PPM KLYSTRONS FOR ACCELERATOR SYSTEMS

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Abstract

Calabazas Creek Research, Inc. (CCR) is engaged in the development of high power periodic permanent magnetic (PPM) focused klystrons for Accelerator Systems. There are at present 3 ongoing development programs. A 10 kW CW S-band klystron for the Advanced Photon Source at Argonne National Laboratory is nearing completion. An SBIR Phase II grant to develop an S-band 5.5 MW pulsed klystron for the Varian Medical Systems, Inc. CLINAC was funded in April, 2013. An SBIR Phase I grant to develop an S-band 75 MW pulsed klystron for the X-FEL linac at Los Alamos National Laboratory was received in February, 2013. The present development status of these 3 klystrons will be presented.

INTRODUCTION

The impetus to develop high power CW and pulsed PPM focused klystrons is to reduce the cost of producing a large number of klystrons as required by pending high energy linacs. The electron beams for the majority of klystrons for these linacs are focused using electromagnets. These electromagnets require a DC power supply and external fluid cooling. In addition, the electromagnet adds size and weight to the klystron. Employing a PPM structure in lieu of the electromagnet with DC power supply reduces the cost, size and weight substantially with no degradation in operation and life time.

CCR is nearing completion of the fabrication of the 10 kW CW S-band klystron. A 3D pictorial of this klystron is shown in Figure 1 below. The PPM structure consists of as standard geometry with a fixed period where the conventional ring magnets have been replaced by 4 pill box magnets in each half period. This geometry allows ready access to cavity tuners and cooling lines. The four long magnets around the RF output cavity are required to focus the spent electron beam as it loses energy. Initial simulations predicted an efficiency of 70%. However, after determining that the spent electron beam was intercepted just after the output cavity, the PPM structure was redesigned to include the large magnets with the efficiency decreasing to 55%. The electrical parameters for this PPM klystron are listed in Table 1.

Table 1. Electrical Parameters for the APS Klystron

Frequency	2.815 GHz
Beam Voltage	20 kV
Beam Current	1.0 A
Efficiency	55%
RF Output Power	11 MW
Saturated Gain	49 dB
Frequency	>5 MHz

The second PPM program is the development of a 5.5 MW pulsed S-band klystron similar to the solenoid focused klystron presently used in the Varian Medical Systems, Inc. CLINAC. The CLINAC is an X-ray source for treating cancer. The initial SBIR Phase I addressed the L-band RF sources for Project X at Fermi National Laboratory. It was redirected to the 5.5 MW S-band klystron due to the reduction in funding for Project X. The revised program is

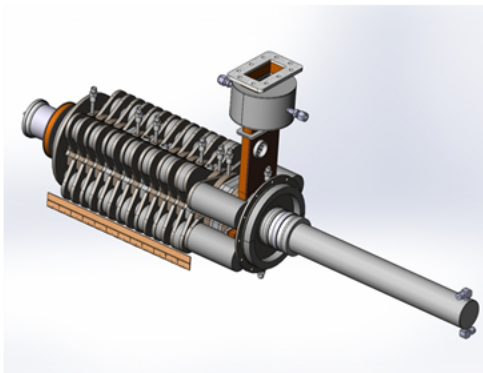

Figure 1: The 10 kW CW S-Band PPM Klystron.

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focused on reducing the size, weight and cost of the klystron and associated systems. The techniques established in this Phase II can be directly applied to all DOE klystron programs. The results are listed in Table 2.

Table 2. Electrical Parameters for the CLINAC PPM Klystron

Frequency	2.856 GHz
Beam Voltage	127 kV
Beam Current	90.5 A
Efficiency	48.8%
RF Output Power	5.61 MW
Saturated Gain	48 dB
-1 dB Bandwidth	>10 MHz

One goal is to include using as many existing subassemblies from the present solenoid focused klystron including the electron gun and output waveguide and vacuum window. The cathode will require a slight change in spherical radius with a small change in the focus electrode geometry.

The third PPM klystron development began in February, 2013. The initial specifications stated that a 50 MW klystron operating at 2.8175 GHz was required. At a meeting at LANL after receipt of the grant, the parameters were changed to the higher frequency of 2.856 GHz where there is more knowledge and hardware available and the RF output power was increased to 75 MW with an increase in pulse width from 3 microseconds to 12 microseconds. Further restrictions were imposed on the beam voltage not to exceed 450 kV and the beam current not to exceed 450 A. The resulting electrical parameters are listed in Table 3.

Table 3. Electrical Parameters for the LANL Klystron

Frequency	2.865 GHz
Beam Voltage	450 kV
Beam Current	379 A
Efficiency	48.2%
RF Output Power	82.2 MW
Saturated Gain	51 dB

SUMMARY

Several new klystrons are in development that use PPM focusing to reduce the size, weight and cost of RF systems. The novel approach to PPM focusing provides access to the RF circuit for cavity tuners, and water cooling and eliminates shunting to achieve axially symmetric magnetic fields. PPM focused klystrons can significantly reduce the cost of future accelerator and collider systems.

ACKNOWLEDGEMENT

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REFERENCE

[1] Patrick Ferguson, et al., “Development of a 10 kW CW High Efficiency S-Band PPM Klystron” ICOPS, June, 2013, San Francisco.