A REDUCED GRADIENT OUTPUT DESIGN FOR SLAC'S XL4 X-BAND KLYSTRON*

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Abstract

X-band klystron work began at SLAC in the mid to late 1980's to develop high frequency (4 times the SLAC S-band klystron), high power RF sources for the linear collider designs under consideration at that time. This work culminated in the current workhorse X-band RF source, the XL4. To date 26 XL4 tubes have been built. The XL4 4-cell disk loaded traveling wave output structure has a high operating gradient. A new 6-cell structure has been designed to reduce breakdown and to further improve the klystron's robustness. Initial simulations show the 6-cell design reduces the gradient roughly 25% and that the structure is stable. A physical XL4 will be retrofitted with the new output cavity and hot tested in the near future.

INTRODUCTION

The XL4 klystron has been a workhorse for X-band research and development. These 50MW tubes nominally operate at 11.424GHz, 420kV, 1.5µs and 60Hz PPS.

The XL4 design is mature, but there is room for improvement. In the output structure, gradients are high and damage from breakdown is observed. Increasing the number of cells and redesigning the output iris are two improvements that would decrease gradients and increase tube robustness.

These changes can be integrated into future XL4 production with little effect on cost, since little or no mechanical changes are required outside the output structure.

IMPROVING THE EXISTING 4-CELL OUTPUT CAVITY

The existing XL4 klystron has a 4-cell travelling wave output structure. This structure has performed well in existing klystrons but could be improved by reducing gradients.

Before making design modifications, the existing structure was simulated in both 2D and 3D using MAGIC [1].

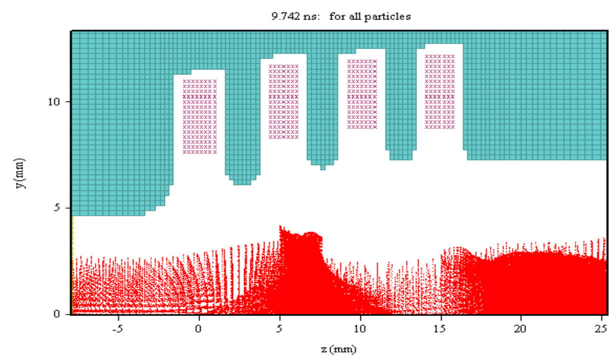

Figure 1: Cylindrically Symmetric MAGIC3D Simulation of the Output Cavity Phase Space (shaded areas in cavities represent loss).

The first MAGIC3D simulation (Figure 1) was run using a cylindrical output cavity and loss region to model the external Q. In this way the results could be compared with the MAGIC2D cylindrically symmetric simulations. In both cases the output power was 60MW (Figure 4).

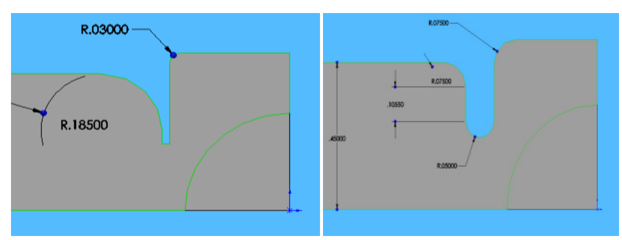

Figure 2: Rounding the Output Cell Iris.

To improve observed breakdown in the output iris, a large radius was added to the existing iris design as seen in Figure 2 (this rounded style iris design was already successfully demonstrated on the XL5 12GHz klystron [2]). After adding the radius the external Q and final cell frequency were re-tuned to their original values using HFSS and the Kroll-Yu method [3]. The final 4-cell geometry with the rounded iris design is shown in Figure 3.

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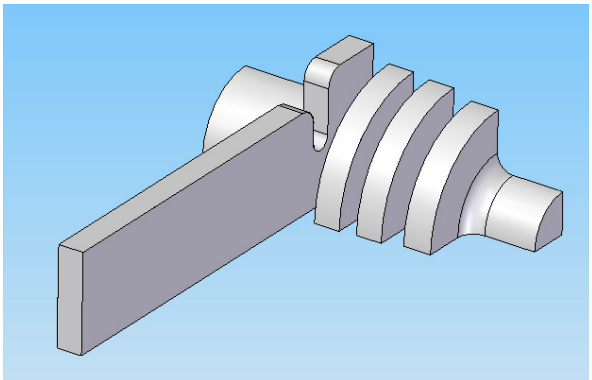

Figure 3: 4-Cell Rounded Iris Design.

The final geometry with the rounded output iris was simulated in MAGIC3D. The output power agreed well with both the MAGIC2D and MAGIC3D cylindrically symmetric equivalent circuits. These three simulations all produced approximately 60MW of output power. The output power as a function of time is shown in Figure 4.

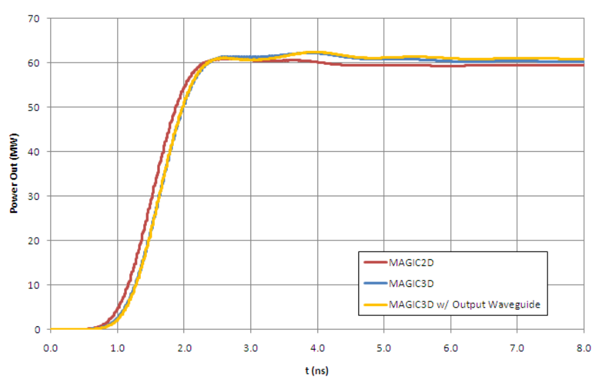

Figure 4: Output Power Comparison.

DESIGNING A LOW GRADIENT 6-CELL OUTPUT STRUCTURE

The existing XL4 4-cell output structure reliability can be improved by decreasing the gradient. Adding cells to the output structure successfully decreases gradients [4]. To decrease the gradient in this design, a 6-cell output structure is used.

The preliminary 6-cell structure design used a tapered impedance approach similar to Figure 5. The geometry for each cell was approximated one at a time using a periodic Superfish simulation (Figure 6) to calculate the cell impedance. Once this geometry was implemented in MAGIC2D the cell radii were modified slightly to optimize the gradient.

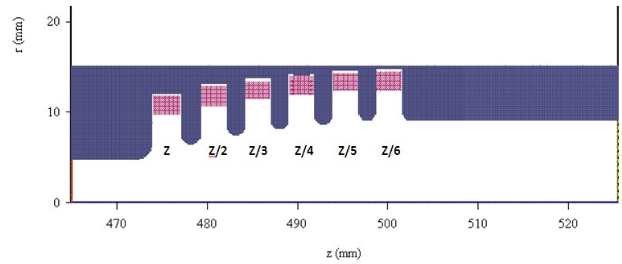

Figure 5: 6-Cell Tapered Impedance Design in MAGIC2D.

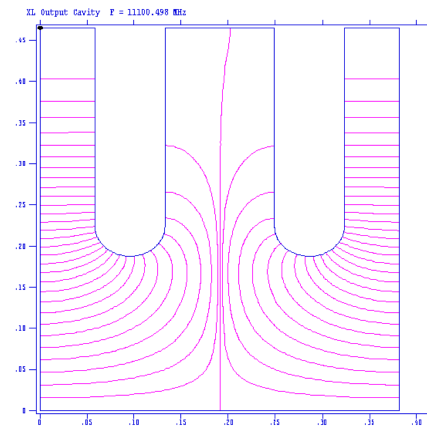

Figure 6: X-Band pi/2 Mode.

After 2D optimization, HFSS was used to design the 3D output cell. The external Q and frequency were tuned to the MAGIC2D values by changing the cell and iris heights.

The output cell width, is a third independent variable. The width is chosen such that the fields are relatively flat for a given radius as in Figure 7.

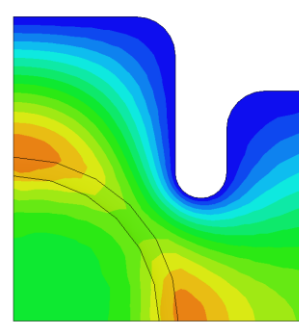

Figure 7: Output Cell Width is Used to Optimize Field Flatness in the Output Cell.

MAGIC simulations of the 6-cell output geometry show gradients are roughly 25% lower than the 4-cell design. With further optimization the 6-cell design should achieve a 33% reduction in gradient.

MAGIC simulations were done with a constant solenoid field. Since the real magnetic field decreases quickly after the output structure it was necessary to confirm the magnetic field extended far enough to confine the beam in the additional two output cells (Figure 8).

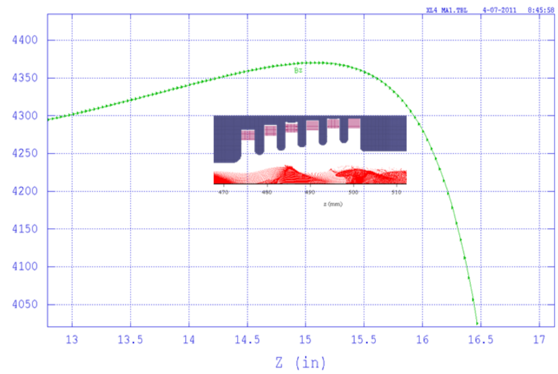

Figure 8: Phase Space Simulation of the 6-Cell Output Structure Showing the Magnetic Field Profile.

Simulations using the real magnetic field showed good confinement and 59MW of output power (Figure 9).

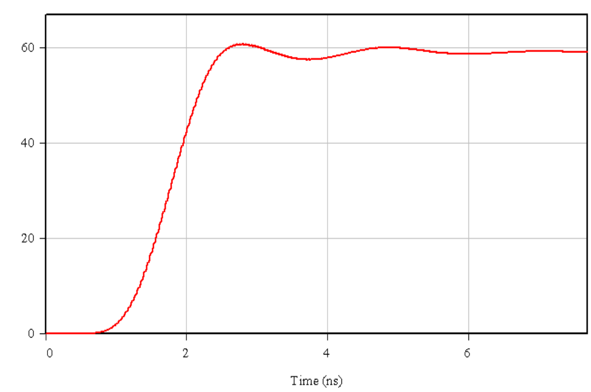

Figure 9: The Final 6-Cell Output Structure Using the Real Solenoid Field Achieved 59MW of Output Power.

OSCILLATION MITIGATION

The final output cavity geometry was used to calculate beam loading. Two of the axially symmetric modes were found to be unstable at the operating voltage of 420kV. These instabilities are typical of multi-cell structures and have been successfully suppressed in the XL and XP designs. This is achieved by using a side loss cavity at the correct position to reduce the Q and damp the mode.

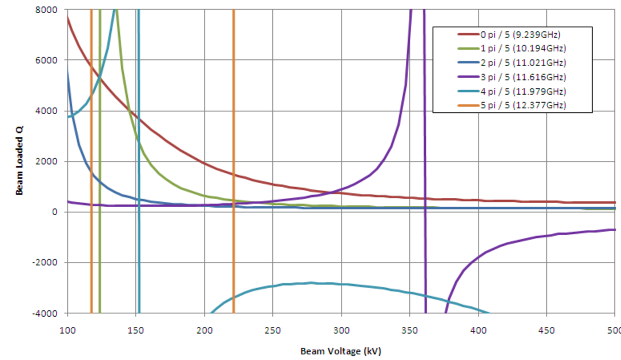

Figure 8: Output Cavity Beam Loading as a Function of Beam Voltage.

SUMMARY

A 6-cell output structure compatible with the existing XL4 klystron has been designed. The output power achieved in simulation was 60MW at 420kV and operated with a gradient 25% lower than the 4-cell design.

Final simulations of the output cavity and stability requirements are being made.

The 6-cell output cavity will be hot tested on an existing XL4 klystron in the near future.

REFERENCES

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