HIGH POWER, CW, UHF KLYSTRONS FOR STORAGE RING APPLICATIONS*

SLAC-PUB-1499
October 1974

Gerhard T. Konrad

Stanford Linear Accelerator Center

Stanford University

Stanford, California

ABSTRACT

The klystrons to be described in this paper operate at a fixed frequency of 358.54 MHz. They are designed for 125 kW CW with an efficiency in excess of 50 percent. Four cavities are used resulting in a gain of approximately 50 dB. Design values of operating voltage and microperveance are 41 kV and 0.7, respectively. The klystrons are required to be stable when working into any accelerator VSWR up to 2:1 and at any phase angle. This requires the versatile and rugged output system to be described. An operating efficiency of 57 percent is reported and the highest output power is 160 kW CW at 42.5 kV.

INTRODUCTION

The SPEAR II (Stanford Positron Electron Asymmetric Ring) klystrons built at Stanford are UHF, CW tubes to be used specifically for energy upgrading of the storage ring at SLAC. Four tubes are required. They operate at the 280th harmonic of the particle circulation frequency in the storage ring. Thus the operating frequency of the tubes is fixed at 358.54 MHz. The power generated is used to make up for radiation losses of the circulating stored beams.

KLYSTRON DESIGN

The operating parameters for the SPEAR II klystrons are shown in Table I.

Table I

Frequency	358.54	MHz
Instaneous Bandwidth (1 dB Points)	∿0.5	%
Beam Voltage	41	kV
Beam Current	6	A
RF Output Power	125	kW
Duty Factor		CW
Gain	∿50	dB
Efficiency	>50	%
Load VSWR	Up to 2:1 at any phase angle	

*Work supported by the U.S. Atomic Energy Commission.

It should be noted that a CW power level of 125 kW at an efficiency of 50 percent is formidable enough to require some care in the electrical and cooling designs. A microperveance as low as 0.7 was chosen in order to enhance the probability of obtaining an efficiency greater than 50 percent within an overall tube length of approximately 10 feet.

The design of the klystron interaction space is quite conventional. Four cavities are used, resulting in a gain of approximately 50 dB. The low perveance chosen results in a higher beam impedance and hence a higher value of Q_L in the output cavity than is true in many other high power klystrons. This allows more options in the output coupling scheme. In the SPEAR II klystrons loop coupling is used. The output circuit consists of a short section of 3 inch diameter coax with the free end of the center conductor being surrounded by a ceramic cylinder. This cylinder, the inside of which has a thin Ti film, acts as the vacuum window. This whole structure forms the launching system in a reduced height WR-2100 waveguide. A single step and an inductive matching post are used to transform into standard WR-2100 waveguide.

Figure 1 shows a photograph of a SPEAR II klystron. The output window and the cathode seal make use of the same ceramic bushing, which incidentally is used for the cathode seal on all SLAC S-band klystrons. The collector requires a water flow of 50 gpm, while the body and the RF output system require approximately 2.5 gpm. All cavities, drift tubes, the anode and the window along with the RF output inner and outer conductors are water cooled. The klystron operates in a focusing system of approximately 150 gauss, which is 2.5 times the Brillouin field. The whole package stands vertically with the gun-end down. The cathode socket and seal are under oil.

The gun utilizes a convergent Pierce-type design. The cathode diameter is five inches and the area convergence is 6.75 to 1. This represents a cathode loading of only 50 mA/cm^2 at operating conditions. An oxide coated cathode supplies this current density comfortably.

DESIGN CALCULATIONS

A one-dimensional large-signal digital com-

(To be presented at the 1974 Internat'l. Electron Devices Meeting, Washington, D.C., Dec. 9-11, 1974)

puter program was used to calculate the performance of the SPEAR II klystron design. This program has agreed quite closely with experimental results in the past. The efficiency as a function of input power for various operating voltage levels is shown in Fig. 2. A maximum efficiency of 59 percent is indicated for 41 kV. The maximum output power and efficiency are plotted as a function of voltage in Fig. 3.

TUBE PERFORMANCE

The first SPEAR II klystron was tested during the early part of 1974. Four additional tubes have since been completed and tested. The experimental data reported in this paper are based on the first tube, although subsequent tubes performed substantially the same. Along with the curves calculated for Fig. 3 there are shown experimental points for the output power and the efficiency. The actual operating microperveance is between 0.75 and 0.8. The highest power output levels can be obtained with non-uniform focusing of the electron beam. The non-uniform focusing leads to some beam interception in the final drift tube and the output gap. Furthermore, oscillation power of a few kW is generated in the tube when no drive signal is present at voltages above 39 kV. For these reasons a more uniform magnetic focusing field is chosen. This reduces the interception and eliminates the oscillations, but the efficiency is between 50 and 53 percent at 40 kV.

Figure 4 indicates phase excursions of 20° to 40° at a fixed voltage and various frequencies as the power is varied from low level through saturation and beyond. Saturation occurs for each frequency shown at the point farthest to the right. Note that the total phase shift through the tube is in the order of 1500 to 2000 degrees. Thus, as the beam voltage is swept over the desired operating range of 25 to 40 kV, the total phase shift decreases by several hundred degrees.

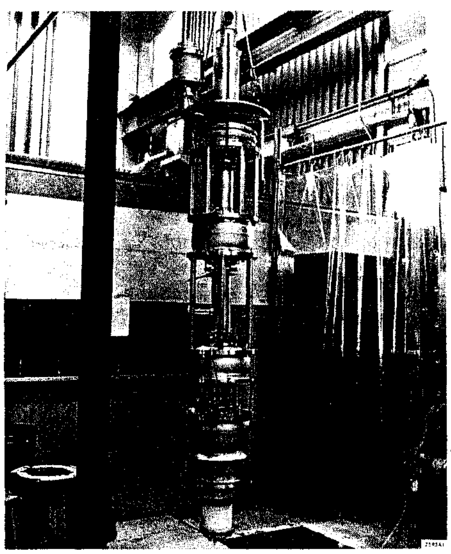

Fig. 1 SPEAR II Klystron

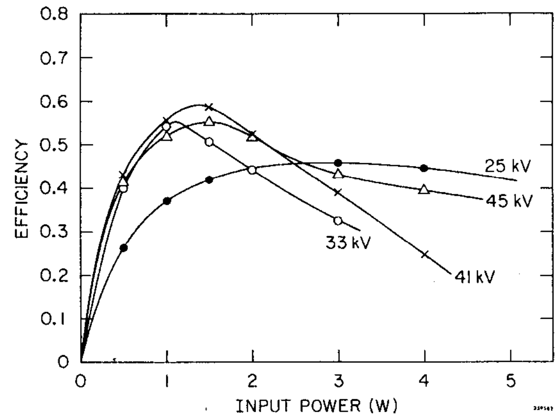

Fig. 2 Efficiency vs. Input Power for SPEAR II Klystrons (P_μ = 0.7) Computed Results

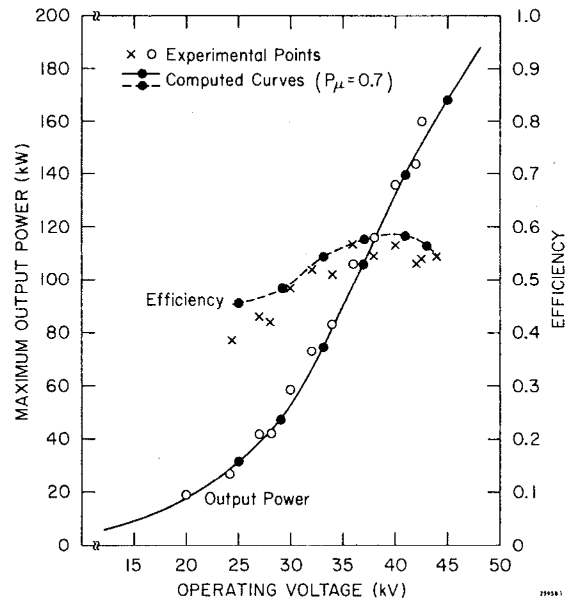

Fig. 3 Output Power and Efficiency vs. Operating Voltage for SPEAR II Klystrons at 358.5 MHz

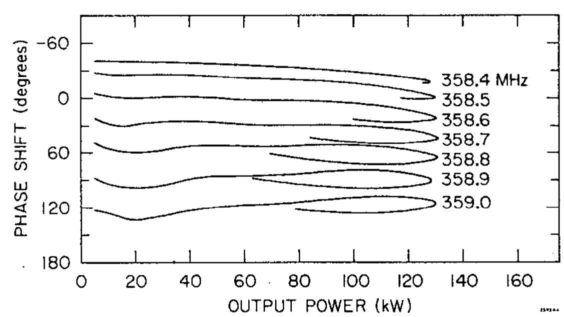

Fig. 4 Measured Phase Shift vs. Output Power for SPEAR II Klystrons. V_o = 40 kV