DEVELOPMENT OF THE X-BAND RF POWER SOURCE FOR JLC

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Abstract

In this paper, we summarize our activities on X-band RF power source development for the Japan Linear Collider (JLC) project. First, we have designed and tested a solenoid-focused klystron at 11.424 GHz with a pulse length of 1.5 µs and with an efficiency of 47%. A periodic permanent magnet (PPM) klystron, the first in that kind at KEK, is also under development. In parallel to this activity, another PPM klystron has been developed and remodeled in collaboration with BINP. Second, a new RF window with 100-MW power-handling capability has been designed and tested. It utilizes the TW mixed mode (TE11 and TM11 modes) to reduce the surface field at the brazing edge of the ceramic. The cold model test shows a low electric field at the brazing point as predicted by HFSS calculations. The high power model is now in manufacturing and the testing will start soon. Third, the Blumlein modulator was upgraded to produce a pulse with 2 µs flat top and 200 ns rise time at 550 kV output voltage. Fourth, the multi-mode 2x2 DLDS (Delay Line Distribution System) pulse compression system has been designed, and its basic unit was manufactured and tested for proof of the principle. The measurement results show that the system works well with a high power distribution efficiency. The so-called mode stability experiment is also under preparation in the ATF linac tunnel in collaboration with SLAC. This experiment is aimed for examination of the stability of linearly polarized TE12 mode in a 55m long waveguide, a key issue in the present configuration of multi-mode DLDS. Details of these developments and measurement results are presented.

1 KLYSTRON

The 1-TeV JLC (Japan e^+e^- Linear Collider) project[1] requires about 3200 (/linac) klystrons operating at 75 MW output power with 1.5 µs pulse length. The main parameters of solenoid-focused klystron are tabulated in the second column of Table 1. The 120 MW-class X-band klystron program at KEK[2], originally designed for 80 MW peak power at 800 ns pulse length, has already produced 9 klystrons with solenoidal focusing system. To reduce the maximum surface field in the output cavity, the traveling-wave (TW) multi-cell structure has been adopted since the XB72K No.6. Four TW klystrons have been built and tested. All of them share the same gun (1.2 microperveance and the beam area convergence of 110:1)

Table 1: Specifications of X-band solenoid-focused and PPM-focused klystrons for JLC.

	XB72K	PPM
Operating frequency (GHz)	11.424	11.424
RF pulse length (µs)	≥ 1.5	≥ 1.5
Peak output power (MW)	75	75
Repetition rate (pps)	120	120
RF efficiency (%)	47	60
Band-width (MHz)	100	120
Beam voltage (kV)	550	480
Perveance (x10^{-6})	1.2	0.8
Maximum focusing field (kG)	6.5	
Gain (dB)	53-56	53-56

and the buncher (one input, two gain and one bunching cavities).Only the output structures have been redesigned each time. XB72K No.8 (5 cell TW) attained a power of 55 MW at 500 ns, but the efficiency is only 22%. XB72K No. 9 (4 cell TW) produced 72 MW at 520 kV for a short pulse of 200 ns so far. The efficiency is increased to 31%. The limitation in the pulse length attributes a poor conditioning of the klystron.

The latest tube, XB72K No.10, was designed at KEK, and has been build in Toshiba. The testing started from January 1999. It produces 29MW power at 379kV at 1.5 µs pulse length, 16% larger than the prediction. The output RF signal is shown in Fig. 1.

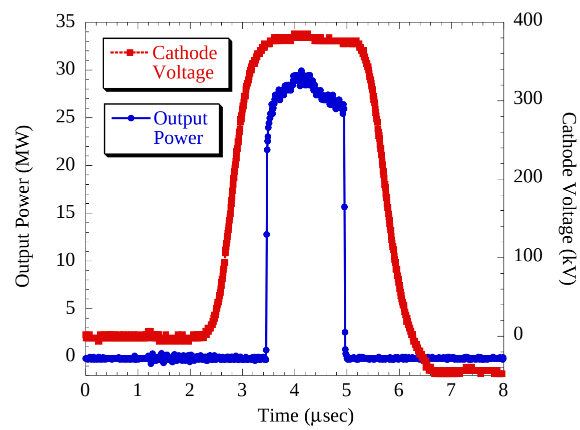

Figure 1: Output power and cathode voltage signals from XB72K No.10.

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At the beam voltage over 380kV and without input power, the oscillation signal is observed at 20.7 GHz in the spectra of the output RF signal and the signal reflected from the input. When the input power is increased, the oscillation signal disappears up to the cathode voltage of 390kV. The slight increase of the magnetic field down the drift space changes the signal frequency to 20.7 GHz. The measured perveance was found to be 20% larger (about 1.4μ) than the design value. It turned out that the manufactured gun has a wrong dimension, with no effects of the thermal expansion taken into account. The cathode and the wehnelt are closer to the anode by 1-2mm than the design, and their radial sizes are larger by 0.5-1 mm. As the result, the emitted beam has a 15% larger beam size than the design value, and has a large scalloping due to the mismatch with the focusing field. The fatter beam increases the coupling with the cavities: the measured gain is about 8 times larger than the design value. The analysis shows that the large scalloping pronounces the driving power to the parasitic modes in the range of 21 GHz. Further analysis and measurements are in progress.

Apart from the solenoid-focused XB72K series, KEK has also started a PPM (periodic permanent magnet) klystron development program. The design parameters are shown in the last column of Table 1. Its goal is to produce a 75MW PPM klystron with an efficiency of 60 % at 1.5 μs or longer pulse. The first PPM klystron was designed and built by BINP in the collaboration with KEK. It achieved 77 MW at 100 ns, but there is a clear sign of RF instability at higher frequencies (17GHz, 19.5GHz, and 21.2GHz). The DC current monitor in the collector shows about 30 % loss of particle when RF is on. The remodeling of the BINP PPM klystron has been made: the new buncher produces the RF current of 1.62. The inner walls of the output cavity and every tube between the cavities are brazed to stain-less steel to dampen trapped oscillations. The small solenoid magnet to control the focusing field to stop the particle interception replaces the periodic permanent magnet at the output cavity. The testing of the rebuild PPM klystron will start from fall of 1999.

2. RF WINDOW

All the windows with traveling waves (TW) in the dielectric use only one-mode. Namely, RF energy is carried by only one mode - either TE11, or TE01. The idea exploited in the development of a new window is to arrange the combination of space harmonics on the dielectric surface so that the electric field strength value almost vanishes at the brazing area. At the same time, the mode propagation regime in the dielectric is maintained to be close to that of pure traveling waves. Based on this idea, the windows for 11424 MHz have been developed with the dielectric 53 and 64 mm in diameter [3]. The permittivity was assumed to be equal to 9.8, i.e. that of Al_2O_3 ceramics. The dielectric thickness was chosen to be close to 1/4-wavelength to ensure the maximum bandwidth and the maximum tuning away of the operating frequency from the "ghost" modes. With the diameter 53 mm, the dielectric thickness becomes 2 mm, whereas it is 2.15 mm for 64 mm. All the computations were done using HFSS 4.0 code. The shapes of the window with 53 mm diameter is illustrated in Fig. 2.

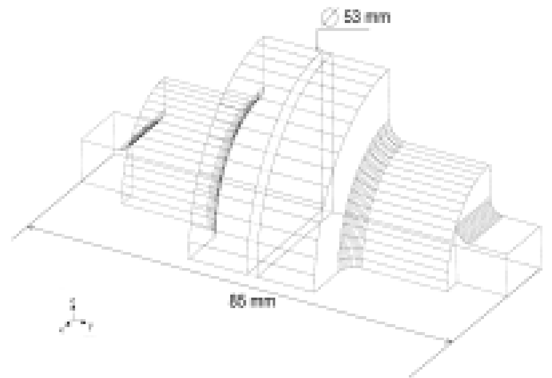


Figure 2: Shape of the TE11+TM11 mixed-mode type window with 53mm diameter.

Figure 3 shows the measurement results of ratio of electric field at the brazing point to that at the ceramic center for TE11+TM11 mixed-mode type window. The electric field decreases toward the ceramic surface as designed. The closest distance was limited by the finite size of the used bead. The high power model is now in manufacturing and the testing will start in summer 1999.

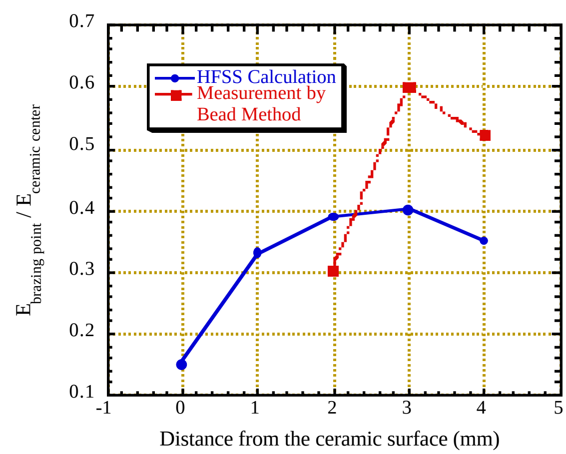


Figure 3: Measurement results of ratio of electric field at the brazing point to that at the ceramic center for TE11+TM11 mixed-mode type window with 53mm diameter.

3 DLDS PULSE COMPRESSION

The Delay Line Distribution System (DLDS) was invented by KEK for the compression and distribution of the RF power from klystrons to RF structures. In DLDS, the long pulse of combined klystron output is subdivided into a train of shorter pulses and each subpulse is delivered to accelerating structures through a delay line distribution system. This system utilises the delay of the electron beam in the accelerator structure of the linear collider to reduce the length of the waveguide assembly. A conceptual improvement is proposed by SLAC to further reduce the length of waveguide system by multiplexing several low-loss RF modes in a same waveguide. Thus, the subpulse in the distribution waveguide is carried by different waveguide modes so that they can be extracted at designated locations according to their mode patterns. Based on the SLAC multi-mode DLDS, a 2×2 DLDS [4] is proposed at KEK for JLC. The advantage of 2×2 DLDS is that it's simple and easy to be expended to accommodate combinations of more klystrons, and also it has good transmission efficiency.

A test unit is proposed and studied to verify the principle of multi-mode 2×2 DLDS[5]. It includes the TE01-TE11 mode launcher, the TE01 extractor and the TE11 to TE01 converter. Fig. 5 is the schematic layout of the unit.

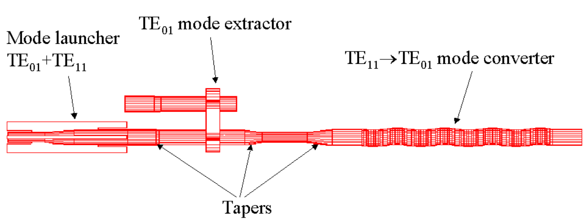
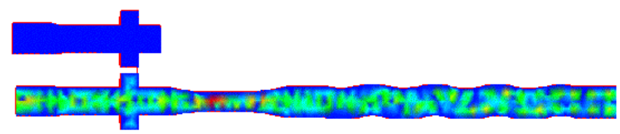


Figure 4: Schematic layout of the basic 2×2 DLDS unit.

Fig. 4 shows the electric filed pattern propagating in the system. The power of TE01 mode is extracted to a parallel waveguide with efficiency better than 96% as shown in Fig. 4(a), while the power of TE01 mode goes through the extractor directly and then is converted to again to TE01 as shown in Fig. 4(b). The transmission efficiency is better than 95%. All the above components have been manufactured. The low power test has been conducted. Figure 6 shows the measurement of azimuthal angle (along the circular waveguide) dependence of TE11 mode from the mode launcher. It has an almost pure sinusoidal shape of TE11 mode as designed.

In order to reduce the resistive loss in long distance transmission, the low loss TE12 mode is considered in the circular waveguide. The experiment to test the stability of TE12 mode propagating for long distance i.e. its sensitivity to all kinds of perturbations is being planed at the ATF tunnel as the joint activity between KEK and SLAC. The main purpose is to measure the purity of linearly polarized TE12 mode (largeness of rotation and conversion to other modes) in a 55m long waveguide whose diameter is 4.75 inches. To detect the change in the phase advances due to thermal expansion of waveguide, a special phase reference system has been designed and is being manufactured. The experiment is scheduled to be conducted in summer 1999

(a) TE_{01} mode input from left.



(b) TE_{11} mode input from left.

Figure 5: Electrical field patterns in the test unit.

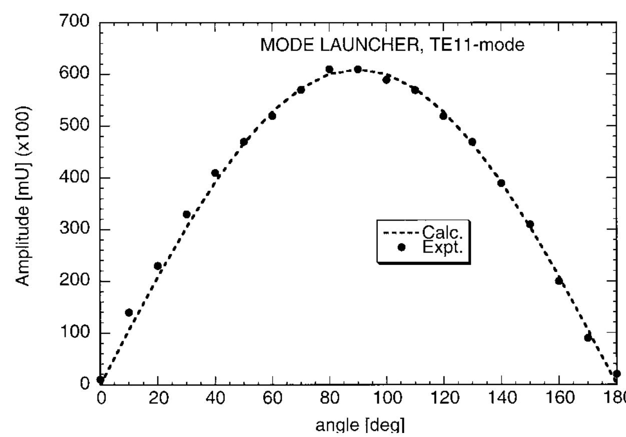


Figure 6: Measured azimuthal angle dependence of TE11 mode from the mode launcher.

4 REFERENCES

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