

A 100 KW, 1497 MHZ, CW KLYSTRON FOR FEL DRIVER ACCELERATOR

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Abstract

This paper describes a 100kW 1497MHz CW Klystron that was developed to drive the cryogenic cavities in the injector stage of the FEL Driver Accelerator at Jefferson Lab. Only 0.35W of rf drive power was required to achieve a saturated output power of 112kW. The efficiency was 51%. Because the rf output phase and power gradient must be controlled to a very high degree of accuracy, the klystron operates in a high-gain feedback system in the accelerator. This requires the klystron to be operated below the saturation knee at 80kW where the incremental gain is at least 0.5dB/dB. The normal beam voltage is 33.5kV and the beam current is 6.6A. The diode electron gun was designed for long life and contains a dispenser type tungsten matrix cathode. The body assembly consists of 6 tunable rf cavities and an output waveguide terminating in a pillbox window. The rf output coupler is a WR-650 standard waveguide flange. The input rf coupler is a type N female connector. As required by the specification, the entire klystron was designed to be especially rugged and robust with a significant margin of safety. The klystron is 147cm (58 inches) long and the focusing solenoid is 46cm (18 inches) in diameter. A total of 3 klystrons were delivered to Jefferson Lab.

1 INTRODUCTION

Although the 1497 MHz, 100-kW CW klystron does not push the energy levels of the super-power devices, the development still presented numerous challenges. The key customer desire was a robust, reliable klystron. The efficiency request was for a modest 50%, with a gain of 48 dB and a bandwidth of 5 MHz. Additionally, the tube had to tolerate a 1.35:1 mismatch at any phase. The gun was to be a diode type and the collector had to be capable of dissipating all of the beam power.

2 DESIGN

2.1 Electrical Design

Our existing codes and design processes were used for this klystron. The rf circuit consists of six cavities; no second harmonic cavity is incorporated. The first three cavities are staggered around the operating frequency to provide the bandwidth. Next are two inductively tuned cavities to optimize the electron bunching. The output cavity then extracts energy from the beam.

2.2 Mechanical Design

The frequency and relatively low output power led to a reasonable size device. The klystron operates vertically with the gun down. Figure 1 displays the overall size of the klystron and the various key elements. It is shipped separate from the electromagnet and the two are integrated at the customer's facility.

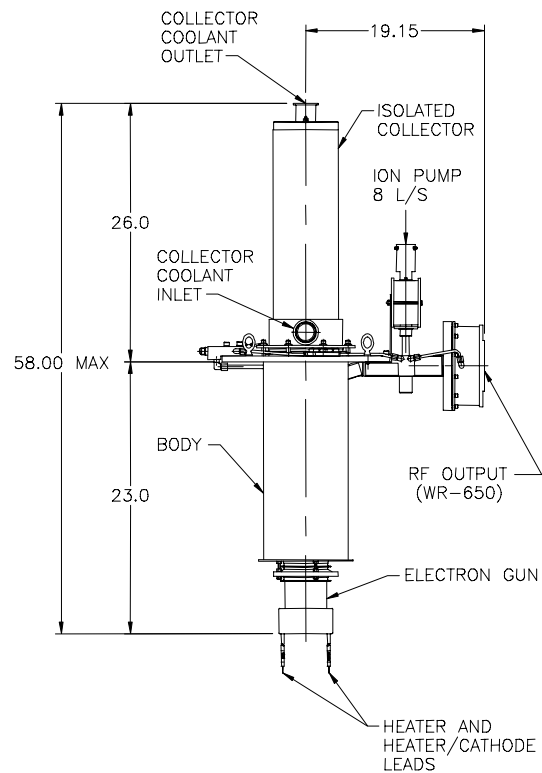


Figure 1: VKL-7966A Klystron Outline

The entire rf circuit is made from copper with rectangular cavities. All cavities have a diaphragm tuner mechanism to optimize the cavity settings at test. The output window is a pillbox design with an alumina ceramic.

Unlike super-power klystrons, the collector on the VKS-7966A is isolated from the body to allow the monitoring of body current. It is made with thick-walled OFE copper with drilled-holes for the coolant to pass.

3 TEST RESULTS

All three klystrons met the specification requirements. Even with the high gain of over 55 dB, the klystrons showed no hint of instability. Typical measured data at saturated rf output power is presented in Table 1 and Figures 2, 3, and, 4.

Parameter	JLab Specification	Measured
Beam Voltage, kV		33.5
Beam Current, Amps		6.5
Frequency, GHz	1.497	1.497
Output Power, kW	100	110
-1 dB Bandpass, MHz	5	14
Efficiency	> 50%	51%
Gain	48 dB	55.5 dB
RF Drive Power, Watts	1.6 max	0.31
Incremental Gain, dB/dB	> 0.5	0.53
Body Current, mA		13
DC Body Current, mA		3
Magnet Current, Amps		22
Magnet Voltage, Volts		86

Table 1: Typical VKL-7966A Operating Data

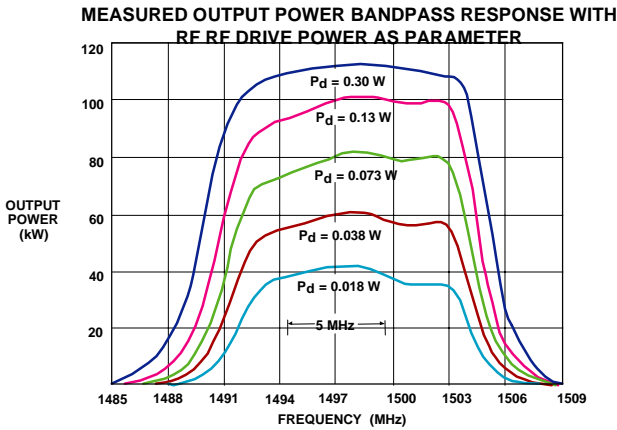


Figure 2: Output Power vs. Frequency at Varying Drive

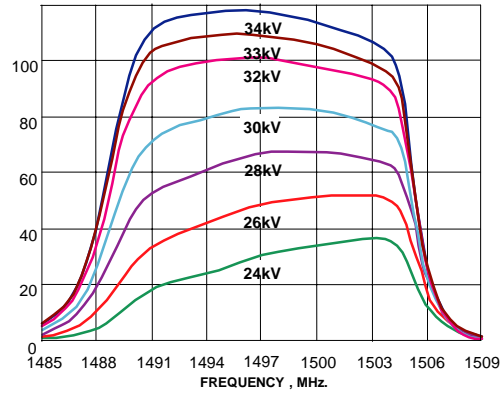


Figure 3: Output Power vs. Frequency at Beam Voltages

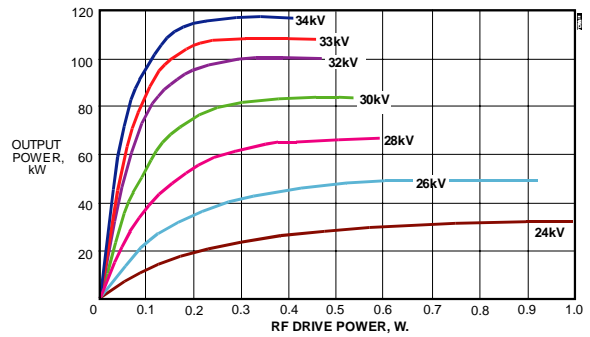


Figure 4: Transfer Curves at Beam Voltages

A key concern was the Incremental Gain of the klystron at the 40 and 80 kW operating levels because the RF phase and gradient in the FEL cryogenic cavities must be regulated to a very high degree of accuracy. A broadband, very high gain feedback system is employed in the accelerator system to control the RF drive level of the klystron.

When the klystron is operating at either the 80 kW or 40 kW output power level and the RF drive is changed by 1 dB, there must be a corresponding output power change of 0.5 dB or greater. See Figure 5.

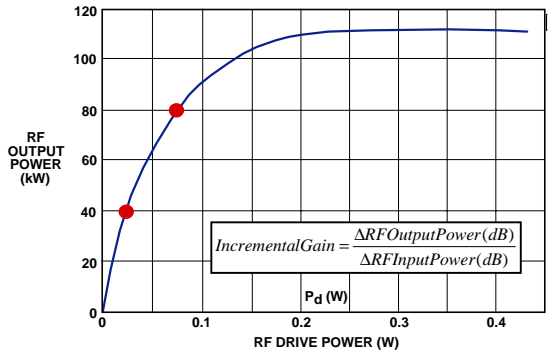


Figure 5: VKL-7966A Transfer Curve

All three klystrons have been delivered to TJNAF. Figure 6 shows the klystron in the magnet at the facility



Figure 5: VKL-7966A Klystron in Electromagnet
(Photo courtesy of TJNAF)

5 CONCLUSION

CPI has reinvented its methodology for the electrical and mechanical design of high-power and super-power klystrons for scientific applications. The measured results, especially the high degree of stability under various operating and mismatch conditions, instill high confidence in our computer simulations. A mode of producing the large klystrons is in place.

6 ACKNOWLEDGEMENTS

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