Title
Pump Port Calculations for the VHF Photoinjector Cavity: CBP Tech. Note 378

Authors
Staples, John
Huang, Gang
Wells, Russell

Publication Date
2007-07-27

CBP Tech. Note 378
July 27, 2007

Pump Port Calculations for the VHF Photoinjector Cavity*

John Staples, Huang Gang, Russ Wells

Lawrence Berkeley National Laboratory
1 Cyclotron Rd., Berkeley CA 94720, USA

*This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Pump Port Calculations for the VHF Photoinjector Cavity

John Staples, Huang Gang, Russ Wells, LBNL

27 July 2007

The VHF photoinjector cavity requires a vacuum in the 10^{-9} to 10^{-11} Torr range, depending on the type of photocathode selected. One possible arrangement of the vacuum pumps replaces the outer cavity wall with a series of slots, and outside the slots, getter pumps are located in the region shielded from the RF fields.


Figure 1. Cavity with Pumping Slots

The slots are oriented so that the wall current flows along the slots. In this configuration, there are 36 bars and 36 slots, each occupying 5 azimuthal degrees. At an inner wall radius of 56 cm, each slot and each bar is 4.9 cm (1.92 inches) wide, for a transparency of 50% through to the getter pumps located in the outside annular plenum.

Calculations were carried out to determine the frequency shift due to the slots, compared to a solid outer wall, the power density on the bars, and the field drop-off to the outer plenum. A simplified version of the cavity was used, with straight-sided walls and no rounded corners in the cavity cross-section. This was to best accommodate the meshing of 3-D electrodynamics codes Mafia-2 and Microwave Studio.

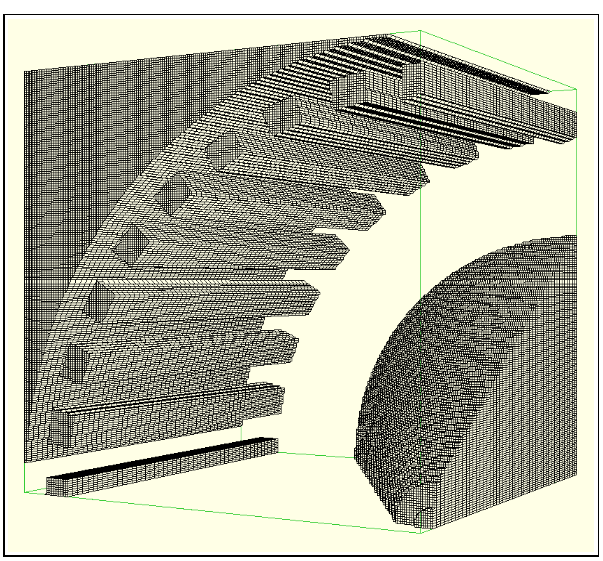
Figure 2. Mafia-2 Mesh

The parameters of the unslotted cavity were calculated with Superfish, and then the parameters again calculated in full 3-D with Mafia and MWS with a solid wall and with a slotted wall.

The parameters calculated with all three codes are all in very good agreement with each other. The Mafia-2 mesh comprised more than 2 million points, whereas MWS, with its better definition of boundary conditions, used approximately 50,000. The Superfish mesh uses much fewer, as it is a 2-D calculation. Figure 2 shows the Mafia-2 mesh for one-quarter of the VHF cavity.

Table 1 lists the important results for the 2-D Superfish calculation, and the 3-D Mafia-2 and MWS calculations, for both the solid wall and slotted wall configurations.

	No slots Superfish	No slots Mafia-2	No slots MWS	With slots Mafia-2	With slots MWS	
Frequency	108.91	107.57	108.69	107.11	108.32	MHz
Gap Voltage	750	750	750	750	750	kV
Q_0	33874	31509		31865		
Power	105.2	113.8	106.2	112.4	115.4	kW
R/Q	157.88	156.9	157.3	157.1	157.5	ohms
Stored Energy	5.2	5.3		5.3		Joules

Table 1. Superfish, Mafia-2 and MWS results

Both Mafia and MWS show less than 0.5% downward frequency shift when the slots are introduced, as more magnetic field volume is added. Mafia shows a slight reduction in required power, but MWS shows an 8% increase in power.

The slots would be expected to increase the power requirement, as the same amount of wall current is constrained to flow along 50% less path. However, some of the current flows along the sides of the bars, and the power is only slightly increased (in MWS).

With this straight-line cavity outline, not the contoured one used for detailed field and power density calculations, the peak power density is 6.8 watts/cm^2 on the central cone 15.5 cm downstream in z from the origin, at a wall sheet current density of 7073 amps/m.

Figure 3 shows the wall power density distribution, as a color-coded plot of the Mafia-2 output. The power density on the bars tends to concentrate on the inner corners, and is in the range of 2.5 watts/cm^2.

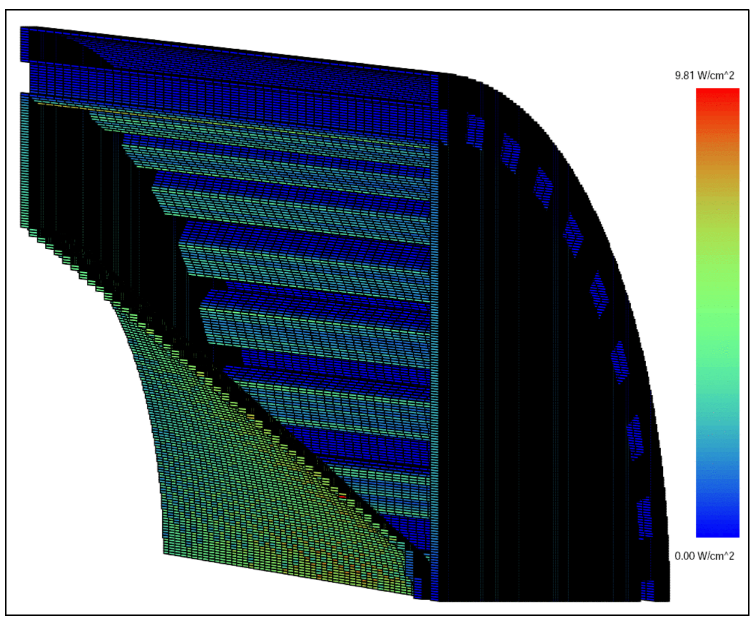

Figure 3. Thermal distribution

Figure 4 shows the arrangement of the bars over a small area of the circumference. When the power density falls below a threshold, the image of the bar does not appear in the plot. The detail of the power distribution on a single bar is shown in Figure 5, where the point index is a measure of the location, starting at the back of the bar, away from the central radius, and wraps around the front to the back again. The details of the power distribution are due to the coarseness of the 2x10^6 mesh points. The

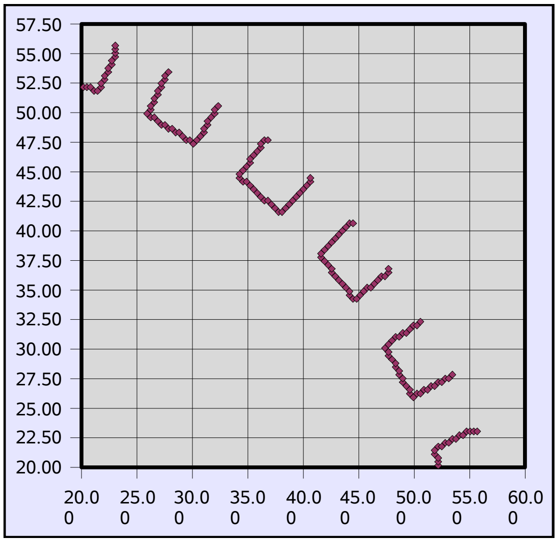

Figure 4. A few bars at the periphery.

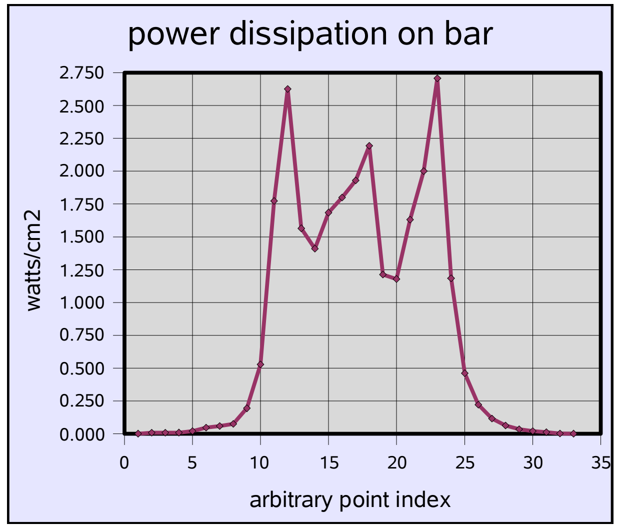

Figure 5, Power Density around Bar

power is maximum at the sharp corners of the bar and wraps around to the sides. The power density profile can be seen to agree qualitatively with Figure 3. Figure 6 shows the absolute value of the RF magnetic field strength in another format, showing the field fall-off in the slots and the field contours in the cavity.

Integrating the power density around the circumference of a bar gives a result that is similar to the power in the same region of the solid cavity calculation, without the vacuum slots.

It appears that the concept of the pumping slots is valid, with only a slight perturbation of the solid-wall cavity frequency and power dissipation. The wall power density on the bars is less than 3 watts/cm^2 and distributed asymmetrically. It remains to be determined whether this will result in significant flexure of the bars, resulting in a perturbation of the cavity resonant frequency.

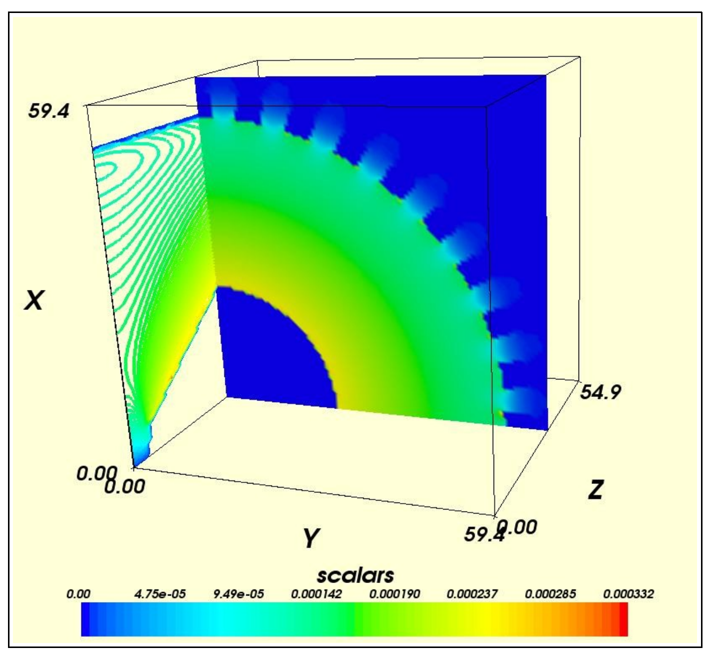

Figure 6. RF Magnetic Field Strength Distribution