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SOLID STATE AMPLIFIERS FOR BEAM TEST SYSTEM OF PAPS AT IHEP*

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Abstract

Solid state amplifiers are being increasingly used as RF power sources in accelerators around the world. Two solid state amplifiers with different output power and frequency have been applied in beam test system of PAPS at IHEP. A 10kW solid state amplifier operating at 1.3 GHz is used to feed a normal conducting buncher. A 650 MHz solid state amplifier with the output power of 150 kW is used to feed two 2-cell superconducting cavities. So far, the debugging and acceptance test of solid state amplifiers have been finished. During the beam test system commissioning and operation, all solid state amplifiers operate stably. In this paper, the specifications and high power test results of solid state amplifiers are presented.

INTRODUCTION

The beam test system for platform of advanced photon source technology R&D (PAPS) is used to test key technologies of 650 MHz superconducting radio frequency (SRF) system, which is mainly composed of a photocathode DC-Gun, a 1.3 GHz buncher, two 650 MHz 2-cell superconducting cavities in a crymodule and a beam dump. According to the physical design requirements, the buncher and two superconducting cavities require RF power of 10kW and 150kW respectively. With the progress of transistor technology, the output power and efficiency of a single transistor has been greatly improved. The high power can be obtained by combination of numerous transistors. Up to date, the power capability of solid state amplifier (SSA) can extend from a few kW to several hundred kW, and the operating frequency from less than 100 MHz to above 1 GHz [1-6]. Compared with vacuum electronic tube, there are many advantages for SSA such as high reliability for redundancy design, high flexibility for module design, high stability, absence of warm-up time and reasonable efficiency [7]. So the SSA is a priority RF power source for beam test system of PAPS. In this paper, the specifications and high power test results of solid state amplifiers are presented.

650 MHz/150 kW SSA

The 650 MHz solid state amplifier with the output power of 150 kW is used to feed two 2-cell superconducting cavities, which is manufactured by Beijing BBEF Science & Technology Co., Ltd (BBEF) in China. It consists of a control cabinet and four power amplifier towers, as shown in Fig. 1. Each tower can produce RF power of more than 45 kW by combining 64 power modules. The single power module must include circulator and absorbing load to ensure isolation between modules and withstand the full reflection power. The status data of every power module such as voltage, current and temperature are monitored. Also, interlock is necessary for external faults like low water flow rate and over excitation. The mean time between failures (MTBF) should be larger than 20,000 hours, and less than 5% of the power modules fail per year. The failure of 2 power modules for each tower can still run. After combining the power of four power amplifier towers, the maximum power can achieve more than 150 kW. The output port is standard WR1500 waveguide. In June 2021, the acceptance test of 650 MHz SSA was completed. Figure 2 shows the relation between input power and output power. The maximum output power reach 159 kW with less than 1dB compression. The 1dB bandwidth is larger than 2 MHz and the total efficiency is about 42%. Figure 3 shows that the harmonic power is less than -50 dBc. Figure 4 indicates that the amplitude and phase stability is less than 0.2% and 0.15° respectively. The high power test results of 650 MHz SSA are summarized in Table 1. All performance indicators meet the requirement of beam test system.

Figure 1: 650 MHz/150 kW SSA.

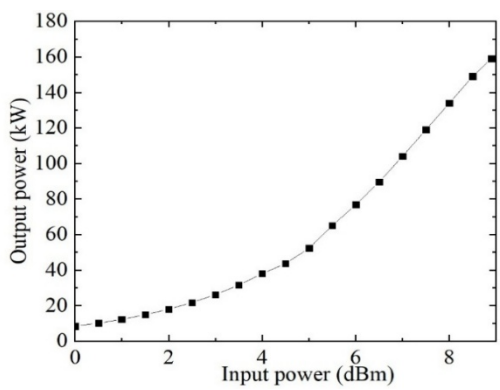

Figure 2: Transfer curve.

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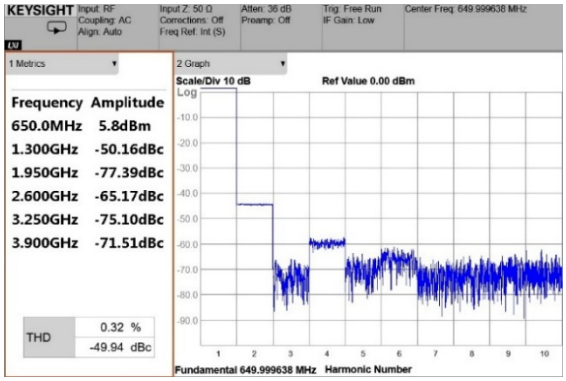

Figure 3: Harmonic test.

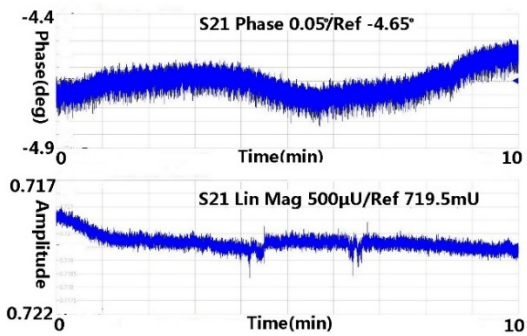

Figure 4: Amplitude and phase stability test.

Table 1: 650 MHz/150 kW SSA Test Results

Parameters	Requirements	Test
Frequency(MHz)	650	650
Output Power(kW)	≥150	159
Gain(dB)	≥70	73.1
Bandwidth(MHz)	≥ 2	≥2
Amplitude stability	≤1%	≤0.2%
Phase stability	≤1°	≤0.15°
Harmonic(dBc)	< -30	-50
Efficiency at 150 kW	≥40%	42%

1.3 GHZ/10 KW SSA

The 10kW solid state amplifier operating at 1.3 GHz is used to feed a buncher, as shown in Fig. 5, which is manufactured by Chengdu Kaiteng Sifang Digital Radio & TV Equipment Co., Ltd (KTSF). The output port is standard WR650 waveguide. The high power test results of 1.3 GHz SSA are summarized in Table 2.

Table 2: 1.3 GHz/10 kW SSA Test Results

Parameters	Requirements	Test
Frequency(GHz)	1.3	1.3
Output Power(kW)	≥10	10.1
Bandwidth(MHz)	≥ 2	≥ 2
Amplitude stability	≤1%	≤0.5%
Phase stability	≤1°	≤0.4°
Harmonic(dBc)	< -30	-53.3
Efficiency at 10 kW	≥40%	43%

Figure 5: 1.3GHz/10 kW SSA.

CONCLUSION

The solid state amplifier has been widely used in accelerators due to high reliability and easy maintenance. The debugging and high power test of two solid state amplifiers with different power and frequency have been finished. All performance indicators meet the requirement of beam test system. So far, no fault has occurred during operation.

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