X-BAND PPM KLYSTRON DEVELOPMENT FOR JLC

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Abstract

In this paper, we summarize the status of X-band PPM klystron development for the Japan Linear Collider (JLC) project. The periodic permanent magnet (PPM) klystrons are under development in the two-stage/two-year project with Toshiba. The goal is to produce 50MW output power with efficiency>50% at 1.5 μs pulse length at the first klystron and then to advance to 75MW with efficiency=55% at the second one. The first PPM klystron has been tested, and it achieved 56MW power with 50% efficiency at the standard 1.5 μs pulse length. Neither oscillation of parasitic mode nor gun oscillation was observed. The particle transmission was found to be 100% when no RF signal is applied. The second PPM klystron is currently under high-power testing. It has improved water cooling system of PPM circuit and the output cavity for 150Hz operation. The RF system was also revised for a higher efficiency. Up to date (June 6, 2001), the PPM-2 klystron produced 73.2MW at 1.4 μs pulse length and 70MW at 1.5 μs pulse length with the efficiency of 54.5%. The maximum efficiency reached 56% at the specified cathode voltage. The high-power testing will be continued to attain 75MW output power with the standard 1.5 μs pulse. Details of these developments and measurement results are presented.

1 PPM KLYSTRON

The 1-TeV JLC (Japan e^+e^- Linear Collider) project [1,2] requires about 3200 (/linac) klystrons operating at 75 MW output power with 1.5 μs pulse length. Periodic Permanent Magnet (PPM) klystrons are being developed to eliminate the expense and power requirements of the focusing solenoids. KEK has begun a two-year project with Toshiba to produce two PPM klystrons in two stages [3]. The design parameters of those klystrons are shown in Table 1. The main emphases of the KEK PPM-1 klystron are to test a new gun design and to study the design and manufacturing of the PPM circuit. The damping structure of parasitic modes was adapted by using the stainless steel beam pipes and the Monel cavities, and by tilting the output couplers slightly to break the symmetry in the output cavity to damp TE_{01} modes (see Fig. 1). The beam size is tuneable between 2.3 mm and 3.3 mm by changing a combination of the bucking coil and matching coil currents. A critical issue for klystron performance is the actual dimension of the gun at operating temperature (so-called hot dimension). The PPM-1 hot dimension was estimated by the thermal code ANSYS (see Fig. 2). An actual measurement was conducted using a anode-like test fixture and a laser beam, showing a good agreement with the ANSYS calculation within 100μm. Prototyping of the 4.5 period (13.5cm long) PPM circuit and the fabrication of this PPM circuit established the quality control method on the magnet pieces of 0.5%.

Table1: Main parameters of the KEK PPM-1 and PPM-2 klystrons.

	PPM-1	PPM-2
Peak power (MW)	>50	75
Beam voltage (kV)	480 - 500	480 - 500
Micro-perveance	0.8	0.8
Efficiency (%)	>50	55
Pulse length (μs)	1.5	1.5
Repetition rate (pps)	50	150
Bandwidth (MHz)	80 at -1 dB	80 at -1 dB
Cooling of PPM	Air	Water

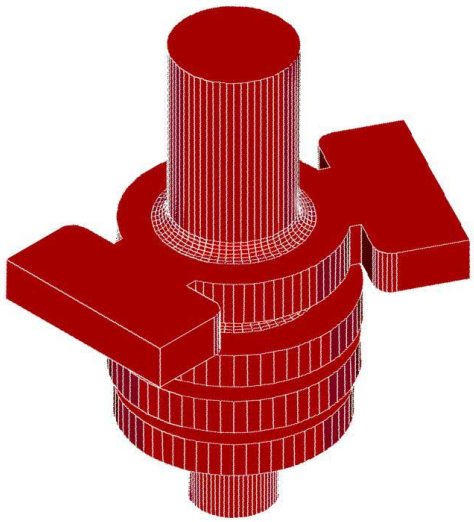

Figure 1: Tilted output couplers for damping of TE_{01} modes.

Figure 3 shows the KEK PPM-1 klystron before mounted on the test bench. The high power testing of the PPM-1 klystron was started in July 2000. Figure 4 shows the output power and the efficiency as a function of the cathode voltage. It achieved the output power of 68MW at

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514kV cathode voltage with the corresponding efficiency of 47%. It also produced 56MW power at standard 1.5 μs pulse length. Neither oscillation of parasitic mode nor gun oscillation was observed. The particle transmission was found to be 100% when no RF signal is applied. The perveance agrees well with the design value within 1.5 %. The temperature rise of about 5 degrees at the output cavity suggests that the repetition rate up to 25Hz is operational even with the present insufficient cooling system.

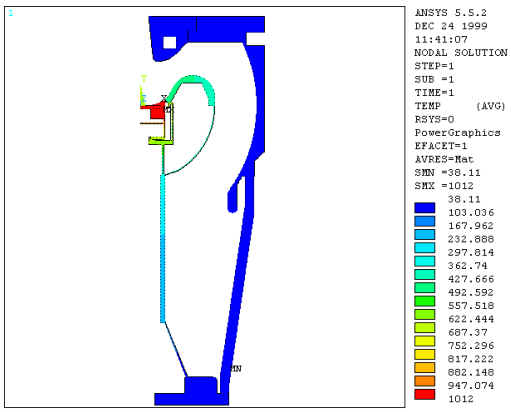

Figure 2: The thermal calculation of KEK PPM-1 gun by ANSYS.

Figure 3: Photo of KEK PPM-1 klystron

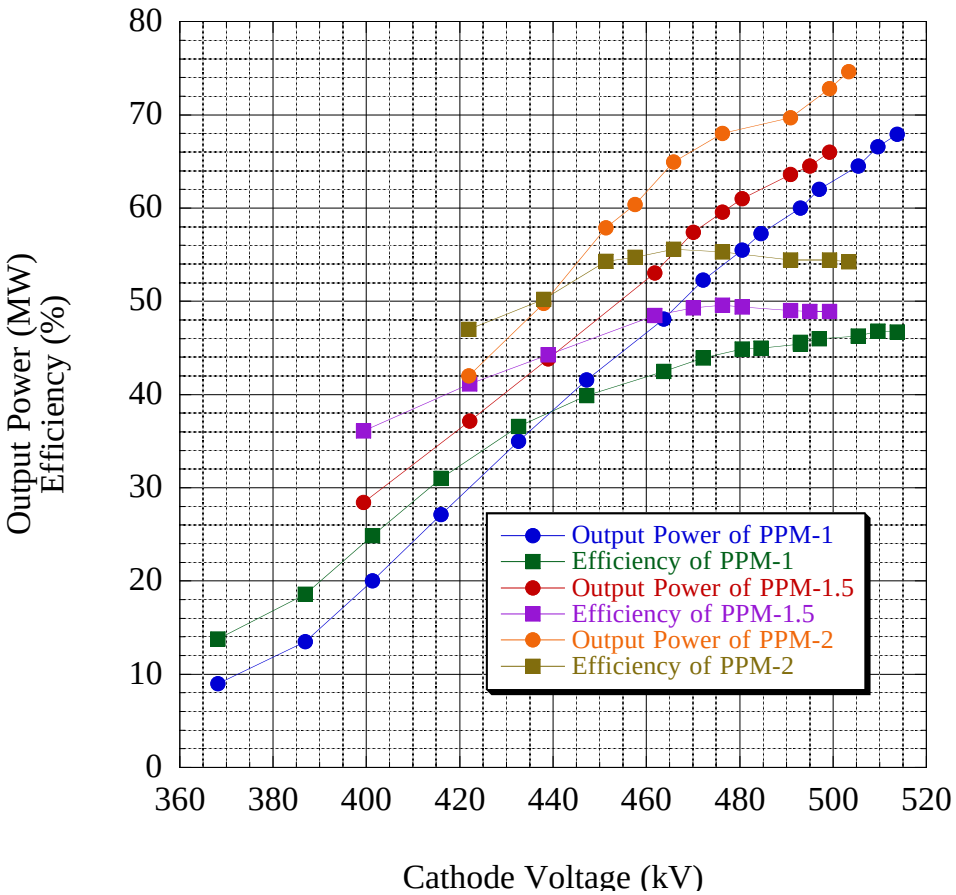

Figure 4: Output power and efficiencyvs. cathodevoltage at PPM-1, PPM-1.5 and PPM-2 klystrons

The gain cavities were mistakenly fabricated at wrong frequencies by the manufacture. It was expected to cost 2-3% on the efficiency. PPM-1 klystron was sent back to the manufacture to apply the following corrections; (1) replacement of the gain cavities by the ones with correct frequencies (2) fine tuning of the output cavity fundamental frequency to a value closer to the design (3) replacement of the RF windows by the more robust Kazakov windows for a better high-power capability. PPM-1 was returned to KEK as PPM-1.5 and testing was resumed from February 2001 and is still under way. Now, the efficiency was increased to nearly 50% at 470-500kV region as shown in Fig.4. The performances of PPM-1 and PPM-1.5 are tabulated in Table 2.

Table 2: Performances of the PPM-1 and PPM-1.5 klystrons.

	PPM-1	PPM-1.5
Peak power tested (MW)	68	67.5
Efficiency (%)	47%	49.6
Pulse length (μs)	1.5 (at 56MW)	
Micro-perveance	0.79	
Repetition rate (pps)	5 (25Hz possible)	

The second PPM klystron has been delivered and is now under high-power testing. This klystron incorporates experience and knowledge gained from the design and testing of PPM-1. The main emphases of the PPM-2 klystron are full satisfaction of JLC specifications and refinement of the design and manufacturing process for future mass production. To meet these goals, the PPM-2 introduced the water-cooling system of the PPM klystron body and the PPM circuit. At the same time, the water-cooling system of the output cavity was improved for a higher repetition rate. Some revisions of resonant frequency of the penultimate cavity and design of the output coupler were also applied for a higher efficiency. Up to date (June 6,2001), the klystron already produced 73.2MW at 500 kV at the 1.4 μs pulse length. Oscilloscope traces are shown in Fig. 5. At 70MW, the standard 1.5 μs pulse was attained with the efficiency of 55%. The maximum efficiency reached 56% at the specified cathode voltage. The performance of PPM-2 klystron up to date is tabulated in Table 3. The high-power testing will be continued to attain 75MW output power with the standard 1.5 μs pulse.

Following the success of those two klystrons, the development plan is now expanded to the coming two years. In FY 2001, we are going to build the PPM-3 klystron; this klystron has an even higher efficiency of 60% by installing two 2nd-harmonic cavities to increase the beam bunching. A small revision of the output cavity shape realises a lower (70MV/m) surface electric field there for an improved reliability. The PPM-4 klystron to be built in FY 2002 is a mass production version. For this end, the design of a clamp-on magnet system is under way.

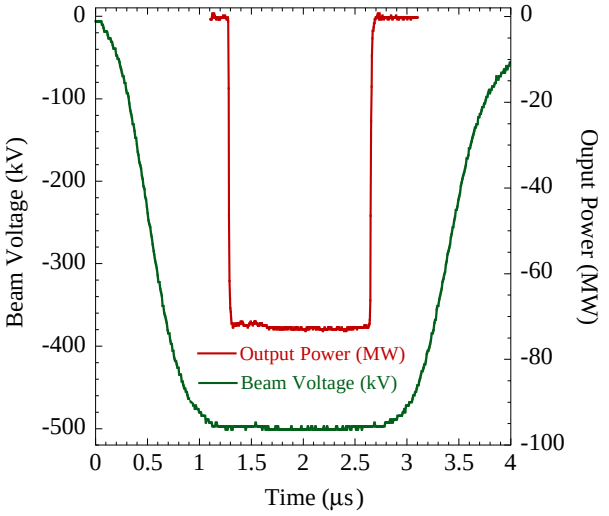

Figure 5: Oscilloscope traces of the output power and beam voltage of PPM-2 klystron for 73.2MW output power at the 1.4 μs pulse length with 54% efficiency.

Table 3: Latest measurement results of performance of the PPM-2 klystron (June 6, 2001)

	Design	Achieved
Peak power (MW)	75	75.1
Efficiency (%)	55	56
Pulse length (μs)	1.5	1.5 (@70MW)
		1.4 (@73.2MW)
Micro-perveance	0.8	0.79
Repetition rate (pps)	150	25

REFERENCES

[1] "JLC Design Report Study", KEK Report 97-1, 1997.
[2] "International Study Group Progress Report on Linear Collider Development", KEK Report 2000-7, SLAC R-559, 2000.
[3] Y. H. Chin et. al., "Development of the X-Band RF Power Source for JLC", in Proc. of PAC99, 1999, p.3414.