Pulsed Klystrons for Next Generation Neutron Sources

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Abstract

The U.S. Department of Energy (DOE) Office of Science has funded the construction of a new accelerator-based neutron source, the Spallation Neutron Source (SNS), which is expected to provide the most intense pulsed, neutron beams in the world for scientific research and industrial development. Communications and Power Industries, Inc. Microwave Power Products Division (CPI-MPP) has been engaged in the development of suitable high power, pulsed klystron amplifiers for use in energizing this new accelerator system. Actual performance data for the VKP-8290A klystron will be presented, as well as, simulated performance for the VKP-8291A klystron, currently under development. Some technical development and manufacturing issues will also be presented.

1. INTRODUCTION

The VKP-8290A and the VKP-8291A klystrons are two new microwave amplifiers developed by CPI for driving the Spallation Neutron Source. This new accelerator system is being built by the U.S. Department of Energy and is expected to provide the most intense pulsed**,** neutron beams in the world for scientific research and industrial development.

2. VKP-8290A — 805 MHz, 2.5-Mw, 10% Duty Klystron

CPI delivered a working prototype of the VKP-8290A to Los Alamos National Laboratory in September 1999. The prototype is being used for test and integration of other system components under development. A layout of the prototype is shown in Figure 1 and RF performance data is shown in the Figures 2 through 4.

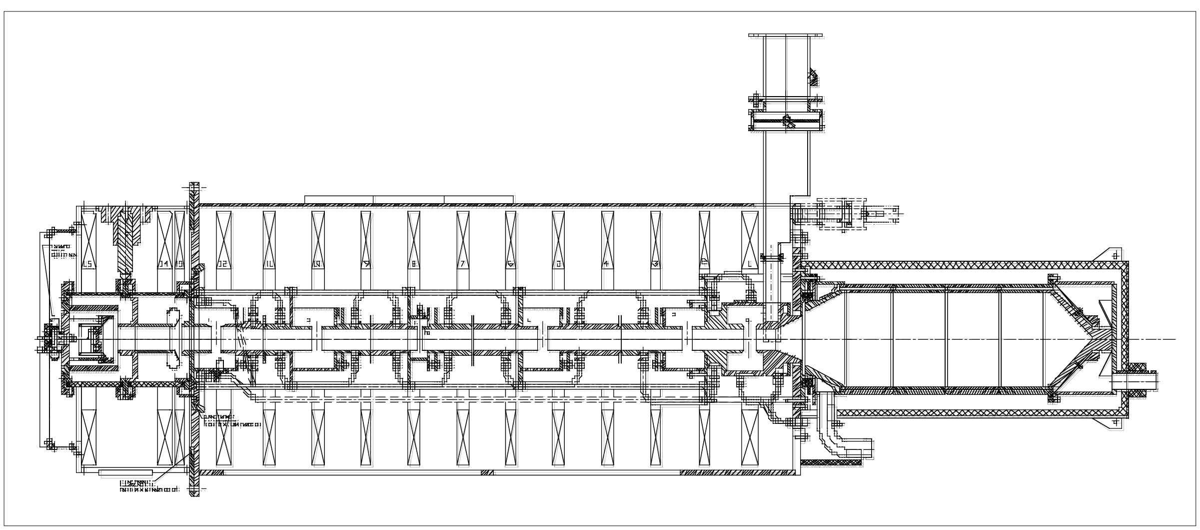

Figure 1 - VKP-8290A Layout Drawing

Operating Parameter	Min.	Nom.	Max.	Units
RF Frequency	-	805	-	MHz
Peak Output Power	2.50	-	-	Mw
Average Output Power	250.0	-	-	kW
RF Duty Factor	10	-	-	%
Pulse Repetition Rate	60	-	-	Hz
DC to RF Efficiency	55	-	-	%
Beam Voltage		118.0	120.0	kVdc
Peak Beam Current	-	39	55	a
Pulse Modulating Anode Voltage	24.00	89	96	kVdc
Micro-perveance	-	0.962	-	A/V3/2
RF Power Gain	45	-	-	dB
Instantaneous Bandwidth (-1dB @ Sat. Power)	+/- 0.7	-	-	MHz
Instantaneous Bandwidth (-1dB @ 80% Sat. Power)	+/- 0.4	-	-	MHz
Average Collector Power (1 Hour with no RF)	-	460.2	660	kW
Filament Voltage	-	20	30	Vac
Filament Current	-	20	30	Aac

Table 1 – VKP-8290A Primary Performance Specifications

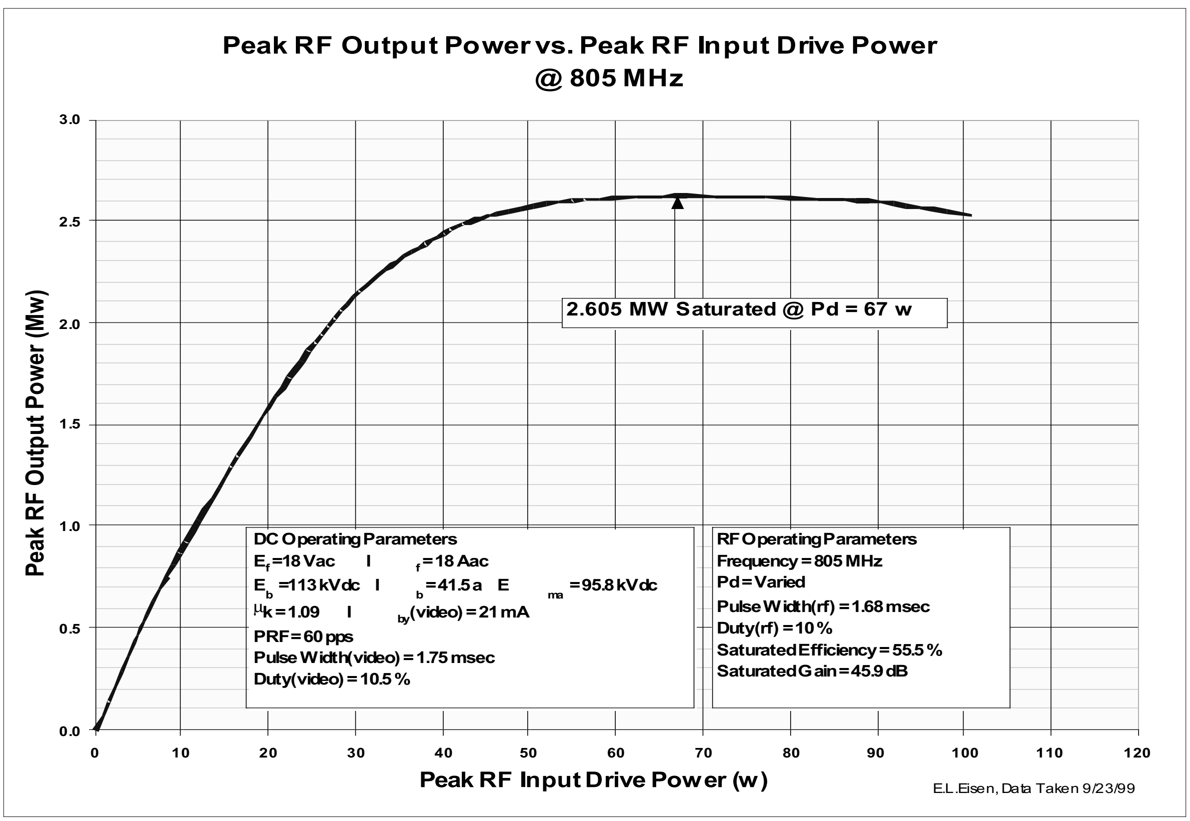

Figure 2 — VKP-8290A Peak RF Output Power versus Peak RF Input Drive Power

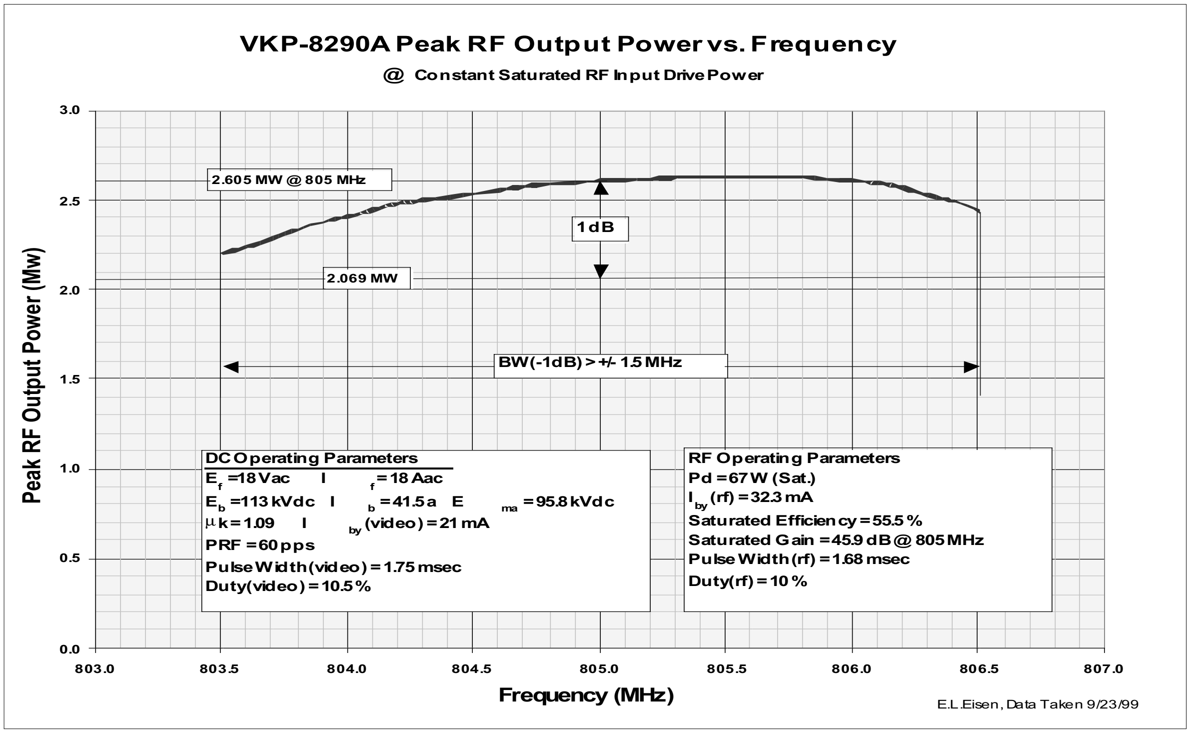

Figure 3 - VKP-8290A Peak RF Output Power versus Frequency

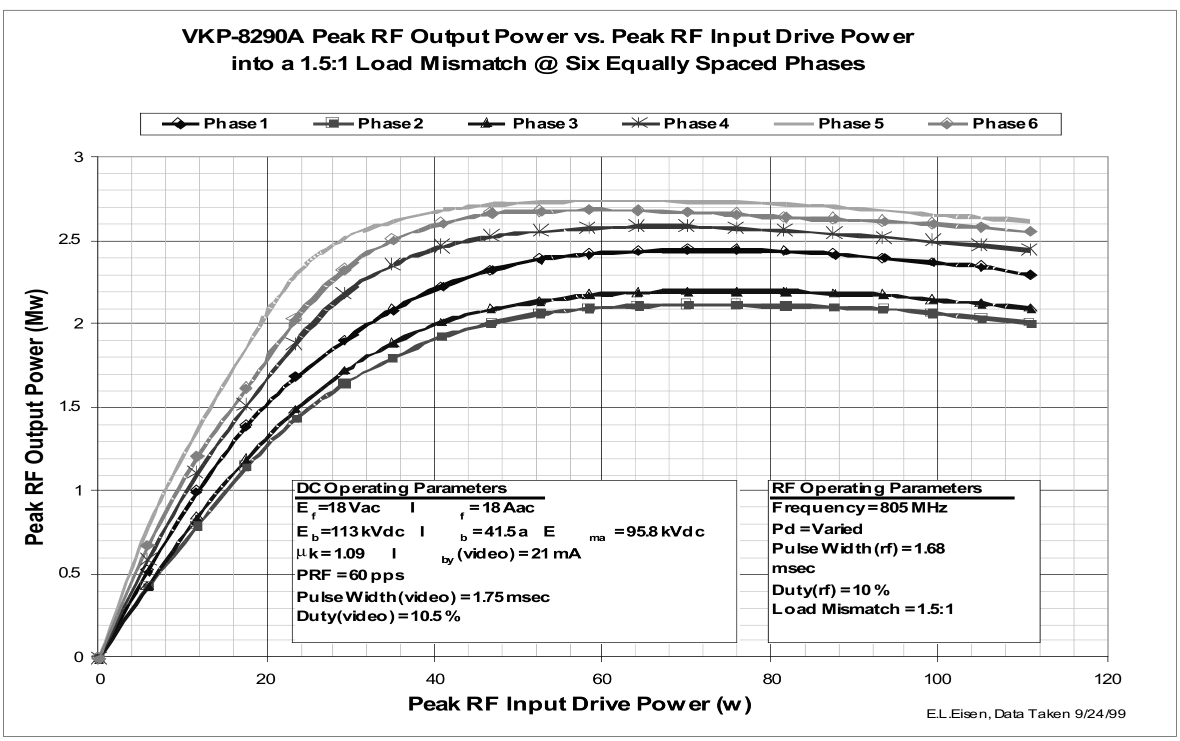

Figure 4 - VKP-8290A Peak RF Output Power versus Peak RF Input Drive Power as a Function of Load Mismatch Phase

The VKP-8290A klystron and solenoid met or exceeded all specification requirements for:

- beam voltage, beam current, and modulating anode voltage
- filament voltage and current
- peak and average output power
- efficiency, gain, and bandwidth
- collector operation with no RF applied
- 24 hour heat run
- operation into 1.5:1 load mismatch
- coolant flows and pressure drops
- RF and x-ray radiation limits
- phase transfer characteristics
- mechanical outline

3. VKP-8291A — 805 MHz, 550-kw, 9% Duty Klystron

CPI is currently developing the VKP-8291A under contract from Los Alamos National Laboratory. Changes in SNS system design philosophy resulting in the use of super conducting RF cavities considerably reduced the peak output power requirement for the klystrons driving the cavities. Though more klystrons will be needed to achieve the desired system power levels, the new lower power requirement for each individual device will allow a much more reliable klystron implementation.

CPI is using Design for Assembly / Design for Manufacture (DFA/DFM) techniques to greatly reduce the fabrication complexity and increased the reliability of our klystron designs. CPI also uses the latest available computer design simulation codes to reduce the time it takes to develop new products and to ensure proper product performance. All these tools were used to great advantage in the development of the VKP-8290A and the design experience is being carried forward in the development of the VKP-8291A. CPI will also leverage the best aspects of several current production klystrons resulting in a klystron design that will be efficient, reliable, and easy to manufacture.

The VKP-8291A klystron, electron gun, and RF vacuum window and waveguide are shown in Figures 5 through 8. The predicted performance is shown in Figures 9 through 19.

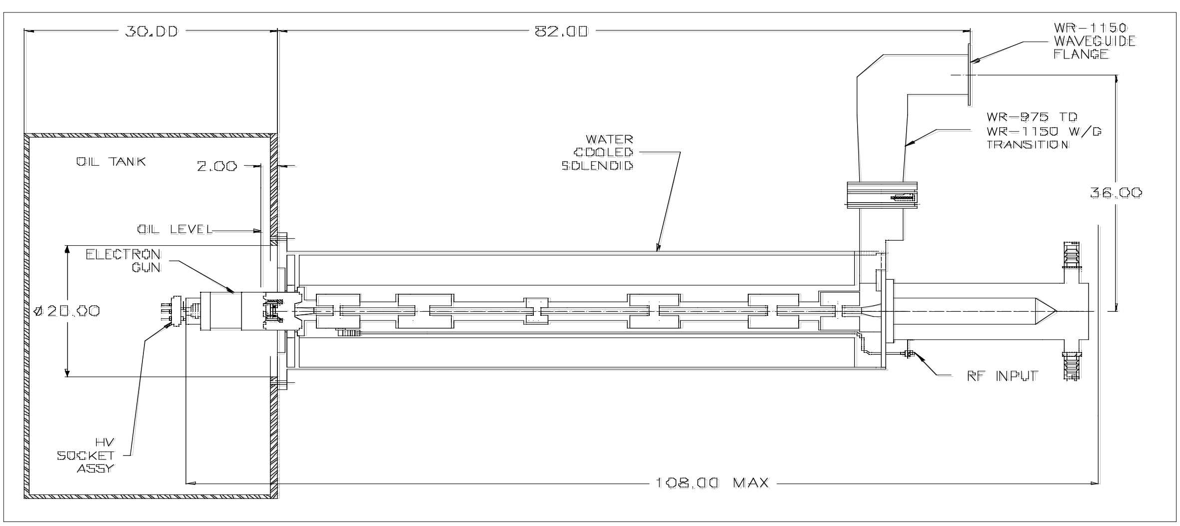

Figure 5 – VKP-8291A Klystron Layout Drawing

Operating Parameter	Min.	Nom.	Max.	Units
RF Frequency	-	805	-	MHz
Peak Output Power	550	-	-	kw
Average Output Power	49.5	-	-	kW
RF Duty Factor	9	-	-	%
Pulse Repetition Rate	60	-	-	Hz
DC to RF Efficiency	65	-	-	%
Beam Voltage	73.5	75.0	76.5	kVdc
Peak Beam Current	-	11.3	11.5	a
Micro-perveance	-	0.550	-	A/V3/2
RF Power Gain	50	-	-	dB
Instantaneous Bandwidth (-1dB @ Sat. Power)	+/- 1.3	-	-	MHz
Instantaneous Bandwidth (-1dB @ 80% Sat. Power)	+/- 1.0	-	-	MHz
Average Collector Power (1 Hour with no RF)	-	81	85	kW
Filament Voltage	-	-	25	Vac
Filament Current	-	-	25	Aac
Main Focus Magnet Power	-	-	2	kW
Auxiliary Focus Magnet Power	-	-	550	W

Table 2 – VKP-8291A Primary Performance Specifications

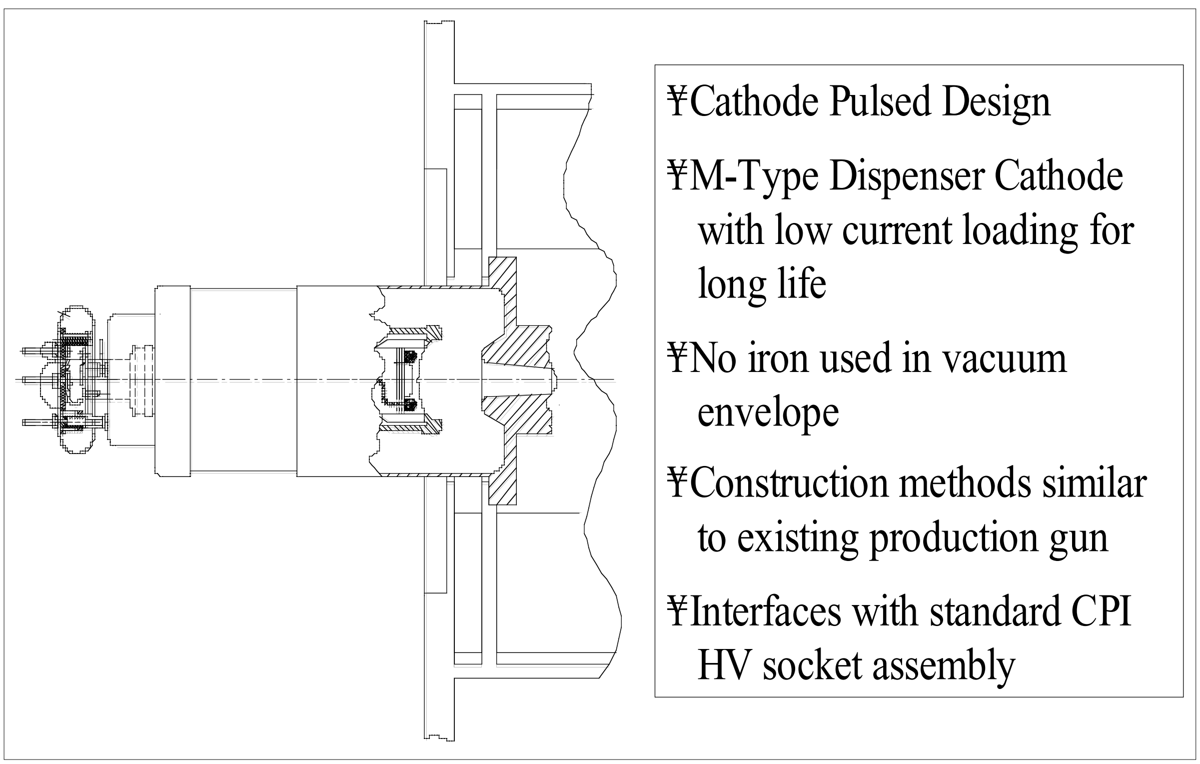

Figure 6 – VKP-8291A Klystron - Electron Gun Design

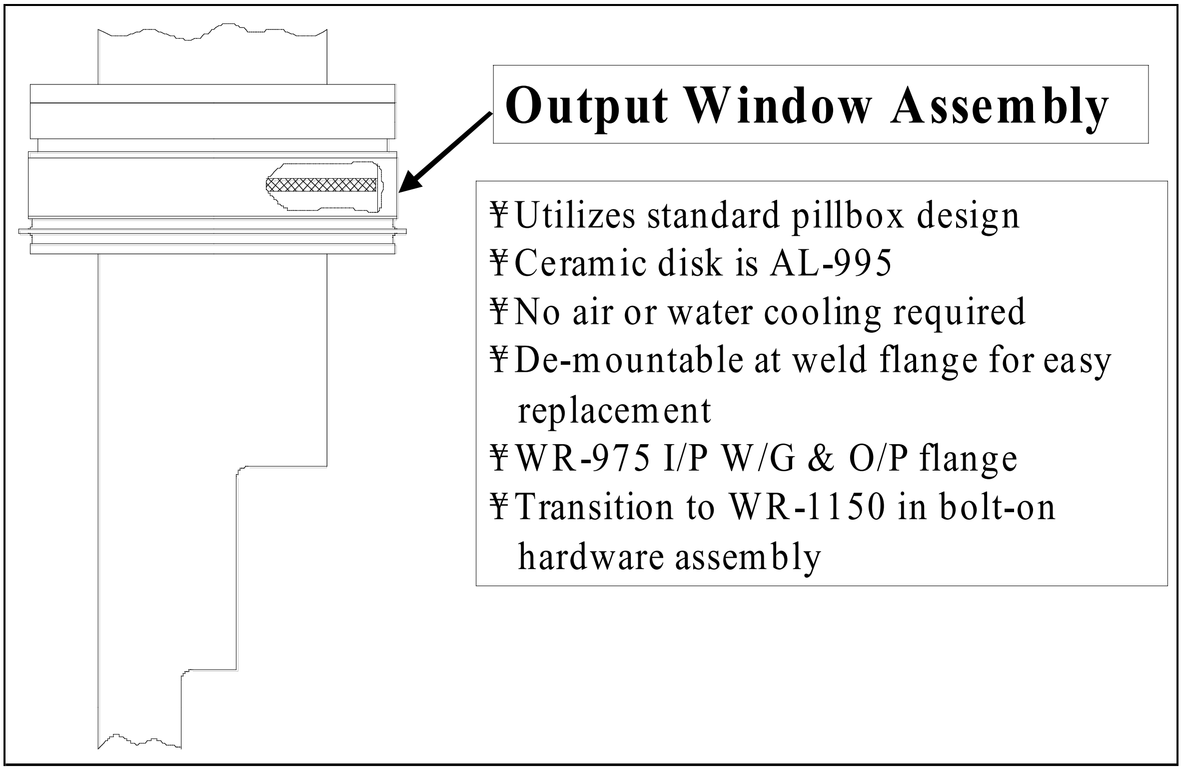

Figure 7 – VKP-8291A Klystron – RF Vacuum Window Design

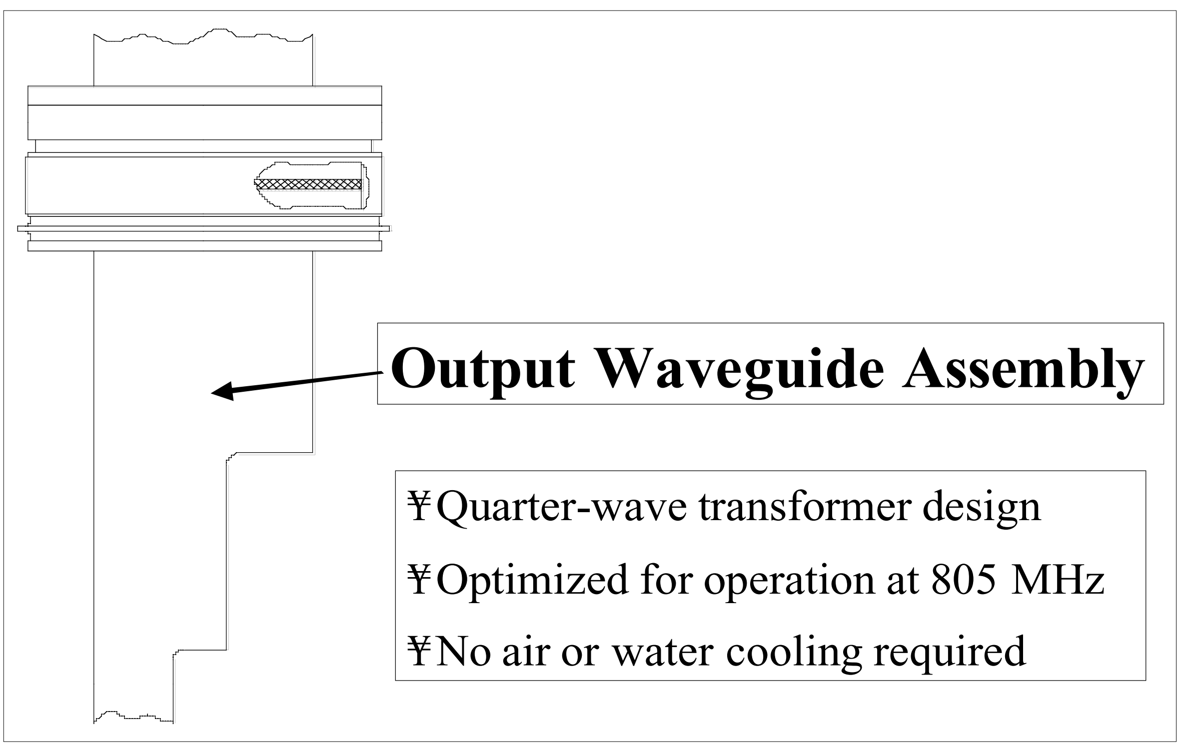

Figure 8 – VKP-8291A Klystron – RF Waveguide Design

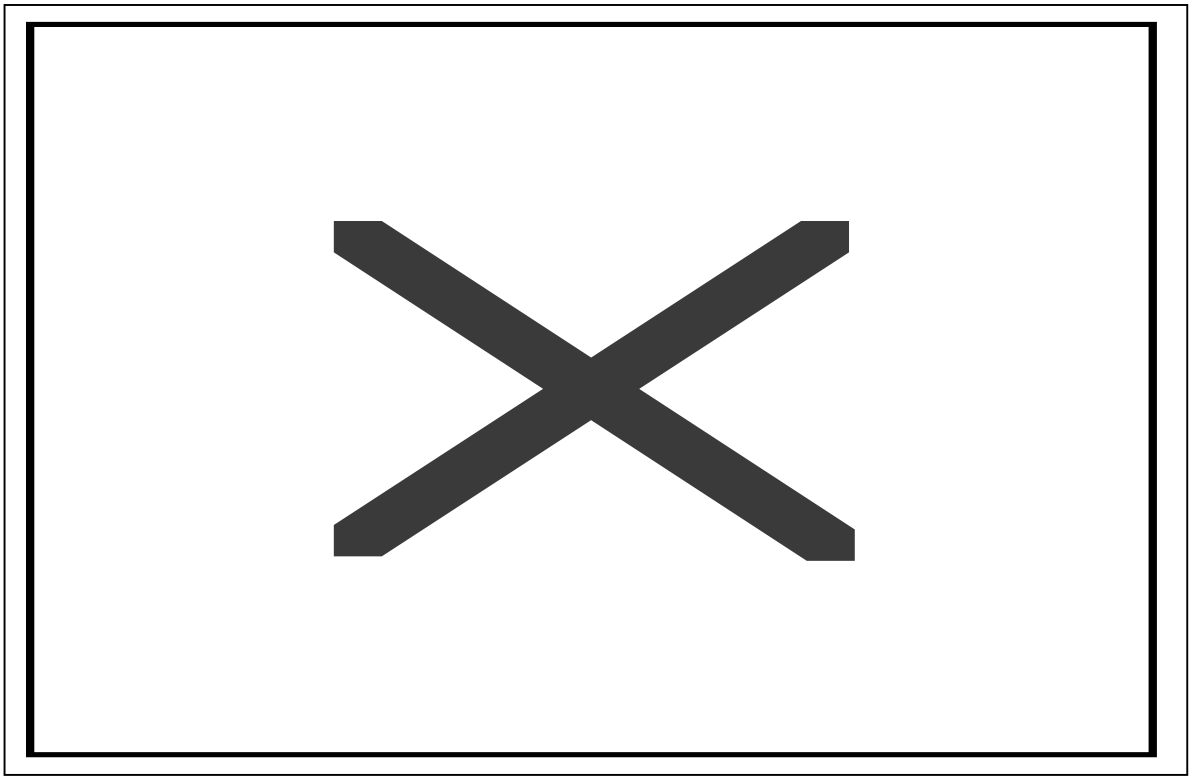

Figure 9 – VKP-8291A Klystron - Electron Gun Electrostatic Performance Simulation

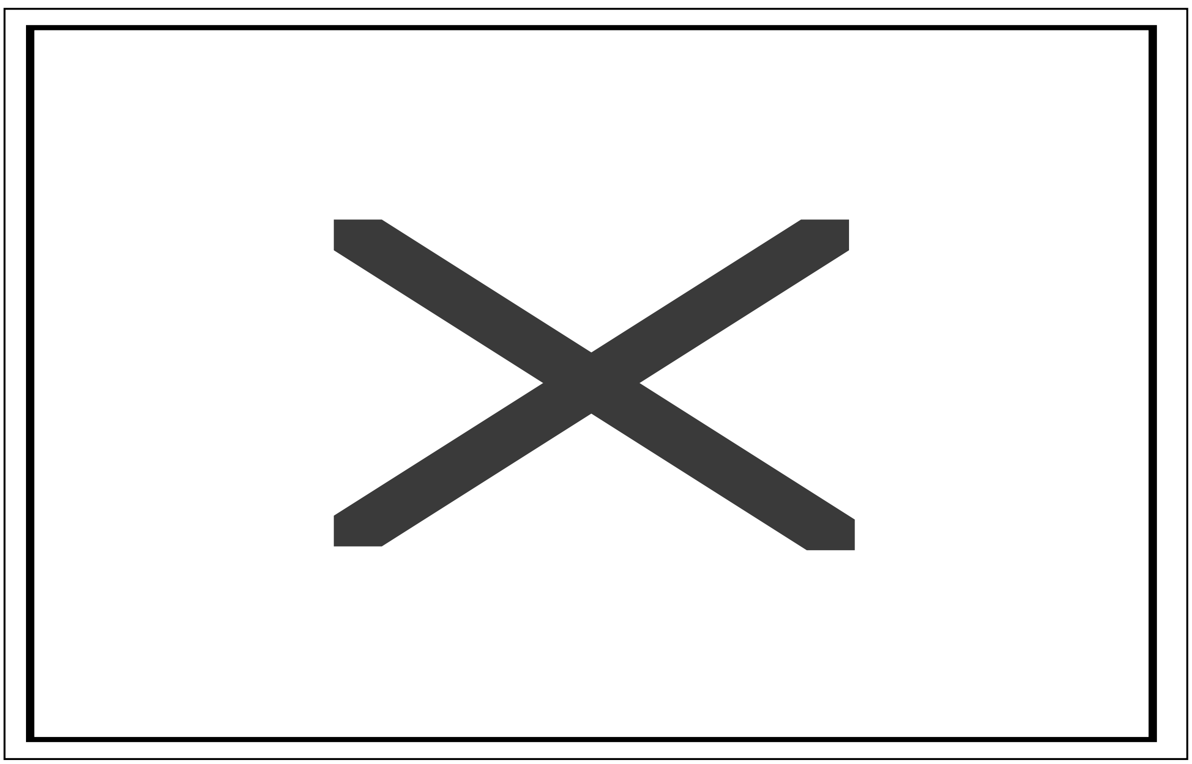

Figure 10 – VKP-8291A Klystron - Electron Gun Magnetic Goal Field Performance Simulation

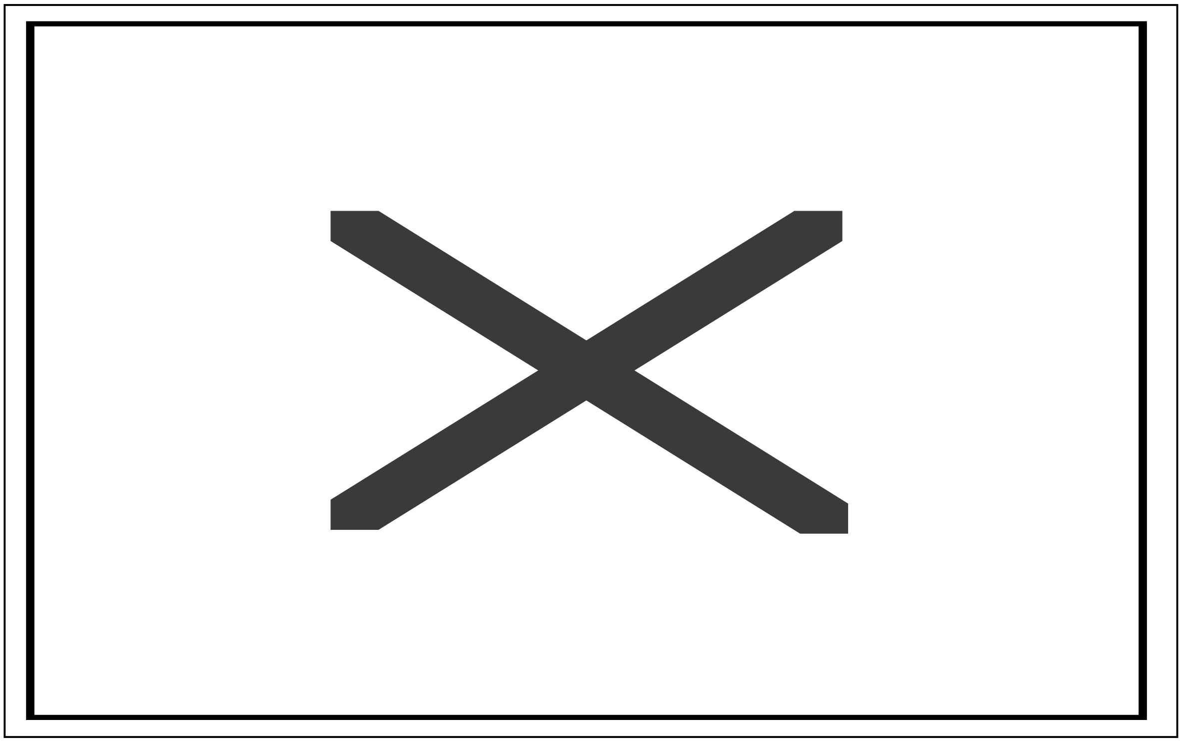

Figure 11 – VKP-8291A Klystron – Solenoid Magnetic Field Profile

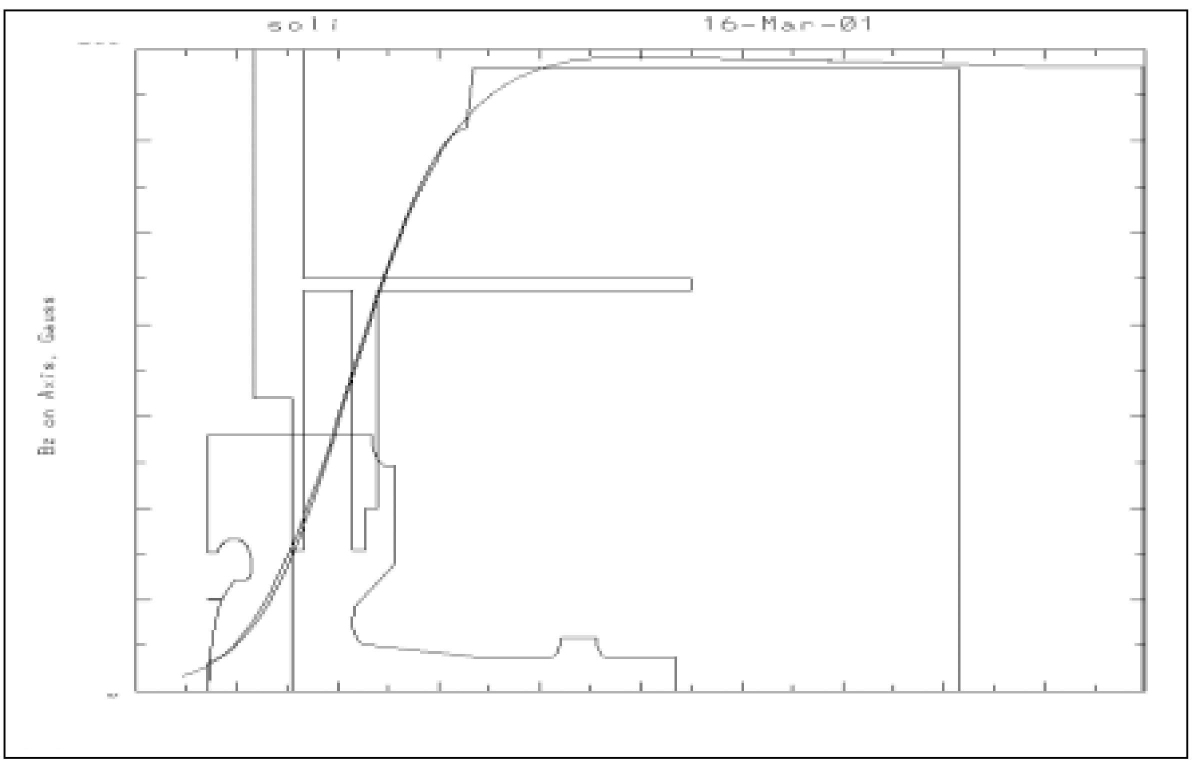

Figure 12 – VKP-8291A Klystron – Solenoid Magnetic Field Profile in Cathode Region

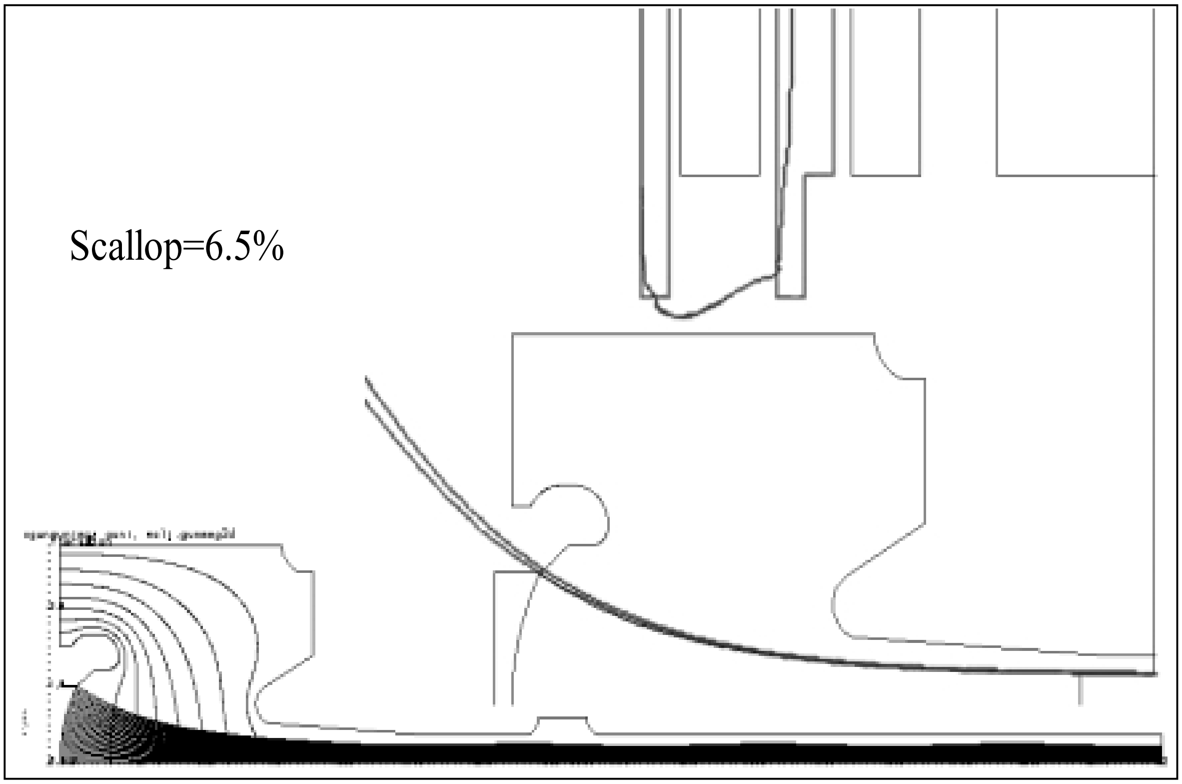

Figure 13 – VKP-8291A Klystron – 2-D Magnetic Field Beam Simulation

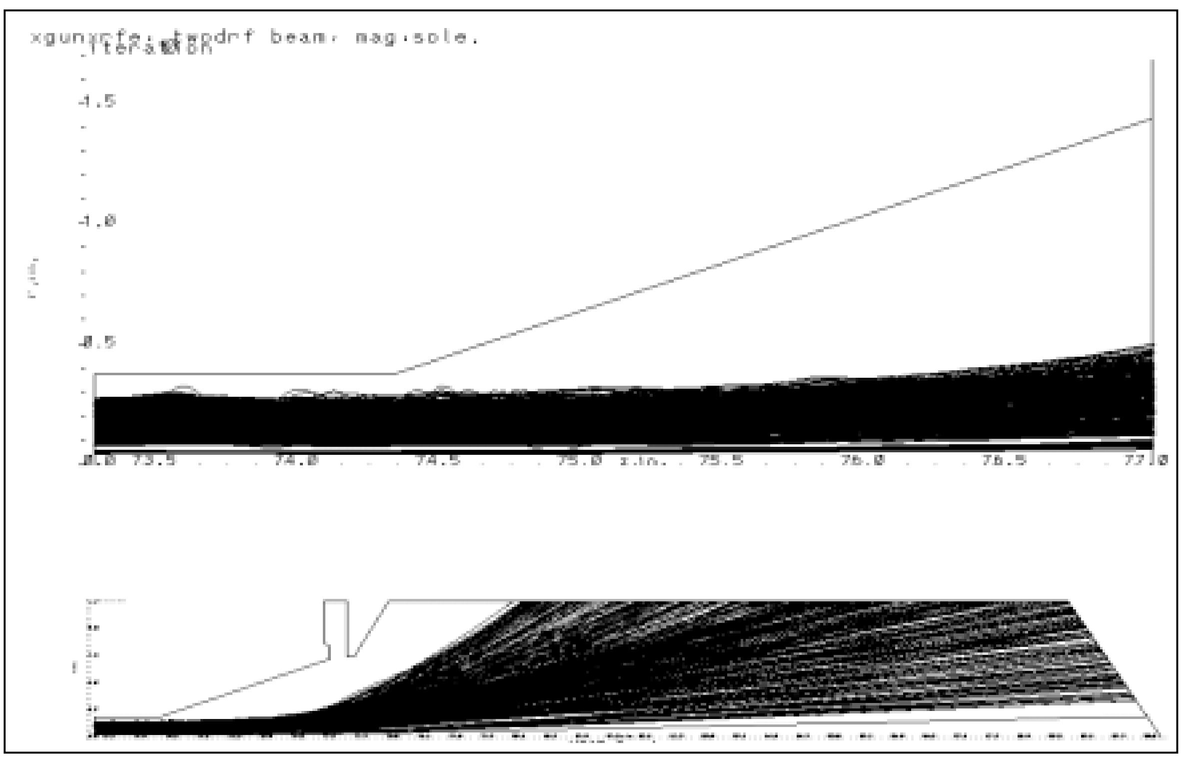

Figure 14 – VKP-8291A Klystron – 2-D RF Beam Simulation in Collector Region

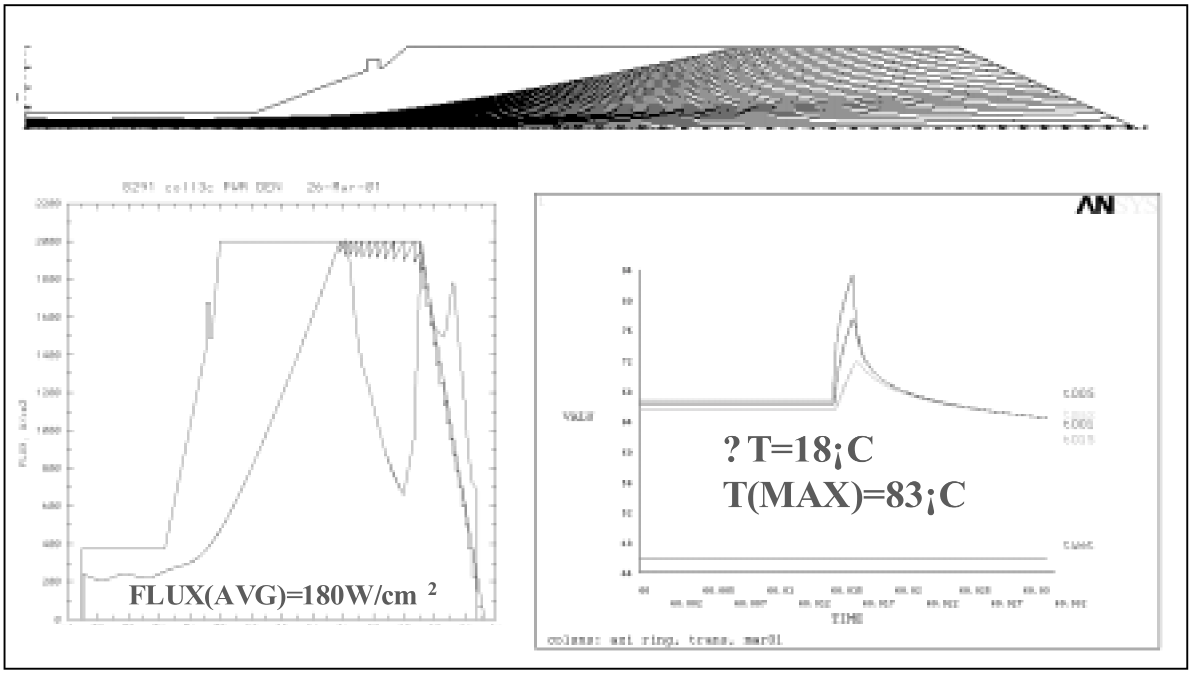

Figure 15 – VKP-8291A Klystron – Beam Simulation in Collector Region – Pulse Heating Simulation

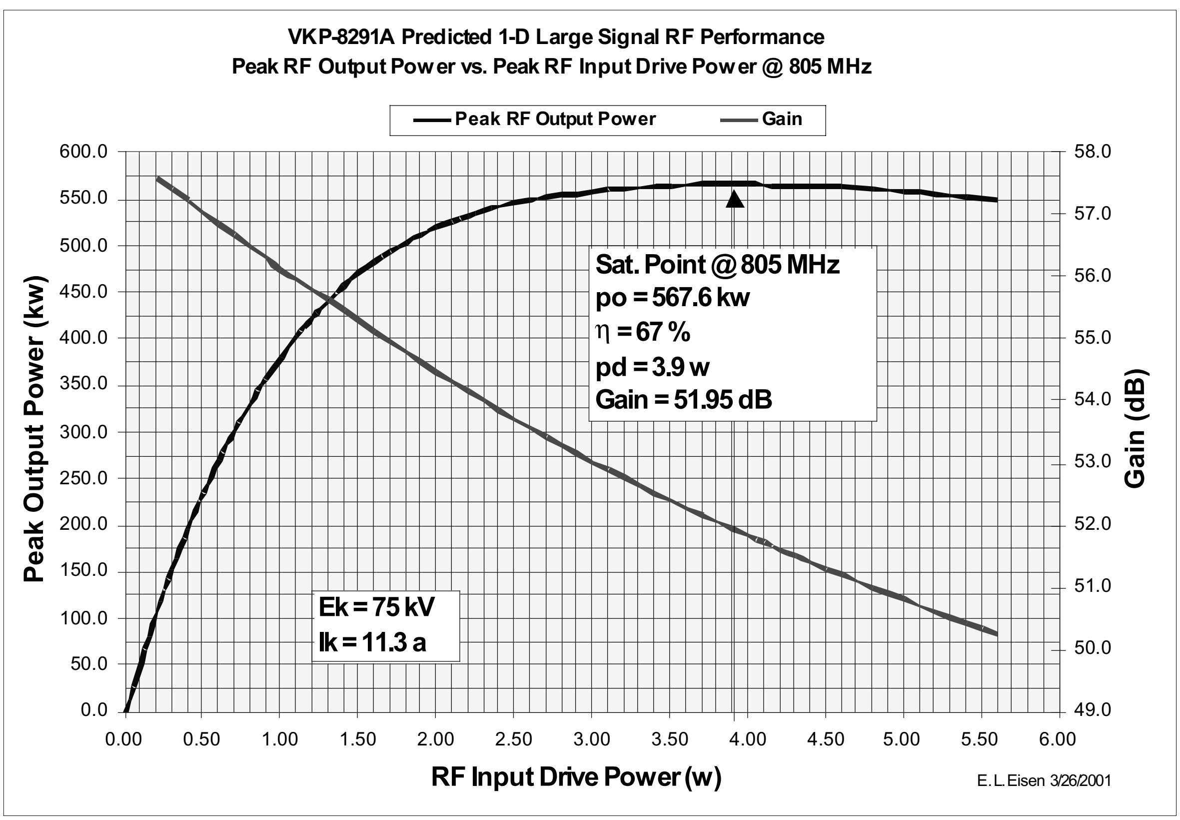

Figure 16 – VKP-8291A Peak RF Output Power versus Peak RF Input Drive Power Simulation

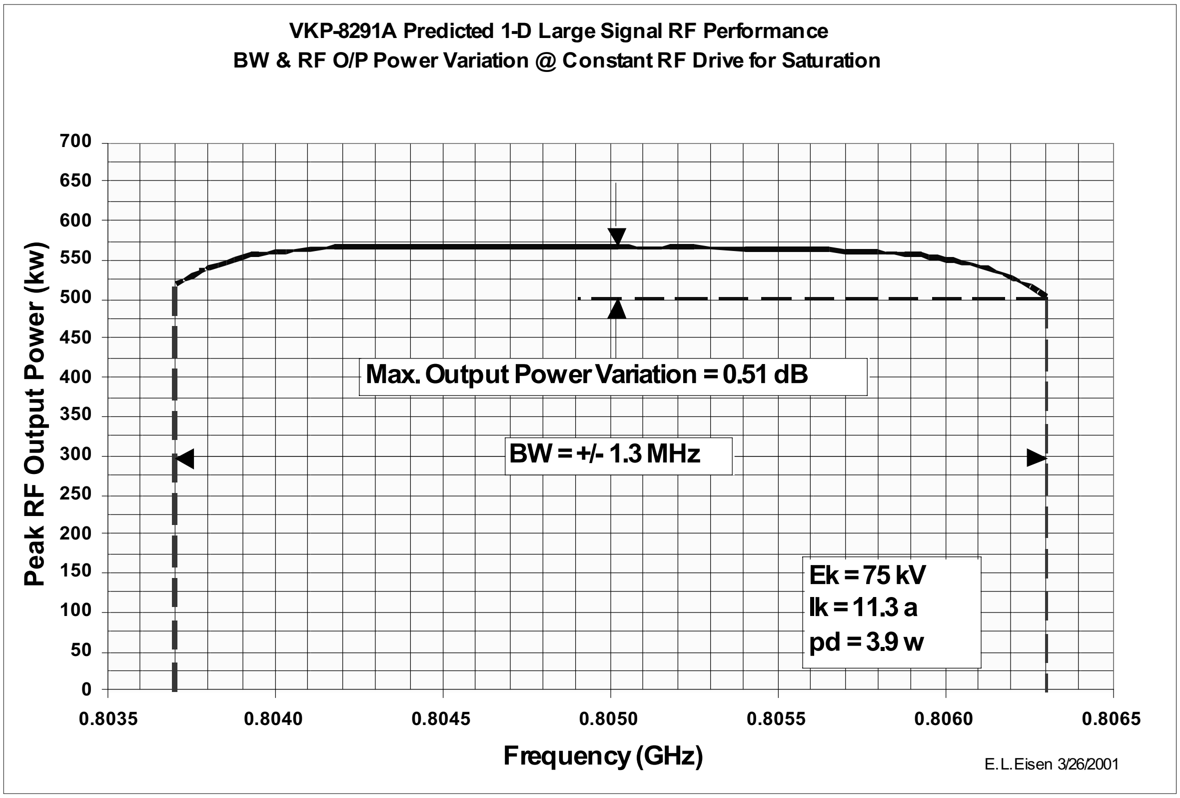

Figure 17 – VKP-8291A Peak RF Output Power versus Frequency — Saturated Output Power Bandwidth Simulation

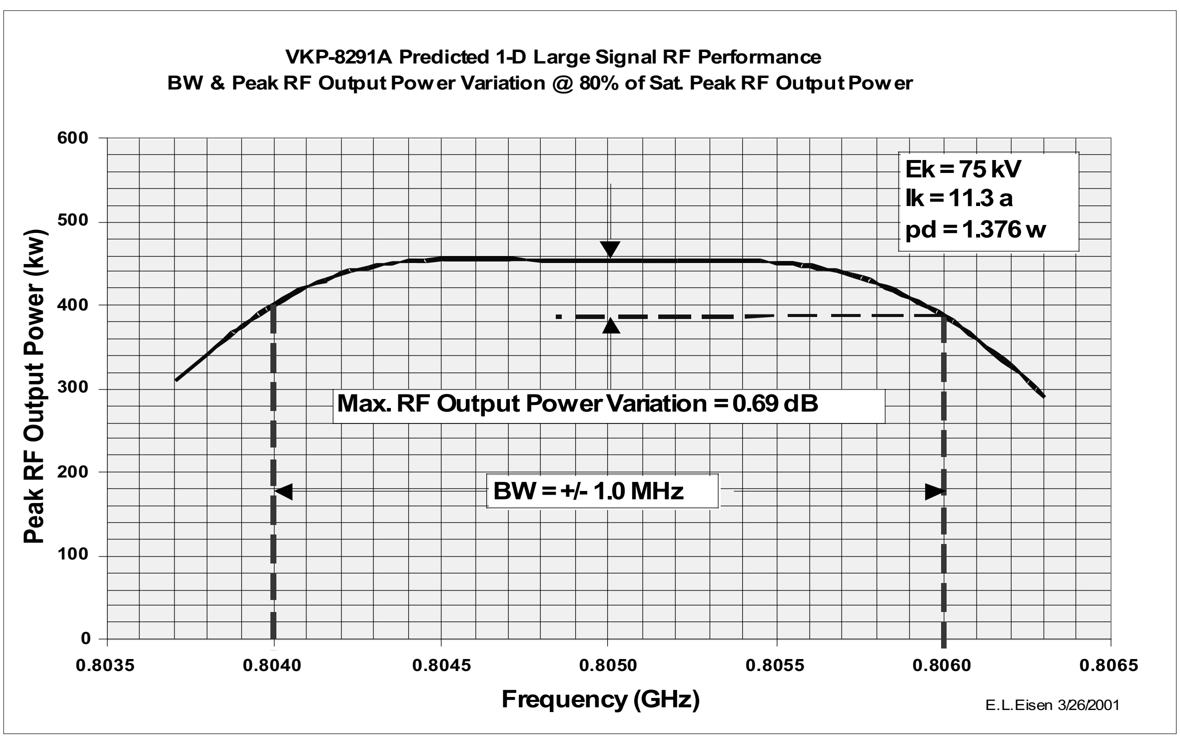

Figure 18 – VKP-8291A Peak RF Output Power versus Frequency — Reduced Output Power Bandwidth Simulation

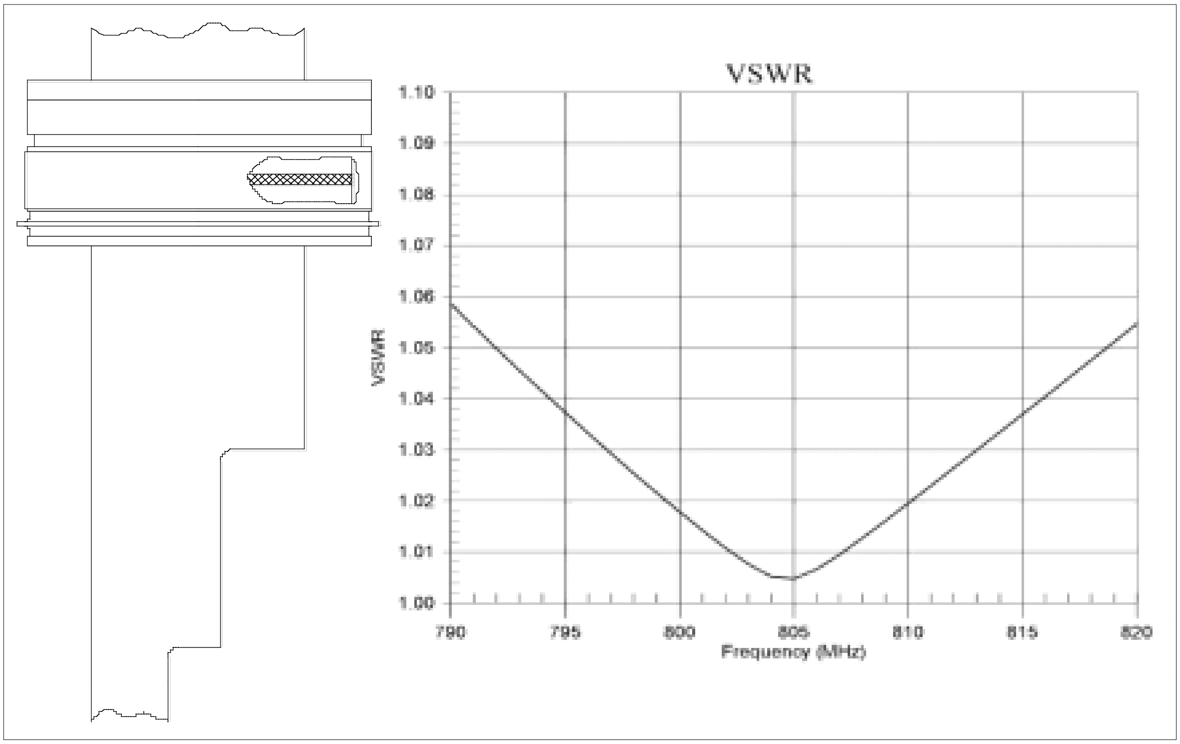

Figure 19 – VKP-8291A RF Vacuum Window and Waveguide Assembly — VSWR versus Frequency Simulation

4. CONCLUSIONS / SUMMARY

Design Techniques

- CPI makes extensive use of sophisticated computer simulation programs and DFA/DFM techniques to simulate all aspects of klystron performance and develop reliable products that meet customer requirements
- This allows CPI to develop successful new products within shorter time frames, necessary to meet our customer's schedules

Current Klystron Development Status

- Baseline design of the electron beam, focusing fields, collector, and RF circuits have been completed on time
- The predicted DC & RF performance meets or exceeds customer requirements
- The mechanical layout meets customer's physical constraints
- Further computer simulations will be performed to fine tune klystron performance