IMPROVEMENT IN THE UPGRADED MODULATOR OF THE KEKB INJECTOR LINAC

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Abstract

An upgrade of the klystron modulator for the KEKB injector linac was completed before March, 1997. In this linac, SLED (SLAC Energy doubler) along with an upgraded klystron (which has an rf output power of 46 or 50 MW) is utilized to accelerate electron and positron beams up to 8 and 3.5 GeV, respectively. It is desirable to increase the pulse flat top of the modulator output pulse voltage for SLED operation. An improvement of the output waveshape had been carried out and a flat-top width of about 4µs was finally obtained. In addition, the time jitter of the modulator output pulse voltage was reduced to about 8ns by modifying the driver circuit for a thyratron.

1 INTRODUCTION

The upgraded modulators in the KEKB injector linac are capable of producing pulses with a 110 MW peak power and a 5.6µs pulse duration (calculated as one without a pulse transformer) for the upgraded klystron. SLED along with this klystron is utilized in order to obtain an energy gain of 160 MeV per one acceleration unit. At the initial stage of SLED operation, it became clear that there were some problems concerning the waveshape and the time jitter of the modulator output pulse voltage.

In order to obtain the aimed energy gain, it became important for the flat-top width of the klystron rf output to be increased as much as possible. A basic concept of the modulator upgrade was doubling the total capacitance of the PFN (pulse-forming network). The size of the PFN housing was therefore enlarged and the inductance of the wiring in the PFN output circuit was increased. The upgraded klystron causes the distributed capacitance of the pulse transformer to be increased, since its step-up ratio must have been increased compared to that in the old modulator [1]. These two factors deteriorated the pulse flat-top width of the output pulse voltage, i.e. the klystron rf output.

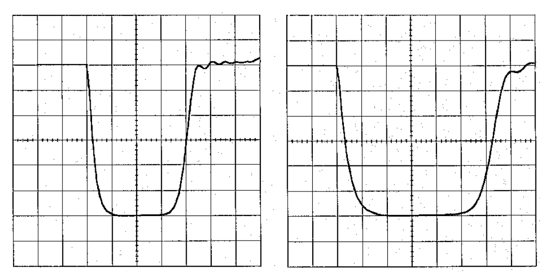
A reduction in the time jitter of the output pulse voltage is also important in order to obtain a stable beam energy. Since the time jitter of the modulator output pulse voltage is strongly dependent on a thyratron operation, improvements to the driver circuit for the thyratron were intensively performed. This paper describes the improvements mentioned above.

2 IMPROVEMENTS TO THE OUTPUT CIRCUIT

2.1 Improvement to the Waveshape of the Output Pulse Voltage

By considering the total number of acceleration units and available output power of the upgraded klystron, a SLED energy multiplication factor of 2.0 was selected as the design value. Taking into account the characteristics of the SLED cavity, a flat-top width of 4µs was reqired for the klystron rf output pulse [2].

Figure 1 shows the calculated output voltage waveshapes in the old (a) and upgraded (b) modulators using the circuit-simulation code "ISSPICE". It can be seen from these figures that the increase in the flat-top width is less than that of the pulse duration due to the slower rise-and fall-time than those in the old modulator. It is therefore necessary to reduce the inductance of the wiring in the PFN output circuit.



(a) old (b) upgraded
horizontal scale: 1µs /div
Fig. 1 Output voltage waveshapes (calculated).

Figure 2 shows the arrangement and the wiring of the output circuit in the upgraded modulator. A copper pipe was being used as the wiring (a) between the thyratron anode and the high-voltage side of the PFN. The length of this wiring became longer than that in the old modulator and its inductance was increased. As for the wiring (b) between the thyratron cathode and the feeder, a copper plate perpendicular to low voltage side of the PFN was being used.

We carried out the following improvements to the output circuit in order to increase the flat-top width of the output voltage pulse (see fig.2):

(1) Another copper pipe was added to the wiring (a) in such a way that the two pipes are separated from each other as much as possible,

(2) The wiring (b) was made parallel to the low-voltage side of the PFN in order to reduce the area of the loop surrounded by the wiring,
(3) The capacitance of the added PFN capacitors was increased from 0.0146μF to 0.0155μF .

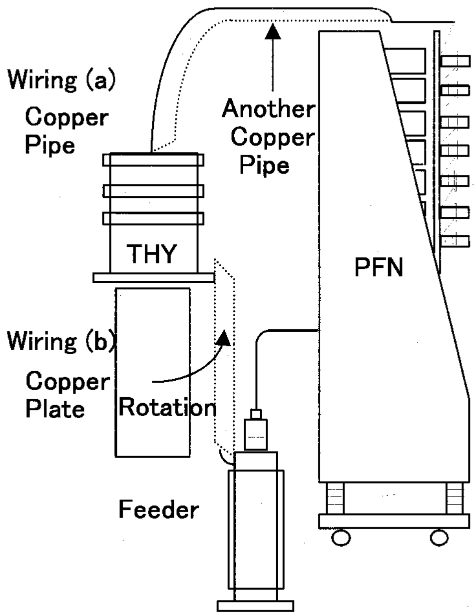


Fig. 2 Wiring of the output circuit.

Figure 3 shows the output-voltage waveshape of the modulator with the improved output circuit. It can be seen from this figure that the pulse duration is increased and the rise-time is being improved compared to fig.1(b). Figure 4 (a) shows an expanded trace of the flat-top of the waveshape. It can be seen that the flat-top width within 0.4% of peak pulse voltage is 3.8μs. Taking into account a recovery time of the oscilloscope, it is possible to say that the flat-top width of about 4μs was obtained. Figure 4 (b) shows an similar trace of the waveshape in the modulator without improvement to the wiring. It can be seen from this figure that the flat-top width increase of 0.4μs was obtained by carrying out the improvement to the wiring. An rf output pulse with the aimed flat-top width was obtained using this improved modulator.

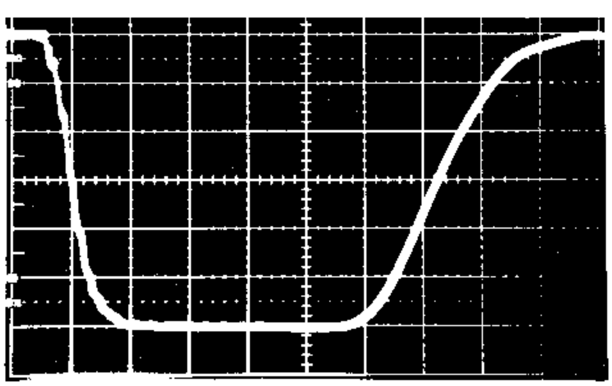


Fig. 3 Output voltage waveshape by the improved output circuit.
(horizontal scale: 1μs /div, peak voltage: 286kV).

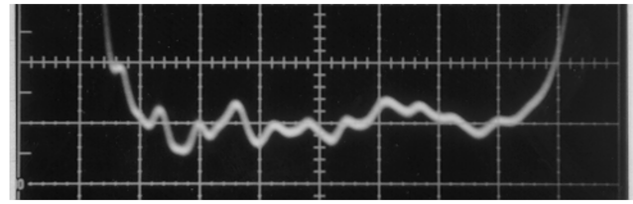


Fig. 4 (a) Expanded trace of the flat-top of an output-voltage waveshape (after improved). (horizontal scale: 0.5μs/div, vertical scale: 0.4% of peak pulse voltage/div).

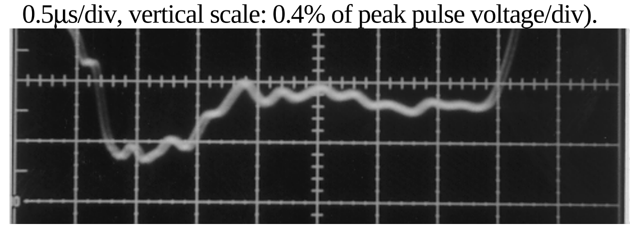


Fig. 4 (b) Expanded trace of the flat-top of an output voltage waveshape(before improved). (horizontal scale: 0.5μs /div, vertical scale: 0.4% of peak pulse voltage/div).

2.2 Improvement to the Thyratron Grid Driver

There are the following four factors which control the time jitter of the output pulse voltage: (1) the thyratron resorvoir voltage, (2) the output impedance of the thyratron grid driver, (3) the rise time of the pulse output voltage in the driver and (4) the input impedance of the thyratron input circuit. Figure 5 shows both the output circuit of the thyratron grid driver and the input circuit of the thyratron. The output impedance is derived from the impedance of the PFN and the step up ratio of the pulse transformer. In the old modulator, the output impedance of the thyratron driver was 100 Ω was equal to the value of the input impedance in the thyratron input circuit.

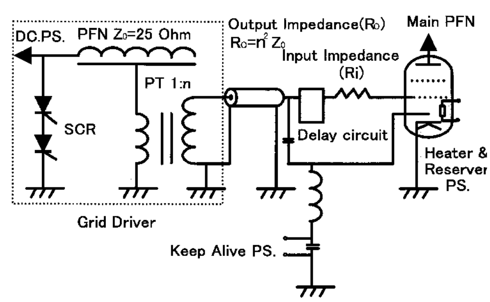


Fig. 5 Circuit between the driver and the thyratron.

Figure 6 shows the dependence of the time jitter in the output pulse voltage on the thyratron resorvoir voltage (jitter-resorvoir relation) measured under repetition rates of 25 and 50 pps in the old modulator. In this figure, it was impossible to measure the time jitter outside of both edges in each curve due to an unstable operation of the thyratron. It can be seen from this figure that the time jitter at each repetition rate and the difference between the values at two repetition rates increases when the resorvoir voltage decreases. This means that the thyratron driver of the old modulator has not fed sufficient power to the thyratron grid. It is also necessary to decrease the time jitter further for SLED operation .

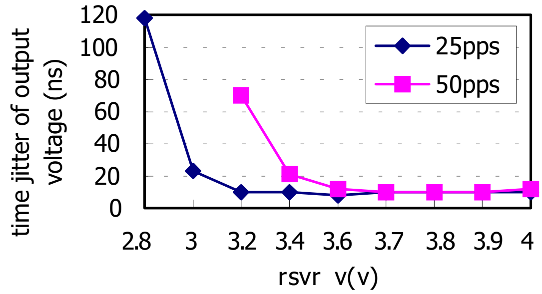


Fig.6 Jitter-resorvoir relations by an old driver.

In order to modify the old driver into one capable of feeding sufficient power to the thyratron grid, the jitter-resorvoir relation was investigated by changing the output impedance (Ro) of the thyratron driver and the input impedance (Ri) of the thyratron input circuit under repetition rate of 50 pps. Figure 7 shows the result of this investigation. The result obtained by changing the input impedance from 100 Ω to 22 Ω while maintaining the output impedance of the driver is almost same as that of the old driver. It is also known that the smaller is the output impedance, the smaller does the time jitter become. Though an output impedance of 28 Ω gives the smallest time jitter, such a modification costs too much, since it needs another PFN. Therefore, we adopted a driver with an output impedance of 56 Ω. Figure 8 shows the results of the jitter-resorvoir relations of this driver under both 25 and 50 pps operation. Since two jitter-resorvoir relations nearly coincide with each other, this driver feeds sufficient power to the thyratron grid.

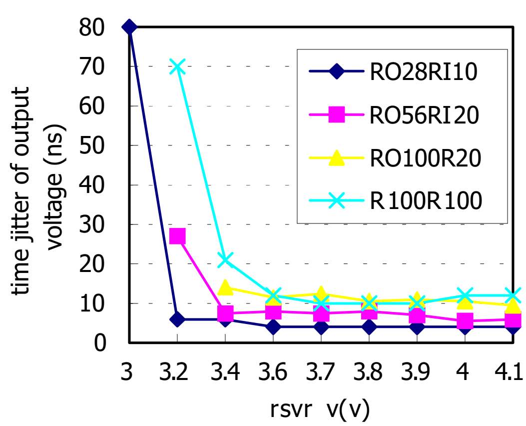


Fig. 7 Jitter-resorvoir relations investigated by changing the impedances (Ro, Ri).

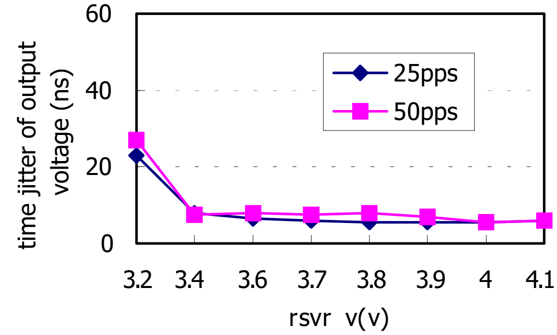


Fig. 8 Jitter-resorvoir relations by a new driver.

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[2] H. Hanaki et al., "Use of SLEDS for high-gradient acceleration" , Proceedings of Linac94, Tsukuba, Japan, August 21-26, 1994, 430-432(1994).