E-GUN ANODE MODULATOR R&D PROTOTYPE FOR RHIC ELENS PROJECT*

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Abstract

In order to increase the polarized proton luminosities, a new E-LENS system will be installed in RHIC tunnel. One of the key parts of this project is achieve a fast rise time for elens electron gun. The electron gun is driven by a fast high voltage rise time and high pulse repetition rate anode modulator.

This paper will discuss some details of the modulator design concept and its simulation, problems during the test, modulator scheme modification and new modulator scheme prototype test results. Meanwhile, some test diagrams, prototype pictures and measured waveforms will be shown in the paper.

The prototype test has reached the specification requirement of the modulator. The output high voltage is 10 kV, HV pulse rise and fall time is about 50nS (10%-90%) and the pulse repetition rate has reached 80 kHz.

INTRODUCTION

The RHIC project has been operating for 13 years since 2000. The beam luminosity has reached much more than the initial design specification. Now the new goal of the beam luminosity upgrade is on the way. A lot of modifications projects for the RHIC are scheduled in order to archive this ultimate goal. One of the projects is the E-Lens system. In polarized proton operation the RHIC performance is limited by the head-on beam-beam effect. To overcome this limitation two electron lenses are constructed and being commissioning currently. The head-on beam-beam effect will be mitigated by an electron lens in each ring.

The E-Lens system consisted of two low energy electron sources; one source is installed in yellow beam line and another is installed in blue beam line. There are two new designed electron guns which will be used in the E-Lens system. Each electron gun is drove by an anode modulator. These two modulators will be located in the RHIC tunnel. In order to reduce the connection wiring inductance the modulator output will be connected to the E-Gun feed through terminals. All charging and control unit will be installed in a control building externally. Both E-Gun anode modulators will be controlled by RHIC computer system remotely.

Table 1, Main specifications

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<tr>
<th>Item</th>
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<td>kV</td>
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<td>Pulse jitter</td>
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E-GUN ANODE MODULATOR prototype R&D

1. Simple Discharging Circuit Scheme Perplexed

Before the engineering design, a high voltage pulse modulator R&D work was conducted. There are two steps during the test. The first step scheme is tested with a simple discharging loop; the energy storage in a storage 200nF capacitor was directory discharged to the E-Gun load through a semiconductor push and pull switch. The test circuit diagram is shown in figure 1.

Figure 1, Simple discharging scheme diagram

This scheme was acceptable with a capacitor load and at low frequency only. The test voltage has been reached to more than 10KV. The test frequency was about 10Hz.

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and the pulse rise time and fall time was satisfied with the specification. However we had a BEHLK broken problem when we switched from the capacitor load to a real electron gun load. And the first semiconductor switch could not operation at 80 kHz frequency mode. A new scheme had to be determined.

2. Energy Limitation Discharging (“PFN”) Scheme

“PFN” Scheme Circuit Simulation

We developed a new scheme for discharging energy limitation, we called 2PFN: scheme. In fact it was consists of one section of a PFN circuit, one resistor and two storage capacitors. Figure 2 shows the simulation circuit diagram. There are two HV power supplies charging two capacitors separately. HV1 charges capacitor C2, 500pF through diode D1, and HV2 charges capacitor C3, 100nF through D2 and resistor R4. C1 and R6 are the equivalent circuit of the E-Gun load. A BEHLKE push and pull switch HTS301-03-GSM HFS DLC (30KV, 30A) is used to bring the energy to the load and dump the energy from load. Figure 3 shows the simulation waveform. The simulation meets the specification well. As the C2 has a low capacitance the discharging energy is small and it would not damage the push and pull semiconductor switch. And meanwhile the capacitor has to be charged to higher voltage to reach an output voltage required. When the C2 voltage decreases to the HV1 voltage, diode D2 will conduct the current to the load. R4 is a current limitation resistor. It will limit the load current when the gun load arcing, it will protect the semiconductor switch.

Figure 2, “PFN” scheme diagram

Figure 3, “PFN” scheme simulation waveform rise time and fall time

Elens E-Gun Modulator Prototype "PFN" Test Circuit

According to the simulation, we build a test modulator prototype circuit, with several modifications. Figure 4 shows the test modulator prototype circuit and figure 5 shows the water cooling system layout. And a prototype picture shows in figure 6.

We used two BEHLKE semiconductor switches in the prototype; one is used for main push - pull switch and the other is used for pulse charging the main capacitor C2 to HV1. Two high power resistor assemblies are used as the push and pull resistors. Both semiconductors switch and high power resistors are cooled by a liquid cooling system.

Figure 4, Test modulator prototype system diagram
We tested the prototype with a real E-Gun load. The test included two parts. One was if the waveform meets the specification. The other was a load arcing test. Both tests had a very good result awaited. Figure 8 shows a load voltage and current waveform. The pulse voltage was 10kV. The pulse repetition we reached was 80 kHz. The pulse width was about 1μS. The blue waveform shows the load current. The pulse rise and fall time waveforms are shown in figure 9. The pulse rise time measured was ~33ns (10%-90%). And the fall time was ~40ns (90%-10%).
The load arcing test was implemented at 1 kV test level. We tested the arcing by shorting the gun load, simulating the gun arcing. And we tested the circuit with a different way in order to compare the difference of two schemes. The test results shows that the “PFN” scheme can load the arcing current greatly, the arcing current can damage the semiconductor switch easily. Figure 10 shows the different test waveforms. We did not have semiconductor switch failure after we use the “PFN” scheme.

Figure 10, E-Gun load arcing test waveforms

CONCLUSION

From the test, the prototype has met the E-Gun modulator specification. The waveform measurement shows that pulse rise and fall time fast. The “PFN” scheme can reduce the gun arcing risk to the semiconductor failure. We tested the prototype system at 10 kV, 80 KHz with an E-Gun load for about one week during the working hours. Now two operation modulators with “PFN” scheme has assembled and it will be used for elens operation soon.

ACKNOWLEDGMENT

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APPENDIX

References


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