2.1: Design and Development of a 6 MW Peak, 24 kW Average Power S-band Klystron

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Abstract: A 6 MW peak, 24 kW average power S-band Klystron is under development at CEERI, Pilani under an MoU between BARC and CEERI. The design of the klystron has been completed. The electron gun has been designed using TRAK and MAGIC codes. RF cavities have been designed using HFSS and CST Microwave Studio while the complete beam wave interaction simulation has been done using MAGIC code. The thermal design of collector and RF window has been done using ANSYS code. A Gun Collector Test Module (GCTM) was developed before making actual klystron to validate gun perveance and thermal design of collector. A high voltage solid state pulsed modulator has been installed for performance evaluation of the tube. The paper will cover the design aspects of the tube and experimental test results of GCTM and klystron.

Introduction

Microwave tubes, such as TWT, Magnetron, Klystron, Backward Wave Oscillator, Gyrotron etc., are indispensible components of most of the modern advanced technologies right from communication to particle physics research. Klystrons are widely used as RF source in charge particle accelerators due to their excellent features like capability of producing high peak and average RF power, high gain, high efficiency and good stability.

A 6 MW peak, 24 kW average power S-band Klystron is under development at CEERI with an aim to use it as RF source in a linac system for cargo scanning as well as in a 10 MeV industrial RF linac system.

Design of Klystron

Various sections of the klystron such as electron gun, RF cavities, input & output couplers, waveguide RF window, collector and magnetic focusing system have been designed using different in-house developed and commercial design codes. In most of the cases the design results obtained from one code have been validated using another code before taking-up fabrication. The electron gun along with magnetic focusing system has been designed using TRAK code and the design was cross checked using MAGIC code. The simulated results of both the codes were in good agreement. The comparative results from the two codes are shown in Fig. 1(a) and 1(b).

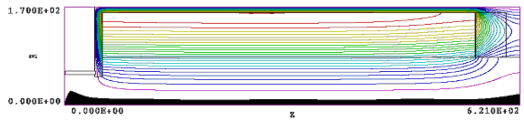

Fig. 1(a)

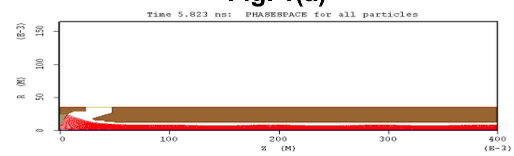

Fig. 1(b)

Fig. 1: Gun and focusing field design using TRAK and MAGIC code

The thermal design of collector using ANSYS code necessitated ducting of its outer surface for efficient cooling using water. Fig 2 shows thermal simulation results of collector.

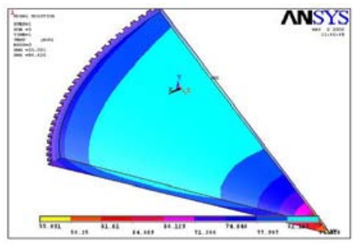

Fig. 2: Thermal simulation of collector

The RF cavities have been designed using CST Microwave Studio and HFSS with an aim to get desired resonant frequency, tuning, quality factor and shunt impedance. Cold test models of cavities were developed to validate the design. The design of full RF section was done using particle in cell code

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MAGIC to get desired tube performance. A typical result showing computed output power is shown in Fig. 4.

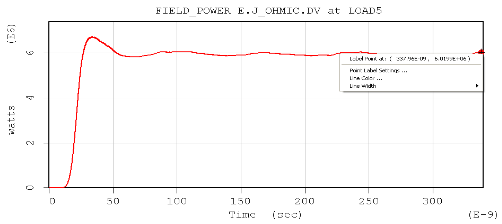

Fig. 4: Computed output power

Development and testing of Gun Collector Test Module

For experimental validation of the design of electron and collector, a GCTM consisting of electron gun and collector designed for actual klystron has been developed.

Fig. 5: GCTM on processing station

The GCTM was vacuum processed in a beljar system having UHV pumps for evacuation of tube and roots-rotary pump combination for creating guard vacuum during baking cycles as shown in Fig. 5. GCTM was conditioned and then operated finally at 135 kV continuously for eight hours at 400 PRF. The measured pulse current was 116 A with a pulse width of 10 μsec. The measured gun perveance has been found very close to design value.

Development of Klystron

After successful testing and design validation of gun and collector, the full klystron was developed. The klystron consists of five cavities including input and output cavities. The signal to be amplified is coupled through a type N coaxial coupler and output is taken through a waveguide. The electron beam focusing through RF structure is done using an electromagnet. The machined piece parts are joined together to make subassemblies mostly through controlled atmosphere brazing and the final integration of sub-assemblies is done through TIG welding. The photograph of tube taken during welding of collector with rest of the tube is shown in Fig. 6.

After vacuum processing and pinching-off from processing station, external parts including collector cooling jacket, cavity tuners and RF input cable are fitted with the tube and there after the tube is mounted on the hot test bench consisting of high voltage pulse modulator, input/output RF plumbing lines, high power load, liquid cooling lines, X-ray shields and equipment for RF performance characterization of the tub shown in Fig. 3. The output circuit consists of an arc detector, a 50 dB cross guide coupler, a waveguide pressurization unit and a water cooled high power load.

Fig. 6: Final integration of tube

A low power meter is connected to coupling port of cross guide coupler to measure the average power. The other port of the cross guide coupler is used to detect the pulse shape on the oscilloscope through a crystal detector. The pulsed beam voltage and current are also measured using the oscilloscope.

Fig. 7 shows photograph of oscilloscope screen corresponding to 5.5 MW output power from the klystron and the associated pulse modulator settings.

Fig. 7: Front and rear views of hot test bench

Currently the conditioning of the klystron is being done and it has produced 5.5 MW of peak power. It is expected that with gradual increase of beam voltage, the tube will reach its expected output power level of 6 MW.

Conclusion

A 6 MW peak, 24 kW average power klystron has been designed and developed fully indigenously under MoU between BARC and CEERI. A gun collector test module has been developed and tested at full operating voltage and current ratings and has met the perveance and thermal specifications. The first prototype of the klystron is at advanced stage of testing.

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