Performance Test of a 65-MW Klystron Unit Relevant to the Microwave Source Upgrade of the KEK 2.5-GeV Linac

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Abstract

There is a plan to upgrade the KEK 2.5-GeV linac regarding its microwave source, which is relevant to both the asymmetric B-factory two-ring collider project and 3-GeV operation of the Photon Factory (PF) storage ring. The required increase in the injection linac energy from the present 2.5 to 4.25 GeV (3 GeV for PF) necessitates the replacement of the existing 30-MW klystrons with new 65-MW units. Since a total modification of the klystron modulator would cost too much, the output voltage and average power of the modulator have remained unchanged. Consequently, an increase in the klystron beam voltage could only be obtained by increasing the pulse transformer step-up ratio from the present 1:12 to 1:15. A new test station using a 65-MW klystron was established in order to confirm a stable operation of the modified unit. An output power of 58 MW with a 1μs duration was successfully generated in a preliminary test.

I. INTRODUCTION

As phase-III of the TRISTAN project, an asymmetric B-factory two-ring collider is being considered [1]. The required beam energy and design luminosity are 8×3.5 GeV^2 and 1×10^{34} /cm^2/sec from physics experiments. The two existing injectors for the TRISTAN main ring, the KEK 2.5-GeV linac [2] and the accumulation ring (AR), are also to be used for the injectors of the new B-factory rings. Since the required injection energy of positron and electron beams for the B-factory are 3.5 and 2.5 GeV, respectively, the energy of the linac should be increased from the present 2.5 to 3.5 GeV.

An energy upgrade of the linac is also required from the PF storage ring. The increase of the ring operation energy from the present 2.5 to 3.0 GeV would provide hard X-ray users with a great number of advantages: a photon flux in the 20 ~ 40 keV region, which is difficult to produce by the usual type X-ray source, except for a synchrotron radiation source, becomes brighter by more than 10 times.

In order to meet the demands (see Table 1) from both the B-factory project and PF 3-GeV operation, a study group of the linac upgrade was organized in June of 1989 and has put forward several linac upgrade designs [3]. Since the injection energy and charge accumulation rate for the PF 3-GeV operation are not severe, compared with those for the B-factory project, we mainly considered the requirements regarding the B-factory project.

The following plans were tentatively adopted: I) In order to increase the positron intensity (1) positron beams with pulse widths longer than 50 ns are accelerated; (2) the location of the positron production target is to be moved from the present 250-MeV down to the 750-MeV point of the linac, since the positron production efficiency is proportional to the injection energy of the primary electron beams, and (3) the positron capture efficiency is improved by enlarging the acceptance of the positron focusing system. II) In order to increase the energy of the linac to 4.25 GeV (750-MeV primary electron beams + 3.5-GeV positron beams) an upgrade of the microwave source is planned by replacing the present 30-MW klystrons with 65-MW high power klystrons. The resultant accelerating gradient is 14.4 MV/m (see Fig. 1), which is sufficient for a linac with a total accelerating structure length of 300 m.

This paper describes the upgrading of the microwave source as well as performance tests of a test station which was established in order to confirm the feasibility of this upgrade.

Table 1
Present status of the linac and requirements from the B-factory project and PF 3-GeV operation.

	percent			B-factory		PF 3-GeV
	for AR		for PF	for AR		for PF
	e$^-$ 2ns	e$^+$ 2ns	e$^+$ 40ns	e$^-$	e$^+$	e$^+$
Energy (GeV)	2.5	2.5	2.5	2.5	3.5	3.0
Charge accumulation rate (× 10^{-8} C/min)	22.5	1.5	12	30 (75)	25 (75)	25
Pulse width (ns)	1	1	40	50	50	50
Peak current (mA)	150	10	2	2 (5)	1.6 (5)	1.6
Pulse repetition rate (pps)	25	25	25	50	50	50
Energy spread (%)	0.5	0.5	~1	~1	~1	~1

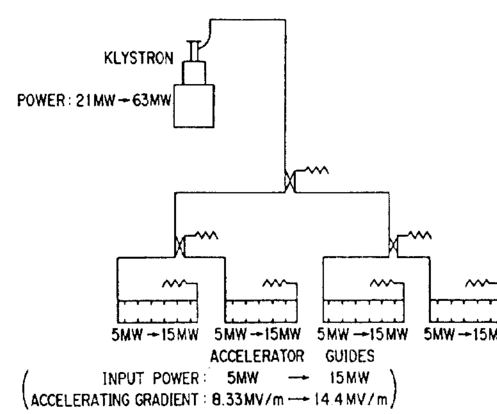

Figure 1. Upgrade scheme of the power feed system to an acceleration unit.

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II. MICROWAVE SOURCE UPGRADE

A. Klystron

Although, klystron E-3712 of Toshiba Corp. has successfully produced a power output of 100 MW [4], we are planning to introduce 65-MW klystrons (e.g. SLAC 5045-type klystron [5]) because of the large reservoir of practical experience from the SLC operation. Table 2 shows the specifications of the original and upgraded klystrons.

Table 2
Comparison of the original and upgraded klystron specifications

	Original	Upgraded
Model designation	Mitsubishi PV-3030	unspecified
PF peak output power (MW)	30	65
Beam voltage (kV)	270	350
RF pulse width (μs)	3.5	2.2
Repetition rates (pps)	50	50
RF gain (dB)	51	50
Micro-perveance	2	2
Efficiency (%)	40	45

B. Klystron Modulator

A doubling of the klystron output power requires a modification of the klystron modulator system. In order to reduce costs of the modulator modification, the output voltage and average power of the upgraded modulator have remained unchanged. An 80-kV increase in the klystron beam voltage is compensated by increasing the pulse transformer step-up ratio from the present 1:12 to 1:15. Accordingly, our new modulator is required to generate pulses with a 23.5-kV peak voltage, 6150-A peak current and 145-MW peak power. Since the output impedance of the pulse-forming network (PFN) has been reduced from the original 6.0 to 3.6 Ω, the pulse width has also been reduced from 3.5 to 2.2 μs. A significant increase in the PFN discharge current is compensated for by using two PFN capacitors in parallel. Figure 2 shows a simplified diagram of the upgraded modulator. Specifications of both the original [6] and upgraded modulators are also shown in Table 3.

Table 3
Comparison of the original and upgraded modulator specifications

	Original	Upgraded
Maximum peak power (MW)	84	145
Maximum average power (kW)	14.7	14.7
Transformer step-up ratio	1:12	1:15
Output pulse voltage (kV)	23.5	23.5
Output pulse current (A)	3600	6150
PFN impedance (Ω)	6.0	3.6
PFN total capacitance (μF)	0.3	0.3
Pulse width (μs)	3.5	2.2
Rise time (μs)	0.7	0.8
Fall time (μs)	1.2	1.5
Pulse repetition rate (pps)	50	50
Maximum pulse height deviation from flatness (%)	0.3 (peak to peak)	0.5
Maximum pulse amplitude drift (%/hour)	0.3	0.5
Thyratron anode voltage (kV)	47	47

III. PERFORMANCE TESTS AT TEST STATION

A. Test Station

In order to confirm the above-mentioned modifications, a test station using a 5045-type klystron was established. This klystron has been delivered from SLAC under the US-Japan collaboration program. Figure 3 shows the new test station of a 5045 klystron and tank assemblies. The PFN unit of a 30-MW klystron test station has changed to a new design which meets the demands from the 5045-type klystron. Since we only have one klystron test station and we must prepare at least one 30-MW klystron unit per month for our linac operation, the 5045-type klystron was set 15 m apart from the modulator in order not to interfere too much with tests of the usual 30-MW klystron unit. The 5045-type klystron unit was connected with the modified klystron modulator using 12 coaxial cables (each cable is 50 Ω and 20 mm in diameter) in parallel in order to ensure impedance matching.

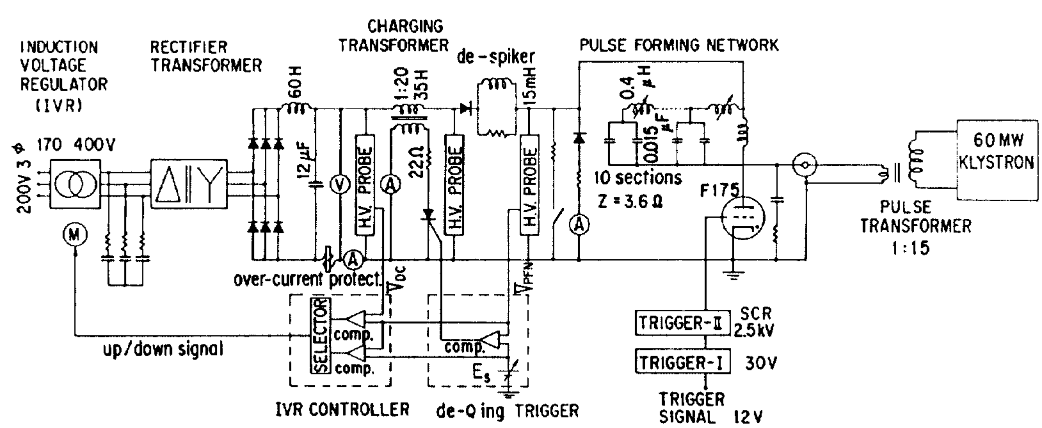

Figure 2. Simplified diagram of the upgraded modulator.

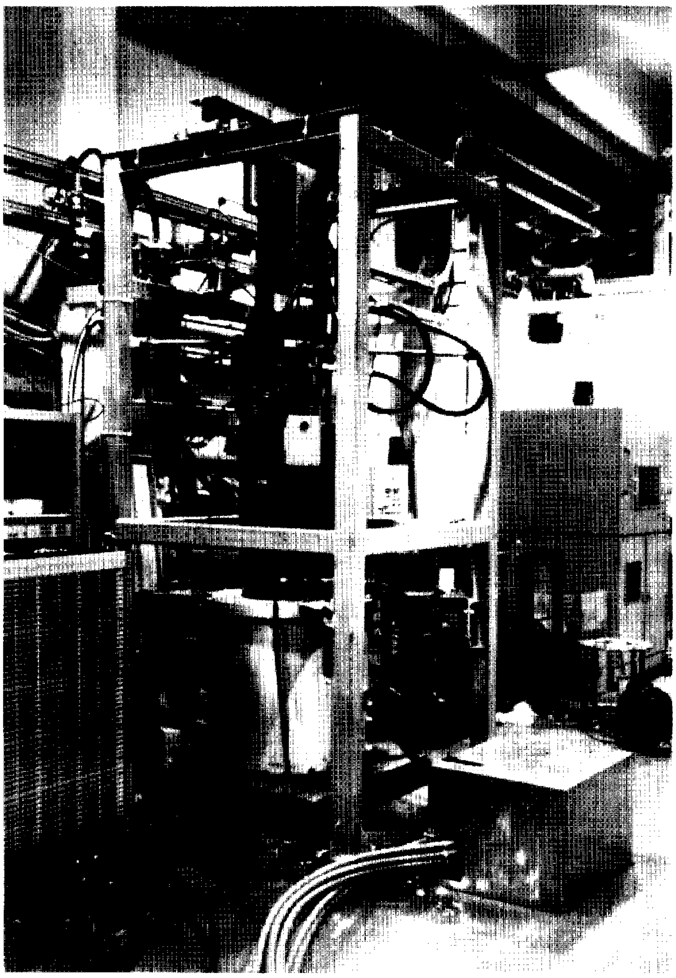

Figure 3. 5045 klystron and tank assemblies set at a new test station.

B. Performance Tests

High-power tests of this test station were performed. Figure 4 shows the beam current and power output versus the beam voltage of the 5045 klystron unit. An output power of 58 MW with a 1 μs duration was successfully generated at a 345-kV peak voltage and 380-A peak current. Figure 5 shows the output pulse voltage (peak 345 kV) and power output (peak 58 MW) waveforms. The rather long pulse rise time may be caused by the use of 15 m long coaxial cables. We are now planning to install at least one 65-MW klystron unit in our 2.5-GeV linac klystron gallery in order to confirm the long-term stability of this unit as well as the modified klystron modulator.

IV. ACKNOWLEDGEMENTS

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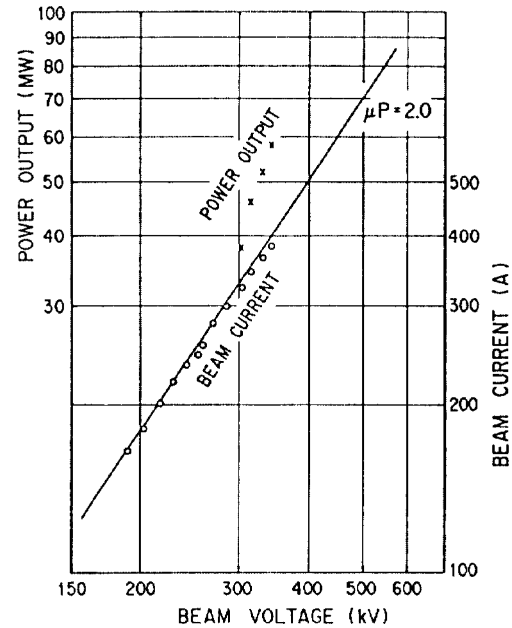

Figure 4. Beam current and power output versus the beam voltage.

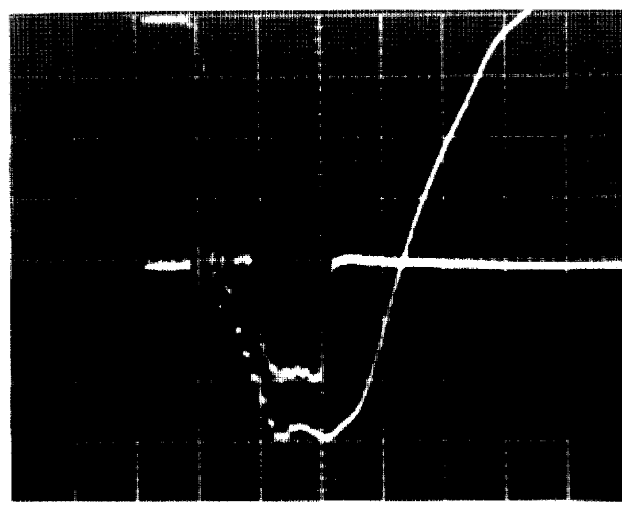

Figure 6. Output pulse voltage (upper; vert. 50 kV/div., hor. 1 μs/div.) and power output waveforms (lower; vert. 10 mV/div.)

V. REFERENCES

[1] ed. by H. Ozaki and Y. Yoshimura, "Feasibility Study for an Asymmetric B-factory at KEK", KEK-Report-90-7, June 1990.

[2] J. Tanaka, "Construction of the Photon Factory 2.5 GeV Injector Linac", Nucle. Instr. Meth., 177, pp.101, 1980.

[3] A. Asami et al., "Linac Upgrade", *Proc, of the Workshop on Asymmetric B Factory at KEK*, KEK-Report-89-17, pp.252, 1989.

[4] H. Yonezawa et al., "Development of a 100 MW S-band Pulse Klystron", Particle Accelerators, 30, pp.219-224, 1990.

[5] T. G. Lee et al., "A 50-megawatt Klystron for the Stanford Linear Collider", SLAC-PUB-3214.

[6] T. Shidara et al., "Klystron Modulator for the KEK 2.5 GeV Linac", Nucle. Instr. Meth., A279, pp.423, 1989.