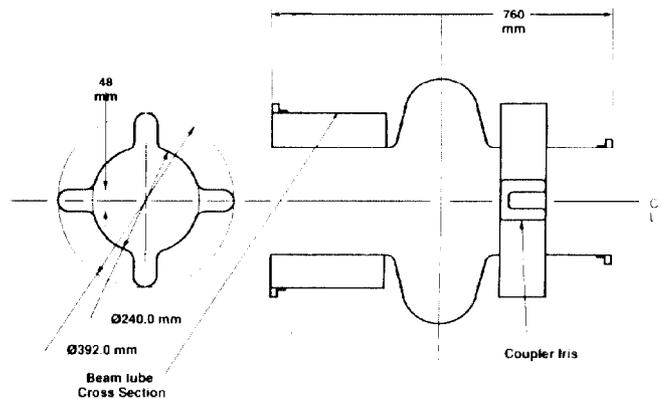


Fig. 3 Fluted beam pipe and input coupler geometries

#### FUNDAMENTAL COUPLER AND WINDOW

In comparison to a coaxial coupler, a waveguide has low power densities and needs only outer wall cooling. The overall size and static heat load is reduced by using a half-height guide. A design of the coupling iris between the cavity and the waveguide has been developed (see Fig. 3). Bench tests on a 3000 MHz copper model show QL as low as  $5 \times 10^4$ . A progress report on the window is given in another paper [5]. A 500 MHz prototype Nb cavity/coupler and high power window have been ordered from industry.

#### HIGHER MODES

Calculated Q values  $< 70$  were found for a representative set of highest R/Q (max 3.5 Ω/cell) longitudinal modes. For this, a 15 cm absorptive band with RF surface resistance  $10^4$  times copper is placed on the beam pipe. A promising absorbing material, called Ferrite-50, possessing the desired properties has been found. A complete discussion of its properties and mode damping success is presented in another paper [6]. A factor of 6 smaller scale copper cavity model (3 GHz fundamental frequency) was equipped with Ferrite-50 beam tube sections.

Strong damping ( $Q < 100$ ) was observed for all discernable modes (longitudinal and transverse). Fig. 4 shows typical results. Calculations using the program ZAP show that this degree of damping will be sufficient to avoid multi-bunch beam instabilities without the use of a longitudinal feedback system.

Calculated  $Q$  expected from a beam pipe absorber for the transverse propagating modes were  $< 75$ . The two trapped modes have quite high impedances (Fig. 2b). A model 3 GHz cavity was equipped with a fluted beam tube at one end, and the  $Q$  of the trapped modes was found to be lowered to  $< 200$ . ZAP calculations show that some transverse feedback will still be required mainly to deal with the resistive wall instability from the impedance of the vacuum chamber, aggravated by the ferrite sections.

At 1 cm bunch length, with HOM loss factor of 0.1 V/pC, the power loss will be 0.8 Kwatts/cell and 4.3 kWatts/cell for the high and low energy rings. In the resonant case, 1.5 kWatts is expected for the worst mode. The image current wall losses are estimated to be  $< 1$  kwatt per section.

Figure 5 shows the cavity and cryostat with input coupler, and higher mode absorber concepts.

#### REFERENCES

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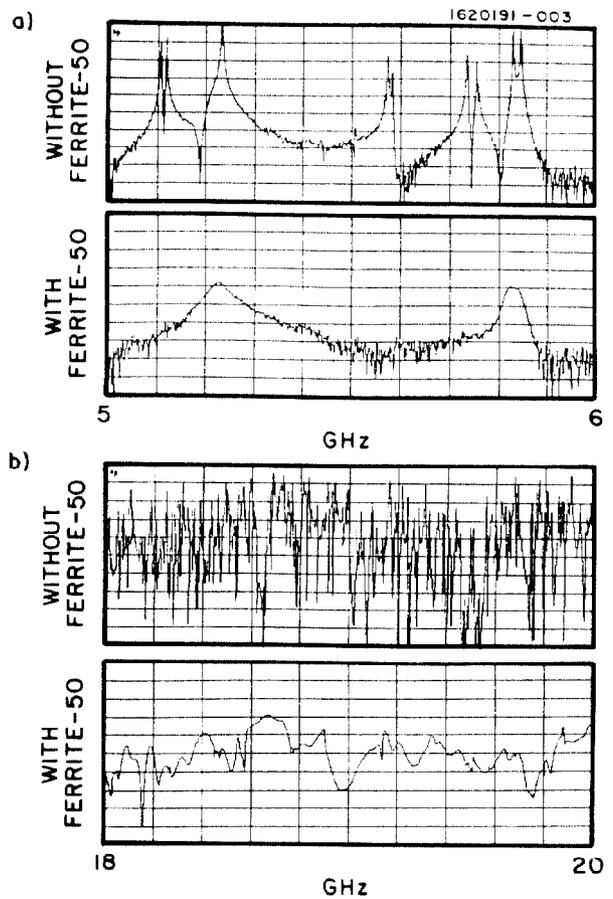


Fig. 4 Damping of higher order modes measured

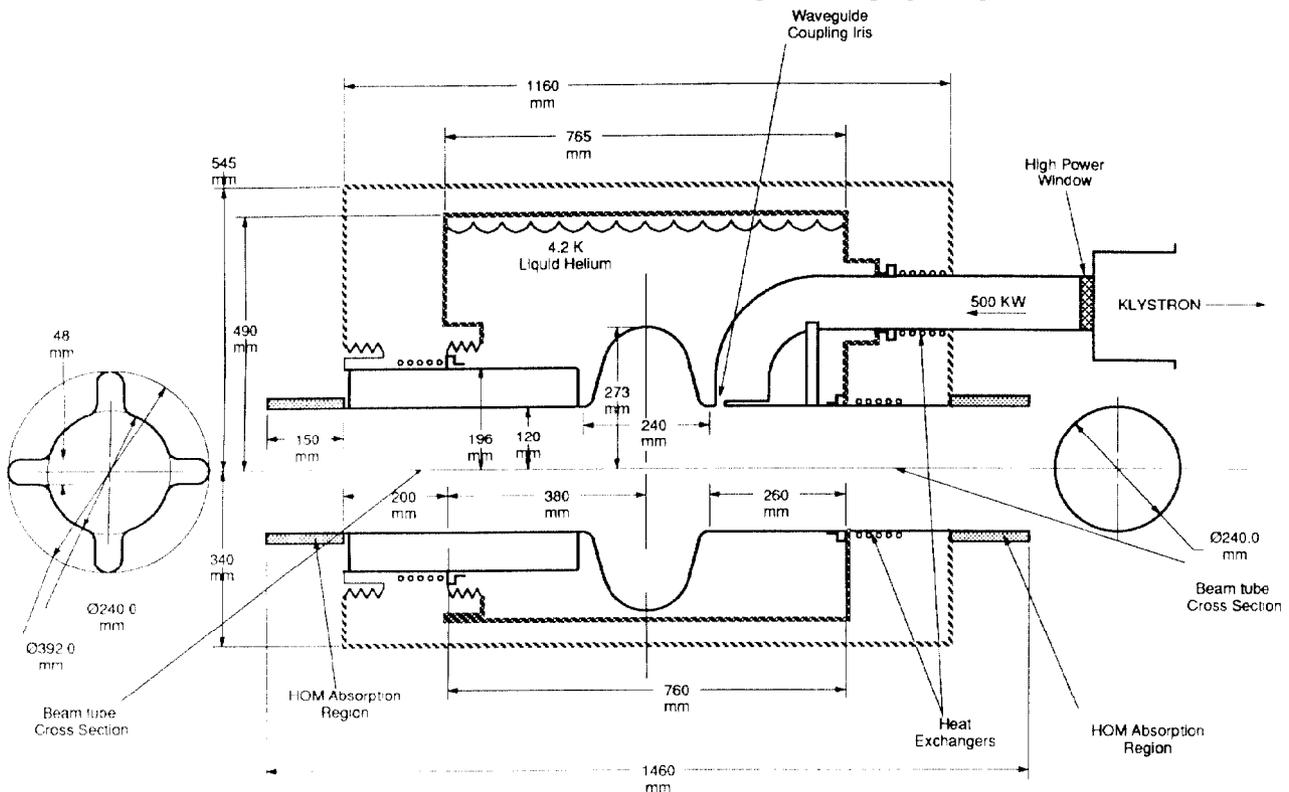


Fig. 5 B-factory SRF cavity, couplers and window concept