A 5 kW, 1.5 GHz KLYSTRON FOR SUPERCONDUCTING CAVITIES

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Abstract

Design considerations and performance characteristics of the Thomson-CSF TH 2466 klystron amplifier are described. It delivers a minimum power of 5 kW CW at 1500 MHz and has been specially designed for accelerator applications.

Introduction

The new generation of electron beam accelerators equipped with superconducting cavities calls for the use of medium power, reliable, low-cost RF sources. Klystron amplifiers appear particularly well-suited, and Thomson-CSF has developed the TH 2466 for this application.

The TH 2466 is derived from production tubes for communication applications which have already demonstrated long life and reliable operation, and employs common components for example the permament magnet (which avoids the use of an electromagnet and associated power supply).

In addition, the TH 2466 has been designed to meet the specific requirements of accelerator service, namely the need for power control by a modulating anode and the ability to operate into high VSWR loads.

Design Considerations

The TH 2466 is a permanent magnet, four cavity klystron ; it uses an impregnated, lightly loaded cathode to ensure long life in operation (figure 1).

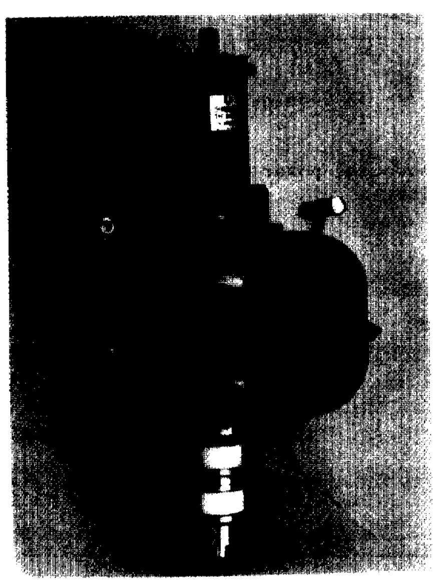

Figure 1 - TH 2466 - 5 kW klystron for accelerator applications

The use of an isolated anode enables to control the beam power while giving the possibility to use a single large power supply common to several tubes. The cavities are pre-tuned to the accelerator frequency. Cooling is by waterflow for improved thermal stability.

The output line is a standard 1 5/8 inch coaxial.

Table 1 gives the typical characteristics and table 2 the different power and phase sensitivities.

Modulating Anode

The modulating anode is an isolated electrode placed between the cathode and the entrance of the body of the tube. The more negative its potential with respect to ground, the smaller the beam current and the output power (figure 2).

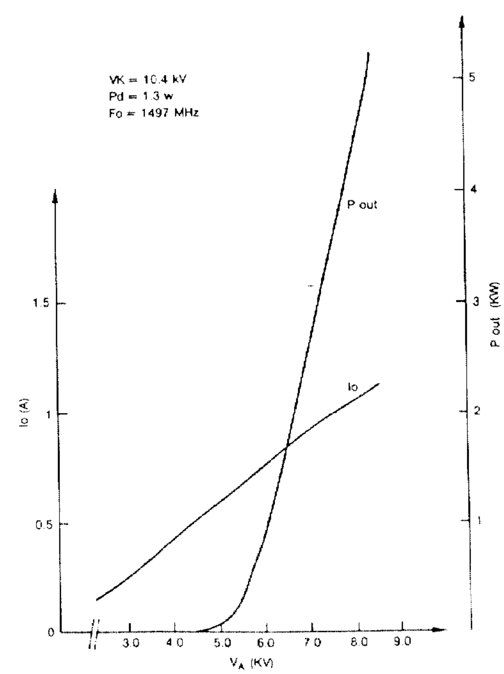

Figure 2 - TH 2466 beam current and output power vs anode voltage

Careful design of the beam using computer simulations allows to obtain a laminar beam for the various anode biasing conditions. Furthermore, as the current intercepted by the anode is very small (< 1 mA), the power consumption of the anode modulator is consequently small.

Table 1 - TH 2466 Typical Characteristics

Frequency	1497 MHz
Output power (CW) (min.)	5 kW
Cathode voltage	10.4 kV
Anode-cathode voltage	8.5 kV
Cathode current	1.1 A
Efficiency (min.)	44 %
Gain (saturated)	37 dB
Bandwidth (-1 dB)	8.5 MHz
Heater voltage	7.5 V
Heater current	4.5 A
Cooling (water flow) :	
- collector	15 l/mn
- body	2 l/mn

Table 2 - TH 2466 Power, Phase Sensitivity

$\frac{\Delta Pout}{\Delta V_k} = 0.7$ W/V V_k = cathode voltage

$\frac{\Delta \phi}{\Delta V_k} = 0.1$ °/V

$\frac{\Delta \phi}{\Delta V_A} = 0.03$ °/V V_A = anode voltage

$\frac{\Delta \phi}{\Delta P_D}$ (AM-PM) $= 6$ °/dB $P_D = P_{drive}$

Cavities

To increase the bandwidth, the cavities are stagger-tuned and externally loaded ; this is to minimize the effect of beam loading variation with anode bias.

A large signal computer code is used to optimize drift tube dimensions and coupling of the output cavity to the load. This output coupling coefficient is defined on a trade-off basis between efficiency and VSWR withstand capability.

Figures 3 and 4 show the bandpass characteristics with varying drive power and anode voltage respectively.

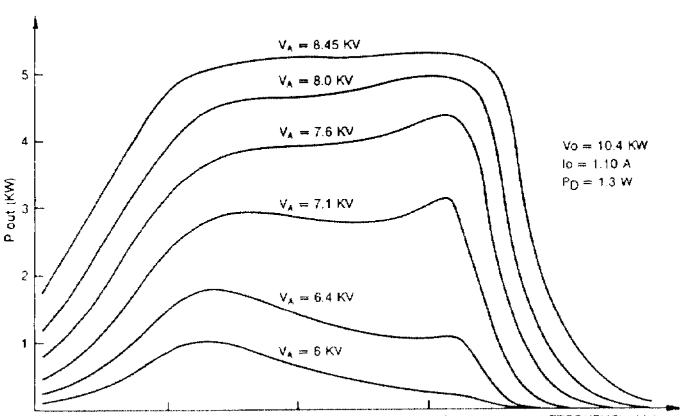

Figure 3 - TH 2466 band pass characteristics vs anode voltage

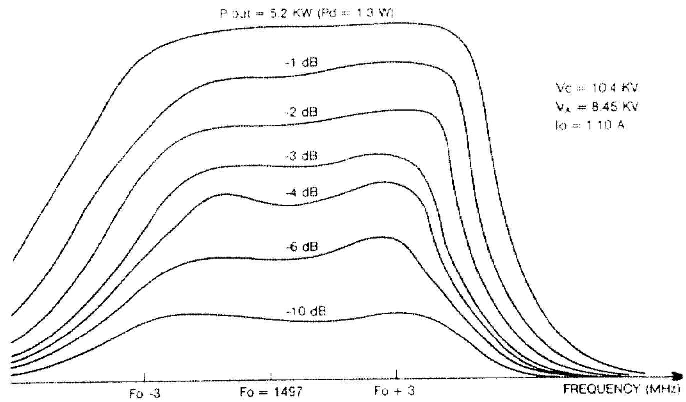

Figure 4 - TH 2466 band pass characteristics vs drive power

Figure 5 represents the transfer characteristics (output power versus drive power) for various values of anode voltage.

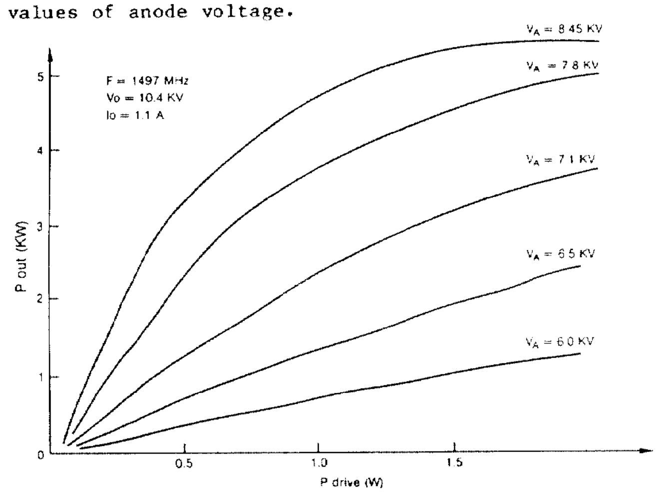

Figure 5 - TH 2466 output power vs drive power

Figure 6 shows the power and phase variation versus cathode voltage.

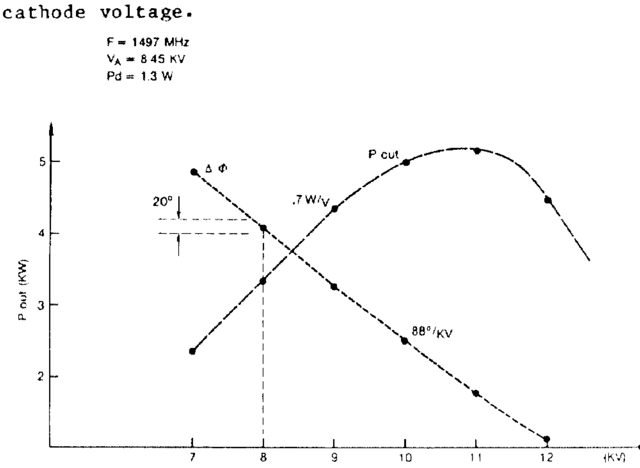

Figure 6 - TH 2466 output power and phase variations vs cathode voltage

Operation with High VSWR

The RF load constituted by the superconducting cavity of the accelerator depends essentially on the beam loading and consequently varies with the beam intensity.

At full beam current, the cavity coupling is defined to obtain good matching to the transmission line ; when the beam is off or at a low value, the cavity presents an open circuit and the VSWR on the line becomes extremely high.

The klystron must be protected against these high reflections, otherwise arcing and excessive interception in the output cavity gap might cause its destruction.

One possible way to do this and avoid the use of costly ferrite circulators or isolators is to monitor the klystron output gap voltage thus eliminating the risk of arcing.

A fraction of the output line voltage is sampled by a probe located at an integral half wavelength from the "detuned short position" of the klystron cavity ; this signal, proportional to the gap voltage, can then be used in a feedback loop to regulate the anode voltage and reduce the output power until an acceptable gap voltage is reached.

This requires an accurate control of the electrical length of the output line of the klystron but appears to be a very attractive method.

Conclusion

The Thomson-CSF TH 2466 klystron amplifier has been specially developed for the new generation of accelerators using superconducting cavities.

Several prototypes have already been constructed and the final tests are presently in progress.

Using the same technology as that which has been developed and improved over the last several years for communication tubes, the TH 2466 should demonstrate the same reliability and long life operation.