THE EXPERIENCES OF OPERATION AND PERFORMANCE OF THE 500 MHZ CW KLYSTRONS AT THE PLS STORAGE RING

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Abstract

There are four RF stations to supply the energy to electron at the storage ring of the Pohang Light Source(PLS). From the beginning of the operation of RF system, 500 MHz 60 kW(CW) klystrons have been operated. As the operation time of the tubes is increased, their performances are decreased. Therefore, four 60 kW tubes were replaced with the same model and two 75 kW klystrons were installed instead of 60 kW klystrons so far. Nowadays two 75 kW and two 60 kW klystrons are operated in the RF system of PLS. Our experiences of the klystron operation and their general performance are described in this paper.

INTRODUCTION

The Pohang Light Source (PLS) is a 2.0 to 2.5 GeV, third generation synchrotron radiation source, which has a full energy linac and a storage ring. The storage ring RF system should provide enough energy for compensating synchrotron radiation loss and the beam loading.

We chose the commercial klystron amplifier of broadcast application as a power source in 1991. This is using YK 1265 klystron made by Phillips company. YK1265 has the external four cavities. The tube is electromagnetically focused and the circuit assembly is designed to reduce tube replacement time to a minimum. The cavities can be detached from the vacuum tube and refitted on a replacement without disturbing the tuning, so that the replacement klystron is coarse tuned at switch-on and requires only loading loop setting adjustments to meet the full transmission specification. The first klystron amplifier was tested at factory and our test lab in 1992. Then it was moved into SR RF station. At the beginning of the SR operation, three klystron amplifiers were installed and operated. The total RF capacity could afford to store the beam current up to 300 mA with 1.2 MV of the accelerating voltage at 2.0 GeV.

In 1996, one homemade klystron amplifier system was added. Therefore, total RF power of 240 kW can provide enough power to store up to 400 mA with 1.6 MV of the accelerating voltage at 2.0 GeV and 200 mA at 2.5 GeV. [1]

CONFIGURATION

Nowadays two 75 kW and two 60 kW klystrons are operating in the RF system of PLS. Table 1. shows characteristics of the 60 kW and 75 kW klystron comparison.

Table 1. Klystron comparison

Maker		Philips	E2V
Model		YK1265	K3773
Frequency	MHz	500	500
Max. Power	kW	60	76
Cavities	EA	4, External	4, External
Beam Voltage	kV	25.5	27.7
Beam Current	A	5.7	6.2
Collector Dissipation	kW	145	161
Gain	dB	35	35
Efficiency	%	41.4	47.3

Both 60 kW and 75 kW klystrons have four cavities. Each cavity is tuned respectively.
Input cavity : 500 MHz + 1 MHz
Second cavity: 500 MHz – 1 MHz
Third cavity: 500 MHz + 10 MHz
Output cavity : 500 MHz
Fig 1. shows the klystron tuning characteristic curve.

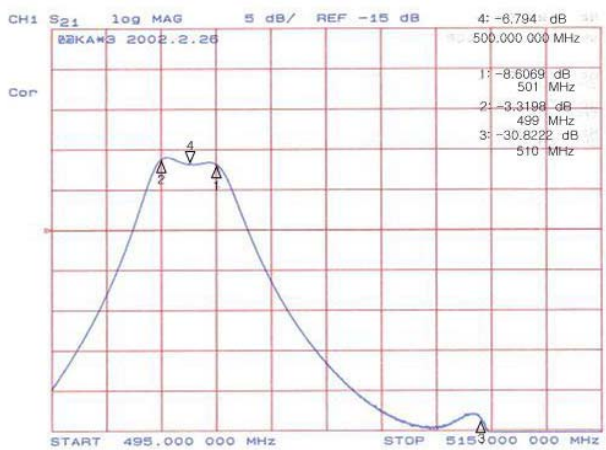

Figure 1. Klystron tuning characteristic curve

Adjusting of the output coupling loop is as shown in Fig 2.[2] The output coupling loop should be operated in overcoupled region. If this is operated in the undercoupled region, RF arcing in the cavities may be occurred. In addition, body current will increase. Therefore, klystron tube may be dangerous.

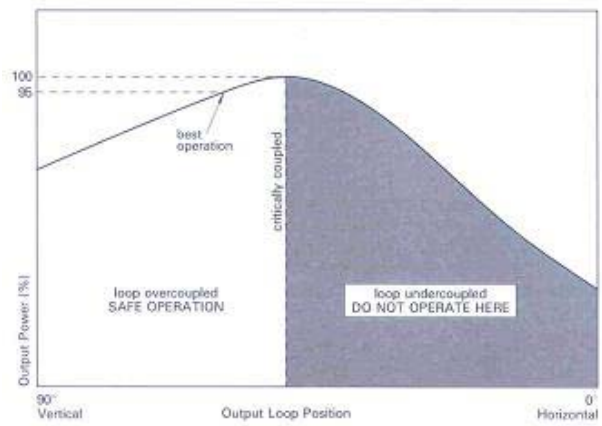

Figure 2. Adjustment of output coupling loop

To protect the klystron, the klystron circuit assembly has a focus field switch, a feeder interlock switch, an air pressure switch, two arc detectors and two cavities high temperature switches. The arc detector and the cavity high temperature switches are installed in the third cavity and output cavity. The cavity high temperature switches work above 90o C. Also logic and control part of the amplifier controls body current high, beam current high, reflected RF power high, collect water flow rate low, and so on to protect the klystron.

OPERATION AND PROBLEM

Four klystron amplifiers were operated between 20 kW and 50 kW level during normal operation at 2.5 GeV of 180 mA. So far, four 60 kW Philips YK1265 klystron tube are replaced after about average 32,000 hours lifetime for the high power RF system. Table 2. shows the status of replaced YK1265.

Table 2. The status of replaced YK1265

Serial Number	Operating hours(H)	Output (Max, kW)	Micro perveance
34803.265	33,568	43	1.35
35102.265	28,467	45	1.24
44602.265	20,257	45	1.31
05214.265	45,701	45	1.56

Klystron performances have been slightly decreasing after about 10,000 hours operation. Therefore, the micro-perveance was decreased from 2.0 to 1.2. That means the available maximum RF power was decreased from 60 kW to about 45 kW. The decrease of micro perveance compensated by an increase of the mod. anode voltage so that the beam current is hold constant. At the near end of life conditions, heater voltage was increased gradually from 7.8V to 8.3V.

To get longer lifetime, we should do a careful and reasonable method of tube operation. Barium is almost indispensable on the cathode surface to get electron emission in electron tubes. It also contributes to keeping a tube in good vacuum as a getter material. Too much barium is, however, very harmful to the tube performance.[3] In order to reduce excess barium, low voltage operation without beam should be avoided if possible. Tube maker recommend that continuous periods of black heat operation should not exceed two weeks and duration of full heat operation should not exceed 30 minute.[4]

We had the two experiences of tube problems in 2001. Tube maker Philips stopped to produce a klystron. Therefore, we purchased two K3672 as same electrical and physical specification of YK1265 for spare tube. When first K3672 tube installed, beam voltage test was successful. However, during RF adjusting, the second ceramic window of first klystron was cracked. In case of second klystron, the output ceramic window of second tube was cracked after about 1000 hours operation. They were in warranty. The reason of tube fault was not cleared. During operation, excess heat was generated inside of output cavity. The rotating joint of output coupler was melted and we couldn't adjust the loop of output coupler. The melting part was manufactured to have better RF contact and replaced. Fig 3. shows the structure of output coupler.

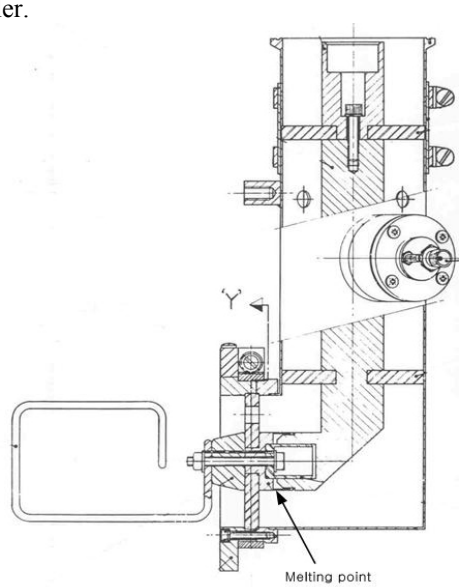

Figure 3. The structure of output coupler

In every summer shutdown, we checked klystron tuning status. Sometimes we found the tuning curve is distorted like as Fig 4. We assume that this reason is affected by a heat during long operation. We retuned to get the correct tuning characteristic like as Fig 1.

As operation hours were increased, microperveance was decreased. The body current was increased and the temperature of the cavity went to temperature high interlock level. The emitted electron from cathode hit the tube wall. To overcome this phenomenon, we retuned klystron cavity, output coupler and focus current. After retuning the operation factor of the klystron was normal.

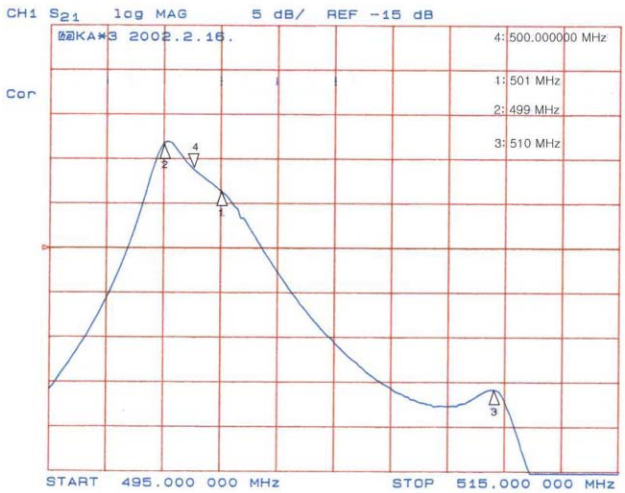

Figure 4. The distorted tuning curve

Another problem was RF arcing. The YK1265 circuit assembly has two arc detectors to detect arc inside of the cavity. Although the output coupler angle set in right position, RF arc occurred frequently. We found that the reason was non-symmetrical cavity structure. The external cavity can be separated by two parts. When we tune the cavity, we adjust only the volume of front cavity but the volume of rear cavity is fixed. This cause symmetrical structure to break. We adjusted to have same volume of both part of cavity. A feature of the cavity design of K3773 is that tuning of both halves of each cavity is by means of a single knob simultaneously.

According to high power RF system upgrade schedule, we are undertaking replacement 60 kW klystron with 75 kW.[1] Already we replaced two 60 kW klystrons with 75 kW klystrons. 75kW klystron has X-ray shielding in the first and second cavity for health. For installation 75 kW klystron we modified such as additional cooling, coaxial lines, and adjusting of the electrical specification. First 75 kW klystron was installed at homemade amplifier KA#1 successfully in 2002. Through same procedure for installation, second K3773 was installed at KA#2. But we found the sideband near center frequency. After examining several operating factor we found the sideband frequency generation was depend on the angle of the output coupler. The loop angle is 41° in safe region that the sideband frequency is not occurred and as the loop angle goes toward zero direction the more sideband frequency is occurred. This means that the loop of output coupler should be in overcoupled region. Fig 5. and Fig 6. show the RF spectrum with sideband and without sideband.

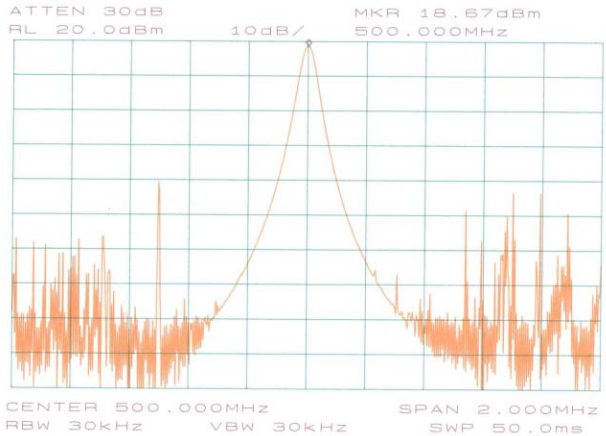

Figure 5. RF spectrum with sideband

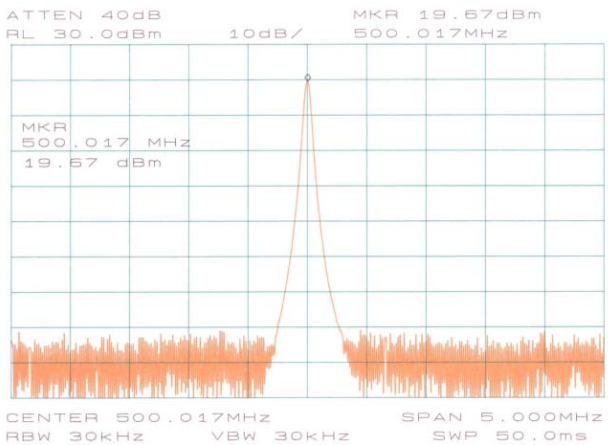

Figure 6. RF spectrum without sideband

SUMMARY

The experiences of operation and performance about 60 kW and 75 kW klystron are introduced. We will replace remaining two 60 kW klystrons with 75 kW klystrons in this summer shutdown. Also we will prepare the fifth klystron amplifier in home made. Although we will have more machines, we expect to operate them stable with many experiences.

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[2] Marconi Applied Technologies, "Assembly Manual MA2174A for klystron amplifier tubes K3573BCD,K3673BCD, K3773BCD in circuit assembly K4653 or K3773BCD"

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