DESIGN AND CONSTRUCTION OF THE PHOTOCATHODE ELECTRON GUN CAVITY*

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Abstract

A 1300-MHz, two-cell rf accelerator cavity has been constructed for the high-brightness photocathode electron source program. Each cell has an rf drive. Cell 1 has a replacement photocathode plug on the back wall and has a shape designed for linear radial fields. Cell two has a more standard high-shunt-impedance shape. SUPERFISH values for shunt impedances are, respectively, 29.5 and 45.8 MΩ/m. Peak surface field maximums are 58.9 and 32.1 MV/m for an electron acceleration of 0.9 and 1.0 MeV. Drive coupling is matched for 55 and 86% beam loading at 1-A average current. The system has vacuum pumping ports, into both cells and is baked at 300°C. Typical operating pressures are in the low 10^{-10}-torr range. Cell frequencies are fine tuned by a combination of operating temperature and cell nose pulling. Cell-to-cell coupling was intended to be low (K = 0.0002); however, because of the high Qs (13 300 and 20 000), substantial coupling effects are seen. Cutting the vacuum-port slots shifted the frequencies by 1.5 MHz and gave an apparent 10% increase in the cavity Qs. Construction of the cavity required a series of four brazes with several annealing cycles. All joints are flat, and the sequence is such that each joint is brazed horizontally; as a result, all joints were successfully brazed on the first attempt. The latest experiment measurements are given in another paper at this conference.[1]

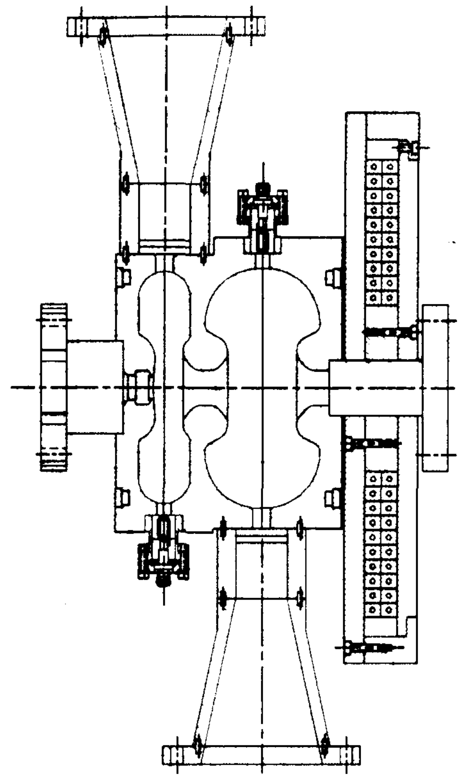

Fig. 1. Cross section of cavity.

Introduction

A 1300-MHz two-cell rf accelerator cavity has been constructed for the high-brightness photocathode electron-source program. A laser pulse traveling down the axis of the cavity causes electrons to be emitted from the photocathode on the back wall of cell 1. With proper phasing, the electrons are then accelerated to 2 MeV before leaving cell 2. Operation of the photocathode electron gun has been reported elsewhere.[1] The present report gives construction details of the rf cavity.

Cell Parameters

Figure 1 shows a cross section of the two-cell cavity. The scale of the figure can be seen by the 4.5-in. end flanges The photocathode plug is inserted from the left side of the figure into the back wall of cell 1. The design is intended for a cathode that will be retracted many times; to that end, a captured watchband rf contact spring is used. Tests of several designs showed this design to be the best with only ~2% drop in the cavity Q with cathode plug as compared to a solid-copper back wall. Figure 2 shows an enlarged view of the cross section of the cathode plug hole. The silver-plated beryllium copper watchband spring fits into the enlarged part of the hole. The tapered entrance is

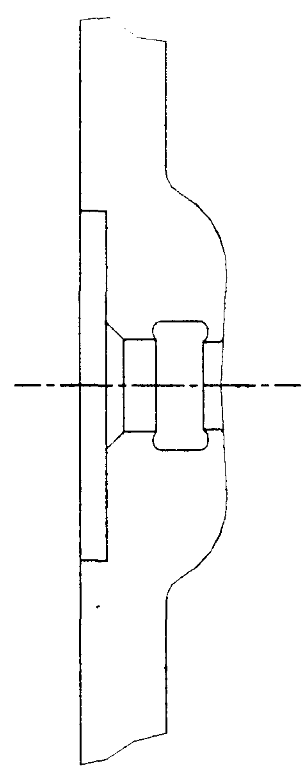

Fig. 2. Enlarged photocathode plug cross section.

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part of the self-alignment required to allow insertion of the plug from the cathode preparation chamber.

The cavity shape was designed for linear, radial space-charge forces in the electron bunch.[2] At the nominal designed field level, the electrons (38.9 MV/m) would be accelerated to 0.9 MeV with the field maximum near 2 times Kilpatrick (58.9 MV/m).

Cell 2 is a typical high shunt impedance cell. It also provides 1-MeV acceleration at near Kilpatrick field values. Other cell parameters are listed below for the design SUPERFISH values (32.1 MV/m). Q measurements of the cells produced reasonable agreement with SUPERFISH before the vacuum slots were cut. Individual measurements seemed to have a reproducibility of a few percent. However, measurements after the slots were cut were 14 800 and 21 800 for cells 1 and 2. They represent at 10% increase and give a value larger than the SUPERFISH value. Aside from comparison to SUPERFISH, the apparent increase in the Q values after cutting the vacuum slots has not been explained. Coupling constant values measured also depend on the measured Q values and are thus not clear. Mismatches in the drive line to a cell gave incorrectly large values for the coupling values even without the question of the Q value. Measured values for cell 1 coupling constant are believed to be close to the desired value but cell 2 values are slightly above that desired.

SUPERFISH CELL PARAMETERS

	Cell 1	Cell 2
SUPERFISH Q (no slots)	13 300	20 300
Field maximum (MV/m)	58.9	32.1
Cavity length (m)	0.115	0.240
Power loss in cavity (MW)	0.589	0.231
No beam drive coupling	2.5	5.3
Match beam loading, 1-A av. (%)	60	81
Shunt impedance (MΩ/m), Z	29.5	45.8
Transient-time factor, T	0.901	0.887
ZT^2 (MΩ/m)	24.0	36.1
Operating frequency (MHz)	1300	1300

System

Individual cells are tuned by pushing/pulling the outside walls. Typical operational tuning is done by varying the temperature of the cooling-water system. [Because of the low operational duty factor (10^{-4}), the cooling-water system is a frequency-stabilization system.] A water channel was cut into the two outside end walls. Figure 1 shows the individual rf drives for each cell and one of two pickup loops in each cell. Relative phase- and power-level adjustment between cells was believed necessary to minimize the momentum spread of the beam. Cell-to-cell coupling was calculated and measured to be low, near $K \approx 0.0002$ (minimum frequency spacing of modes divided by mode frequency). However, because of the large Q of each cavity, critical coupling also occurs at a very low value so that substantial coupling effects were seen in operation. This coupling makes the two cell's amplitude and phase not independent of each other. Adjustment of the amplitude or phase of the drive to one cell makes the other cell's amplitude and phase change. The field level in a cell was consistent with a vector addition of that cells drive and as much as 30% from the other cell coupling. Figure 3 shows not only the rf drive lines, but also the vacuum pumping ports at 90°. Slots were cut on two sides of each cell for vacuum pumping. The cavity and vacuum chamber are baked overnight (200 to 300° C) to achieve a pressure in the low 10^{-10} torr range. Tuning after a bake usually meant adjusting the water temperature to set cell 2 and then adjusting cell 1 at that temperature by moving its back wall. A mechanical tuning device has been installed that has screws to push or pull on the photocathode entrance flange relative to the cavity body. The outside wall on cell 2 also has a device to move its end wall.

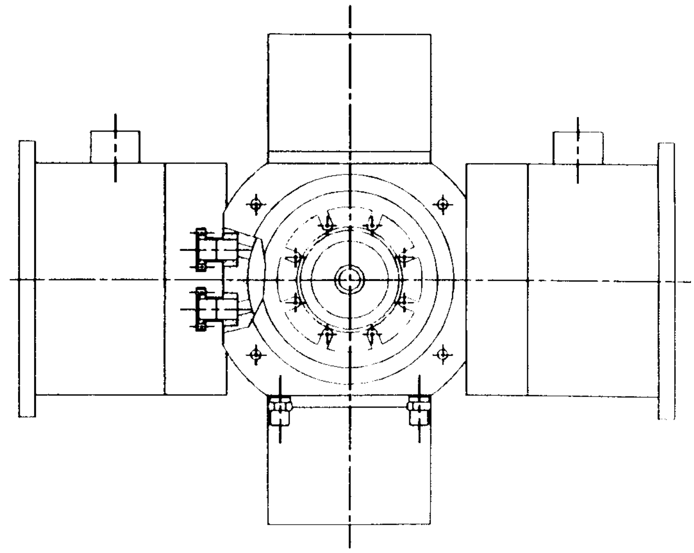

Fig. 3. Photocathode end view of cavity.

Construction

Copper joints and copper-to-stainless joints were brazed together. Stainless-to-stainless joints were welded. The design was done with all flat braze joints so that in a series of four braze cycles, all joints were brazed in a horizontal orientation. The first braze put together the water channels, the stainless-to-copper joints of the flange tubes to the copper half-cell, and the stainless-to-copper joint in the waveguide transition piece. The second braze put the cavity cells pieces together. The third and fourth brazes were necessary for attaching the water fittings, drive loop flanges, and the waveguide transition to the cavity. Appropriate anneal cycles were also included. Because of this design, all joints were successful on the first attempt. No problems with vacuum leaks occurred.

Conclusion

The two-cell cavity was successfully constructed without joint vacuum leaks. The rf conditioning and desired vacuum values were achieved in a reasonably short time. The only problem that proved to be an unexpected annoyance was the cell-to-cell coupling effects.

Acknowledgment

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References

1. R. L. Sheffield, "High-Brightness Electron Gun Theory and Experiments," these proceedings.

2. Michael E. Jones and William Peter, "Theory and Simulation of High-Brightness Electron Beam Production from Laser-Irradiated Photocathodes in the Presence of DC and RF Electric Fields," 6th Int. Conf. on High-Power Particle Beams, Kobe, Japan, June 9-12, 1986, Los Alamos National Laboratory document LA-UR-86-1941.