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Design Parameter of CW Klystron System for KOMAC

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Abstract

The KOMAC(KOrea Multi-purpose Accelerator Complex) linac is composed of RFQ(Radio Frequency Quadrupole), CCDTL(Coupled Cavity Drift Tube Linac) and SC(Superconducting)-linac. The required CW output power of RF system is about 25MW for 20MW proton beam power. Therefore high power RF sources are necessary for cost saving and reliability improvement. The number of klystrons for 0.5 MW at 350MHz and 1MW at 700MHz are 1 and 31, respectively. In this paper, the design parameters of the klystron system including power supply and energy recovery system are presented.

1. Introduction

The KOMAC is the Accelerator-Driven System(ADS) developed mainly for the energy production and the transmutation of the long-lived radionuclides. In addition to these main purpose, it has various application fields such as nuclear physics, biology, medicine and so on.

For producing continuous beam power of 20MW at 1,000MeV, the KOMAC linac is composed of RFQ, CCDTL and SC-linac. The schematic diagram of linac structure is illustrated in Fig. 1. The CCDTL is composed of two sections that optimized in a different energy range. Acceleration to the energy of 1,000MeV takes place in a superconducting(SC)-linac, which is composed of three sections for efficient acceleration in the different energy range.

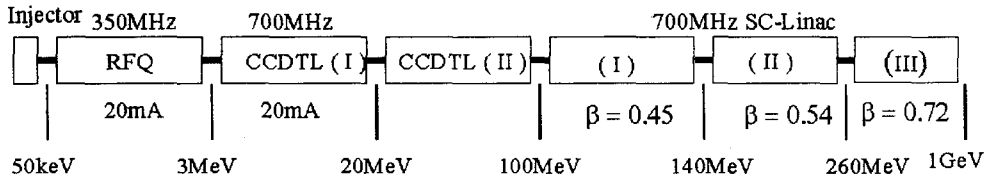

Fig. 1. Schematic diagram of accelerator for KOMAC

The RF system requirements for KOMAC are presented in Table 1. One 750kW CW klystron is required for RFQ and thirty one 1MW CW klystrons are required for CCDTL and SC-linac. At the first phase, commercial klystrons will be used, but it is planned to develop the 1MW CW klystron system including high voltage DC power supply and energy recovery system in KOMAC project.

Accelerator	RFQ	CCDTL		SC Linac			Total
Energy (MeV)	3	20	100	140	260	1000	-
Frequency (MHz)	350	700	700	700	700	700	-
Power of RF source / number	0.75MW / 1 ea.	1MW / 2 ea.	1MW / 6 ea.	1MW / 1 ea.	1MW / 3 ea.	1MW / 19 ea.	0.75MW / 1 ea. 1MW / 31 ea.

Table 1. RF system requirements for KOMAC

2. Klystron System

The klystron system to be developed is composed of klystron, high voltage DC power supply, energy recovery system and other auxiliary systems. The schematic diagram of the klystron system is shown in Fig. 2.

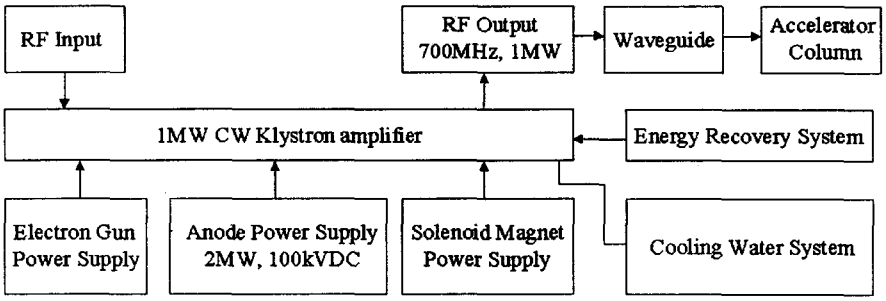

Fig. 2. Schematic diagram of CW-MW klystron amplifier system for KOMAC

2.1. Klystron

A klystron is composed of electron gun, cavity assembly, focusing magnet and collector. The RF power of the CW klystron to be developed is 1MW at 700MHz. For this high power CW klystron, the development of the high quality cathode is required. A dispenser cathode is chosen because it can accomplish the strong demands of long life stable emission, low working temperature, low evaporation rate and high current density. A MMM(Mixed Metal Matrix) type cathode is considered among various dispenser cathode types because it meets the cathode requirements for the high power klystron like these ; The emission current density is 3-8A/cm^2 on CW mode, the life time is above 10,000 hour. The characteristics of the MMM type cathode are presented in Table 2[1].

The preliminary design of the klystron tube body including electron gun, cavity and focusing magnet have been studied. From the results obtained above, optimization is being carried out by using computer codes.

Cathode type	Tungsten + Ir or Os(Metal Matrix) / $BaO+CaO+Al_2O_3$ (Impregnants)
Operating temperature	960 – 1200°C
Life time	1,000 – 1,000,000* hours
Working function	411(Impregnant mole fraction) system at 1200°C = 2.08 eV 411M** system at 1200°C = 2.01 eV 532 system at 1200°C = 2.13 eV 532 M system at 1200°C = 2.06 eV

* : life time including pulsed operation mode

* *: M type for Osmium and ruthenium overcoating on cathode surface with a thickness of 0.5 μm – 1μm

Table 2. Main characteristics of MMM type cathode

2.2. Energy Recovery System

As mentioned above, thirty one klystrons are planning to be installed in KOMAC, but the efficiency of the klystrons are about 60%, and a lot of power is wasted in the klystron collector. So the efficiency of klystron is very important in costs and sizes of klystron power supplies and cooling water system. The klystron efficiency is composed of two efficiencies; tube efficiency and energy recovery efficiency. For the tube efficiency, continuing efforts are going on. But the designs of klystron almost achieved theoretical maximum efficiency[2]. Therefore efficiency of energy recovery from spent beam in collector region of klystron should be increased to enhance the total klystron efficiency. In order to increase the klystron efficiency, several studies of energy recovery systems with Multi-Stage Depressed Collector have been reported[2][3][4]. Recently, new concept of high-efficiency energy recovery system with MES(Magnetic Energy Separator) was considered for the klystrons of KOMAC. Calculated results of recovery efficiency and total klystron efficiency were 70.6% and 89.7%, respectively[5].

2.3. High Voltage DC Power Supply

A SMPS(Switching Mode Power Supply) is a hopeful candidate for KOMAC klystron power supply because it will be possible to operate the power system without crowbar[6]. The specification of high voltage DC power supply for klystron system is presented in Table 3.

Parameter	Values	Comment
Power	2MW	-
Output voltage	100kV	-
Power per module	200kW	10 module
Voltage per module	10kV	Series connection
Voltage ripple	≤ 2%	Peak to peak
Stored energy	≤ 25J	Target
Efficiency	≥ 90%	-

Table 3. Specification of the high voltage DC power supply

It is considered that the modules, each of which has the power of 200kW, are connected in series to supply the total power. The required SMPS topology should meet the condition for the high voltage and high power

operation. A buck converter with current-fed full-bridge DC transformer is chosen as a 200kW single module SMPS topology. IGBTs (Insulated Gate Bipolar Transistor) are used as high frequency switches in SMPS and their specification mainly limits the power rating of the module to be 200kW.

3. Conclusion

The klystron system design of the KOMAC linac was presented. Study on the cathode material and design of the klystron tube including electron gun, cavity and focusing magnet were being carried out. New concept of energy recovery system was proposed and its feasibility study is in progress. Also a SMPS is being studied as a high voltage power supply for KOMAC klystron. In future, detailed design of each component and consideration of the construction facility for klystron system are necessary.

4. Reference

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