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NEW LIGHT LINK SYSTEM FOR HIGH VOLTAGE TERMINAL

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Summary

A new light link system has been running to control the ion source more than 2,500 hours without trouble at the 750 kV preinjector. It has two optical fiber cables and two microprocessors (CPU's). Triggering pulses and control signals are sent serially through one optical fiber cable to the high voltage terminal. Analog parameters of the ion sources are converted to digital data and sent through the other cable from the high voltage terminal. Pre-arc pulses, which synchronize with the booster synchrotron of 20 pps, start cycles of data transfer. To avoid jitter, the arc trigger pulses are not processed in the CPU's, which only regulate gates for the pulses. A word of the control signal consists of 10 bits, a start bit, 8 bit data and a stop bit. The light link is checked in every cycle. When error is detected, then the control signals are not delivered to the ion source and the error is indicated at the control desk. Since the error is mainly caused by noise due to breakdown in the accelerating column, the program does not stall and the next pre-arc pulse starts the data transfer again.

Introduction

The 750 kV high voltage terminal (HVT) of the KEK preinjector is installed with a set of power supplies and control equipments of a duoplasmatron ion source which has delivered ion beams of more than 700 mA. They should be regulated by a telemeter system which transmits and receives control signals of the ion source across the high voltage of 750 kV. The old light link system,[1] which had two infrared light channels, one from the control desk (GS) at the ground potential to the HVT and the other vice versa, had worked satisfactorily from 1974 to July of 1978. However, it had some drawbacks, i.e., optical axes of the light emitting diode and the photomultiplier detector should be aligned carefully, and the noise level was not so low as expected at the output of the photomultiplier. This might be due to infrared light from high pressure mercury lamps which lightened the preinjector room. To avoid errors caused by the noise, every control signal was represented by a sum of sinusoidal waves of two different frequencies ranging from 3 kHz to 5 kHz. When and only when the two waves were detected simultaneously at the HVT, the corresponding control signal was delivered to the equipment of the ion source. Then another signal of the same type was sent from the HVT to the GS. After confirming normal operation of the light link, next control signal was sent. As the two sinusoidal waves were added and sent to the HVT, they were separated by mechanical filters of high Q in the receiver. Their Q's were so high that the output signals of the separated frequency could not build up fast. As the arc trigger pulses of the ion source were sent by the same channel, the control signals were transferred between these trigger pulses. Therefore, the data were transferred very slowly in the old light link system. As it had not been interfaced to the control computer of the accelerator, the ion source and its in the HVT were isolated from the computer control system. This was not favorable, however, to achieve good operation of the machine by a small operating team.

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The new light link system consists of two optical fiber cables and two CPU's with interfaces so that the HVT is connected to the control computer.[2] Its block diagram is shown in Fig.1.

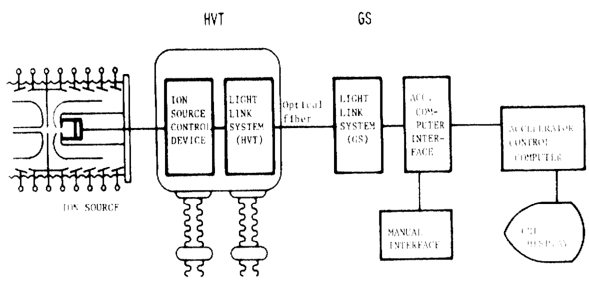

Fig.1 Block diagram of the high voltage terminal (HVT) data link system.

Hardware

There are two channels of data transmission in the new light link system; one sends trigger pulses and control signals for the ion sources from the GS to the HVT and the other transmits digital signals of the ion source parameters from the HVT to the GS. A microprocessor (8080) is at the GS with two interfaces of analog output and control signal input, whereas the other one is at the HVT with two interfaces of analog input and control signal output. They are connected as shown in Fig.2.

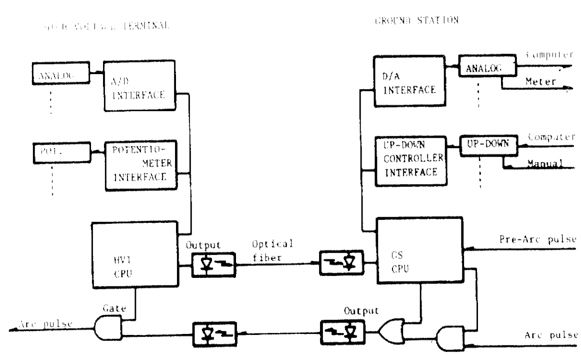

Fig.2 Block diagram of the light link system.

The optical fiber cable is 50 m long and the high voltage of 750 kV is sustained by its part of 3 m long. As two kinds of signals, which are arc trigger pulses and control signals of the duoplasmatron ion source, are sent by one optical fiber cable, they are separated by time. Pre-arc trigger pulses have a repetition rate of 20 Hz and are sent about 30 μs before the arc trigger pulses which fire and stop the arc discharge of the duoplasmatron. Although the arc trigger pulses can be sent up to 20 pps, they are not always delivered at the rate of 20 pps, because it is preferable that the beam is not delivered from the ion source if unnecessary. When the arc trigger pulses are delivered, they always synchronize with the pre-arc trigger pulses. As the arc trigger pulses synchronize with the rapid cycling booster synchrotron, their jitter should be avoided in the transmission system. Thus they are transferred to the arc pulser of the ion source directly through gates without being processed in the CPU's as follows: the pre-arc trigger pulse

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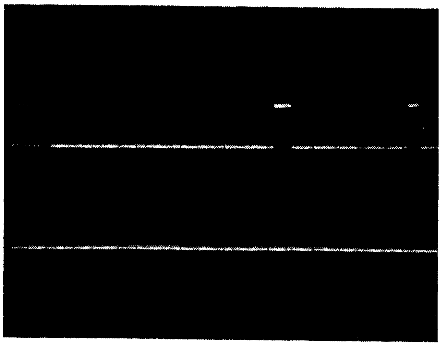

Fig.3 Burst of 9 clock pulses followed by arc trigger double pulse (upper trace). 5 v/div., 5 μs/div.

opens the gate and make the CPU enable at the GS. A burst of 9 clock pulses of 2 MHs is immediately delivered from the GS CPU to the HVT CPU which opens the gate for the arc trigger pulse at the HVT. Then, the arc trigger, which comes from the central control room of the accelerator, passes through the gate of the GS, the optical fiber cable and the gate of the HVT. Fig.3 shows the burst of 9 clock pulses and the arc trigger double pulse which starts and stops the arc discharge.

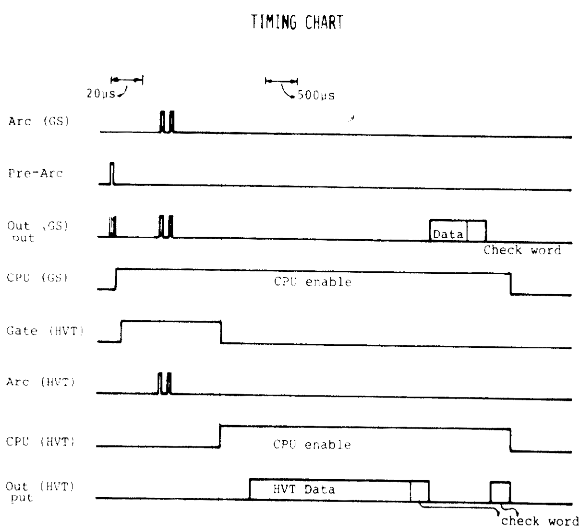

Fig.4 Timing chart of pulses, high voltage terminal (HVT) digital data and control desk (GS) signals.

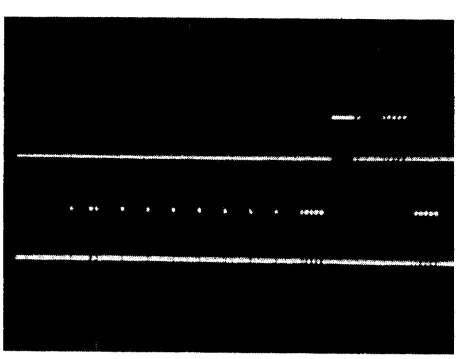

Fig.5 Signals from the control desk (GS) to the high voltage terminal(HVT)(upper trace) and ones from the HVT to GS (lower trace). 5 V/div., 5 μs/div.

The gates are closed about 60 μs later and the HVT CPU becomes ready for the control signals. Although some jitter occurs in the gates due to a phase difference of the CPU clocks and discriminating signals, the arc trigger pulse is not disturbed by the jitter, because the gates are opened sufficiently before the arc trigger pulse. The timing chart of these pulses digital data and the control signals is shown in Fig.4. After the HVT gate is closed, the control signals, digital data and check words are transferred before the next pre-arc trigger pulses. These signals are shown in Fig.5.

Software

The flow chart of the light link system is shown in Fig.6. All programs are written in an erasable PROM which is on the CPU board. A word of the transferred data consists of 10 bits, which include a start bit, 8 bits for data and a stop bit. Speed of the data transfer is about 36 k baud. Error is checked by comparing a check word (hexadecimal 55), which is sent just after transferring the digital data. When error is detected, no signal is delivered to the interfaces of the HVT and the error is indicated at the GS. However, as the error is supposed to be caused mainly by breakdown in the accelerating column, the program is made to be not stalled by the error. The error is being displayed at the GS, and the next pre-arc trigger pulse start the next cycle of the data transfer again. If data pulses of the HVT are not detected at the GS, then failure is displayed. It shows the light link does not work well.

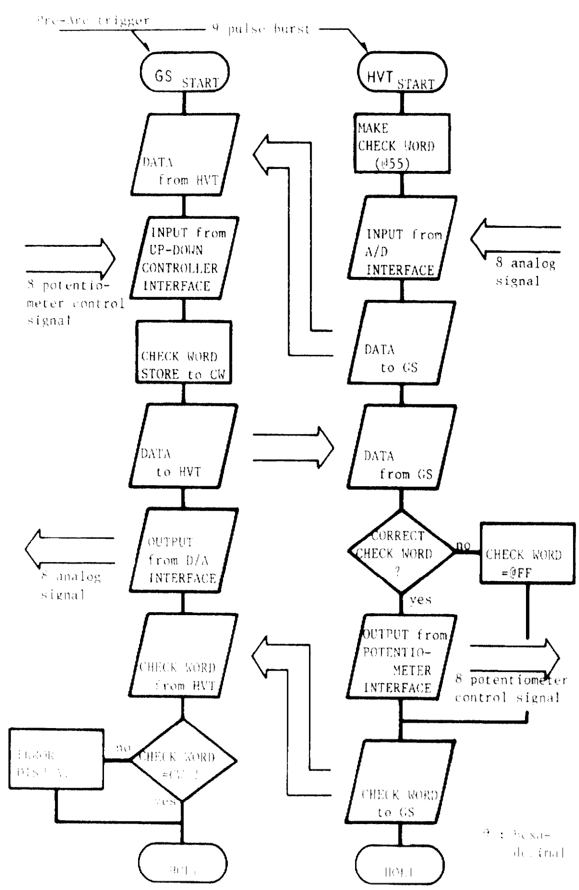

Fig.6 Flow chart of data transfer cycle in the light link system.

Interface

There are four interfaces in the system, two in the GS and two in the HVT.

1) Up-down controller interface latches driving pulses of the pulse motors which are connected to potentiometers. It receives polarity signals also and sends them to the CPU of the GS.

2) D/A interface receives 8 bit digital data and hold pulses for sample and hold circuits from the GS CPU, and it deliveres 8 channel analog signals.

3) A/D interface consists of an 8 channel multiplexer and an A/D converter. It receives channel selection data of the multiplexer and command for the A/D converter from the HVT CPU, and it converts 8 channel analog signals.into digital signals.

4) Potentiometer interface has monostable multivibrators with their gates and pulse amplifiers. Triggers for multivibrators and on-off of the gates are fed from the HVT CPU and it supplies driving pulses to the pulse motor units.

Contents of the data

Following data are transferred between the GS and HVT: polarity signals and driving pulses of pulse motors of 8 potentiometers are sent from the GS to the HVT, and 8 bit digital signlas, which are converted from analog signals of the ion source, are sent from the HVT to the GS. So far, however, only 4 parameters of the ion source are controlled. They are the magnet current, the arc current, the cathode current and the hydrogen pressure of the duoplasmatron. Although eight digital data can be sent from the HVT to the GS, following four data are sent now: the magnet current, the arc current, the cathode current and the hydrogen pressure. These parameters ensure stable operation of the duoplasmatron ion source.

Operation

The new light link system has been worked since October of 1978 and we have never suffered from trouble of the system itself. Error is sometimes displayed at the GS, however, it is mainly due to breakdown in the accelerating column. As the input impedance is high in the amplifier following the light receiving element, the error may be caused by electromagnetic noise due to the breakdown.

The ROM is so-called the E PROM which can be erased by ultraviolet light. During the operation, the ROM is exposed to X-ray of the accelerating column in the HVT. Since the erasing effect of the X-ray is different from that of the ultraviolet light, a ROM was exposed to the X-ray near the duoplasmatron ion source for the test. The TLD radiation monitor was also put there. The X-ray was so intense that the TLD could not show the precise dose but more than 100 R. However, memory of the ROM was not affected by the X-ray. On the other hand, an X-ray of 100 mR was observed for 10 day operation where the ROM of the light link was installed in the HVT. If this is simply compared with the above results, then memory of the ROM will last more than 27 years of continuous operation.

As the microprocessor has enough time to do other job, it will be used to control other parameters in the HVT.

If , however, only data transfer is required, then a special IC of Universal Asynchronous Receiver Transmitter (UART) solves the probelm more easily. An ion source test stand of 100 kV will be installed with such a link system with UART which can transfer 64 bit data from the operational console to the high voltage dome and from the dome to the console. Preliminary test shows the system for the test stand will work well.

Acknowledgments

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References

1) S. Fukumoto, A. Takagi and S. Takano, Ion Source Telemetry System, Proc. 1-st Symposium on Accelerator Science and Technology, 157, 1975 (in Japanese).

2) T. Katoh, et al., "Control Computer System for KEK Proton Synchrotron", IEEE Trans. on Nucl. Sci. (June 1977), Vol.NS-24, No.3, pp.1789-1791.