400-kW RF AMPLIFIER FOR A 201.25-MHZ DEUTERON RFQ ACCELERATOR*

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Abstract

The dedicated 400kW RF amplifier with hypervaportron TH781 tetrode for a 201.25MHz Deuteron RFQ accelerator has been manufactured and tested successfully. It can deliver 400kW pulse power over RF frequency range from 199MHz to 203MHz with maximum pulse duration of 1ms and 10% duty cycle. The exciter with solid-state transistors can output 1kW at both CW and pulse modes. The driver stage can output maximum 20kW. The dummy load with CW 50kW and peak to average ratio of 10 has been modified to fit the requirements of amplifier test measurements.

INTRODUCTION

Up to now, a lot of RFQ and Drift Tube linear accelerators are using klystron amplifiers as RF power supply. They are often operating around 352MHz or 425MHz [1-3]. Klystron amplifiers have very high RF transmission gain (about 45dB). But they need very sophisticated DC power supply technology, higher AC power efficiency (60~65%), and more space. So far they are also much more expensive than the hypervaportron tetrode amplifier. The later one can deliver reasonable high RF power according to their cost and has been made a break through during the last decade [4-6]. Another reason is when the energy of accelerated particles is still low, no matter what RFQ or DTL, they all should operate at lower frequency to get a bit longer wavelength and to make the accelerating cell length longer. 200MHz tetrode amplifiers are very suitable for the RF linear accelerators to accelerate proton or deuteron to several MeV/u. A dedicated 400kW RF amplifier with Thomson tube TH781 has been designed and manufactured in China in the last several years. The initial RF tests show the desired performance has been reached and the TH781 is very suitable for delivering 400kW pulse power with 1ms duration and 10% duty cycle. The figure 1 shows the schematic diagram of TH781 400KW amplifier.

1KW SOLID-STATE EXCITER

Figure 2 shows the 1kW solid-state exciter, which consists of four 300W amplifiers, made of power transistors MRF151G. The input signal of 300W amplifier comes from 1/4 of 50W amplifier MRF172. MRF172 power amplifier needs about 4W RF input,which is consisted of 3DG92A and 3DA192 two stages ofpreamplifier. The 10mW RF signal generated by HP signal oscillator was applied to the base of 3DG92A, and amplified to 0.5W, delivered to the next stage of 3DA192 amplifier. The output power of four MRF151G amplifiers is combined to get 1kW and transmitted to input grid of 20kW IPA.

* Work supported by 985 project and NSFC (Contract number 14055001)

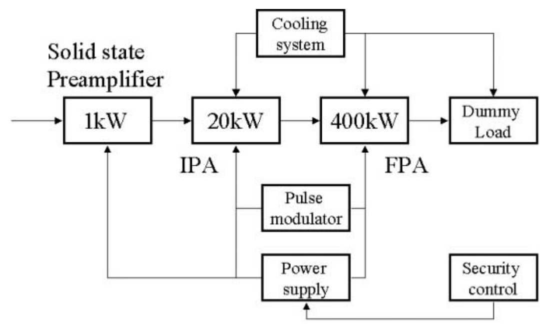

Figure 1: Schematic diagram of 400kW amplifier.

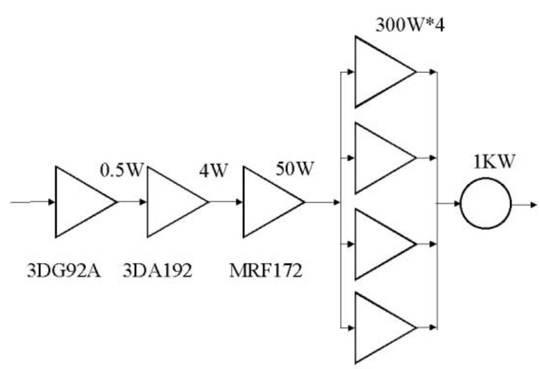

Figure 2: 1kW Solid-state exciter combined by four MRF151G 300W preamplifiers.

20KW IPA

Table 1: Tested Characteristics of FU113F

Items	Tested data
DC plate voltage /kV	7.4
DC grid 2 voltage /V	1200
DC grid 1 voltage /V	-120
Frequency /MHz	200
DC plate current /A	4.2
Drive power /kW	0.8
DC input power /kW	31
Peak RF power /kW	20
Plate dissipation power /kW	11
Efficiency /%	64.5

20kW IPA (Intermediate Power Amplifier) is consisted of tetrode FU113F. Type FU113F is a forced air cooled, thorium tungsten cathode tetrode for frequencies up to 250MHz and widely used in FM transmitter. The final tested characteristics of the IPA stage are listed in the table 1. Figure 3 shows the IPA coaxial cavity and its cooled air channel. The input and output circuits are 3λ/4 and λ/4 coaxial line structure, respectively.

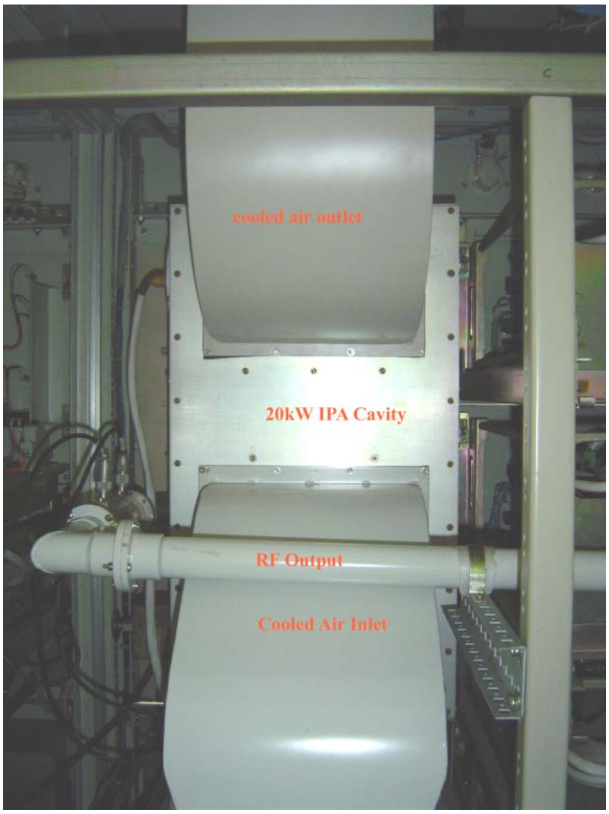

Figure 3: FU113F 20kW IPA cavity.

400KW TH781 FPA

TH781 hypervaportron tetrode is recently and widely used in the RF power system in linear accelerator. The typical rating for tetrode TH781 is CW mode, 200kW with frequency at 200MHz. For the pulse mode, it is suitable to operate up to 250MHz, and delivers pulse peak power 400kW with duration of 1.4ms and 16% duty cycle. Maximum rating of output power at 200MHz is 450kW meanwhile plate dissipation power is about 250kW in peak [7]. TH781 and its cavities were supplied by the THOMSON TUBES ELECTRONIQUES. Fig.4 shows the outline of 400kW amplifier. Figure 5 is TH781 FPA cavity structure. Like all hypervaportron cooled tubes, the coming cooled water must always be connected to the cooler inlet, and outgoing water must always be evacuated via the outlet, meanwhile the screen grid connection is also cooled with water. The cooled water is better de-ionized; at least it should be de-mineralized. Its resistivity at 20°C must be maintained at 500kΩcm or higher. There are two-cooled water systems. The first is self-circulating de-ionzed water system, which is also called as inner water system, it flows through all the FPA inner areas where FPA needs to be cooled, and finally it flows back to the de-ionized water container. The second water system (outer) will cool de-ionized water through plate heating exchanger in the de-ionized water container and keep the inner de-ionized water temperature at TH781 water inlet is less than 20°C. IF the temperature of cooled water is higher than 40°C, the water circulating system will give an alarm signal meanwhile RF signal will be cut off and power supply of amplifier will be shut down.

Figure 4: Outline of 400kW amplifier.

Outer cooled water system consists of a $1.6m^3$ water container, three water pumps, two 40kW Danfos refrigerators, and Siemens PLC. It is capable of keeping the water temperature in ±2°C and providing cooled water flowing of $8m^3/h$. It will also provide the cooled water for the future deuteron RFQ accelerator.

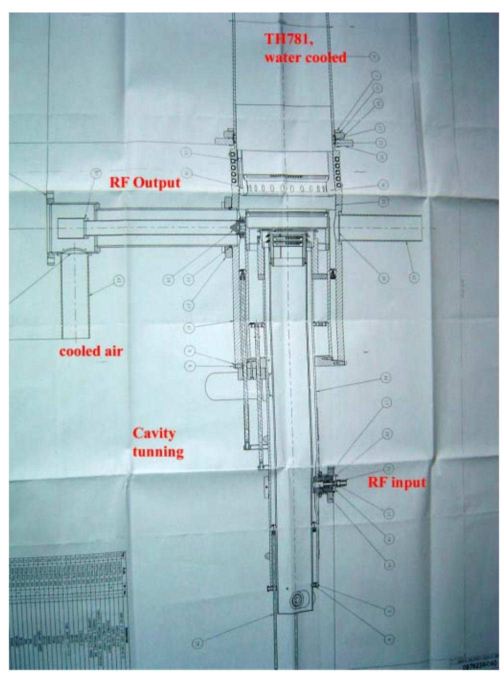

Figure 5: The cavity outline of TH781 FPA.

The RF conditioning of 400kW amplifier has been started several months ago, tested from 1% duty cycle with pulse duration 100μs at 200MHz and gradually up to 10% duty cycle with repetition frequency of 100Hz. At the beginning, the dummy load is air- cooled 50kW CW 50Ω terminator imported from Bird Electronics in U.S.in 1986. It has been improved to add the calorimeter to measure water flowing rate and the temperature difference between the water inlet and outlet.

The RF output level is counted by two ways. One is by the high power directional coupler (~-60dB) and HP peak power meter with additional –10dB RF attenuator; another way is calculated by the calorimeter of 50Ω dummy load. They make good agreements. Figure 6 shows the output RF sample signal. The peak power level is about 487kW. The experiments up to 8% duty cycle were successfully, when RF tests of 10% duty cycle with 100Hz repetition rate was being done in last March, the dummy load was suddenly broken down. One water-cooled dummy load has been modified for the further 10% duty RF conditioning.

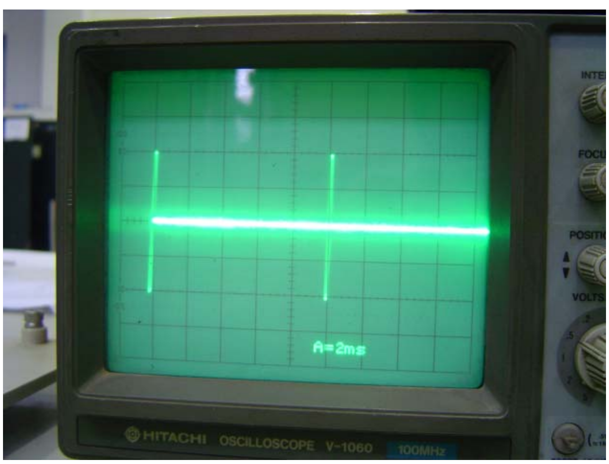

Figure 6: The output sample of 487kW RF signal with 100μs pulse duration and duty cycle 1%.

CONCLUSION

The initial RF conditioning tests of 400kW amplifier has shown design and operation at 200MHz up to 8% duty cycle with repetition frequency of 100Hz are successful. The 10% duty cycle RF test will be repeated and carried out soon through a new modified water-cooled 50Ω dummy load. The outer 80kW water-cooling system with maximum water flowing of $8m^3/h$ can fit the requirements of 400kW amplifier operation and the cooling of future RFQ accelerator cavity.

ACKNOWLEDGEMENTS

The authors would like to thank engineers in Nanjing Research Institute of Electronics Technology for their efforts. We also thank Prof. Dr. U. Ratzinger in IAP, G.Hutter, W.Vinzenz in GSI for their valuable discussions.

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