

Design of Voltage Pulse Control Module for Free Space Measurement-Device-Independent Quantum Key Distribution



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1. Introduction

Measurement-device-independent quantum-key-distribution protocol (MDIQKD), which is immune to all hacking attacks on detection, guarantees the security of information theoretically even with single-photon detectors, whose performance is not perfect. Fiber channel is used by the previous MDIQKD experimental device. However, the signal attenuation increases exponentially along with the transmission distance increases. But using free space as the channel for signal transmission, with the signal attenuation increases squarely (without considering the scattering of the atmosphere), the signal attenuation trend can be effectively reduced. In order to implement free space MDIQKD experiments, a modulation module is needed to modulate the wide pulse chopping, decoy-state, normalization, phase encoding and time encoding. In this paper, we present a design of Voltage Pulse Control Module for free space MDIQKD.

The main function of voltage pulse control is as a modulation circuit, with a total of 5 Digital to Analog Converter (DAC) outputs. The output voltage of 5 DACs can be adjusted from 0V to 6V in 0.05V steps. And all 5 DACs have adjustable delay times of ± 15 ns in 100ps steps. The rising edge of the DAC outputs is about 1ns, and the maximum amplitude can reach 7V with a 50 Ω impedance. And with the increase of power, we can get a flatter pulse, which can better serve the subsequent optical modulator. After that, we are going to implement a system with clock frequency up to GHz. By increasing the clock frequency, we expect that the security key rate can be further increased.

2. Design

The voltage pulse control module is used in the quantum cryptography system, with the microcontroller and DAC chip as the core. The modulation signal is generated under the control of the upper computer for modulating the light pulse that reaches the modulator. The main function of the voltage pulse control module is as a modulation circuit, with a total of 5 Digital to Analog Converter (DAC) outputs. Respectively, the wide pulse chopper DAC has two adjustable amplitudes (AC17, AC2), the decoy-state control DAC has four adjustable amplitudes (AD1, AD2, AD3, AD4) and the normalized control DAC has two adjustable amplitudes (AU1, AU2). There are two adjustable amplitudes (AP1, AP2) for the phase encoding control DAC and two adjustable amplitudes (AT1, AT2) for the time encoding control DAC. Figure. 1 illustrate the structure of the system briefly.

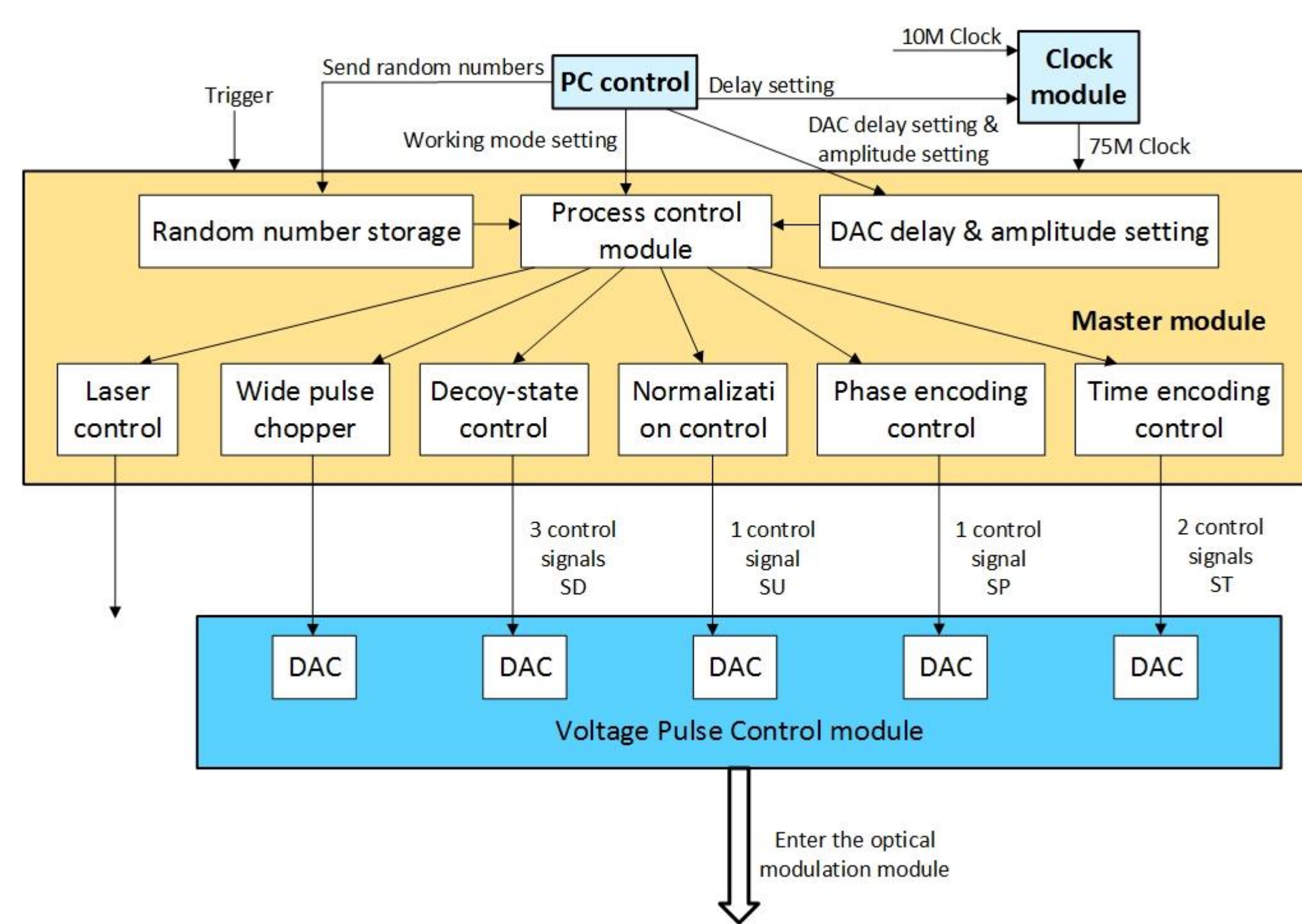


Fig. 1 The simplified structure of the system

Specifications require that the output voltage of all 5 DACs can be adjustable from 0V to 6V in 0.05V steps. And all 5 DACs have adjustable delay times of ± 15 ns in 100ps steps. The rising edge of the DAC output is about 1ns, and the maximum output amplitude can reach 7V with a 50 Ω impedance. Therefore, the power requirements of voltage pulse control module are relatively high. However, with the increase of power, we can get a flatter pulse, which can better serve the subsequent optical modulation module. Later, we will be going to implement the system with a clock frequency of GHz. We expect the security key rate can be further increased by increasing the clock frequency.

In the voltage pulse control module design, the output module of previous voltage pulse control module design uses THS3201, which is a wide gain bandwidth, high speed current feedback amplifier of Texas Instruments (TI), after two stages of amplification, then outputs the voltage. But, there is still a need for a RF power amplifier module independent of the voltage pulse control module before it can be applied to the MDIQKD system.

However, in the new design, we put RF power amplifier directly on the voltage pulse control module, so that we can get enough power and stable voltage output to drive 50 Ω load only by using the one stage operational amplifier and one RF power amplifier. This eliminates the need for an independent RF power module and at the same time we get the output voltage what we need. The block diagram of the new design voltage pulse control module is shown in the Figure 2.

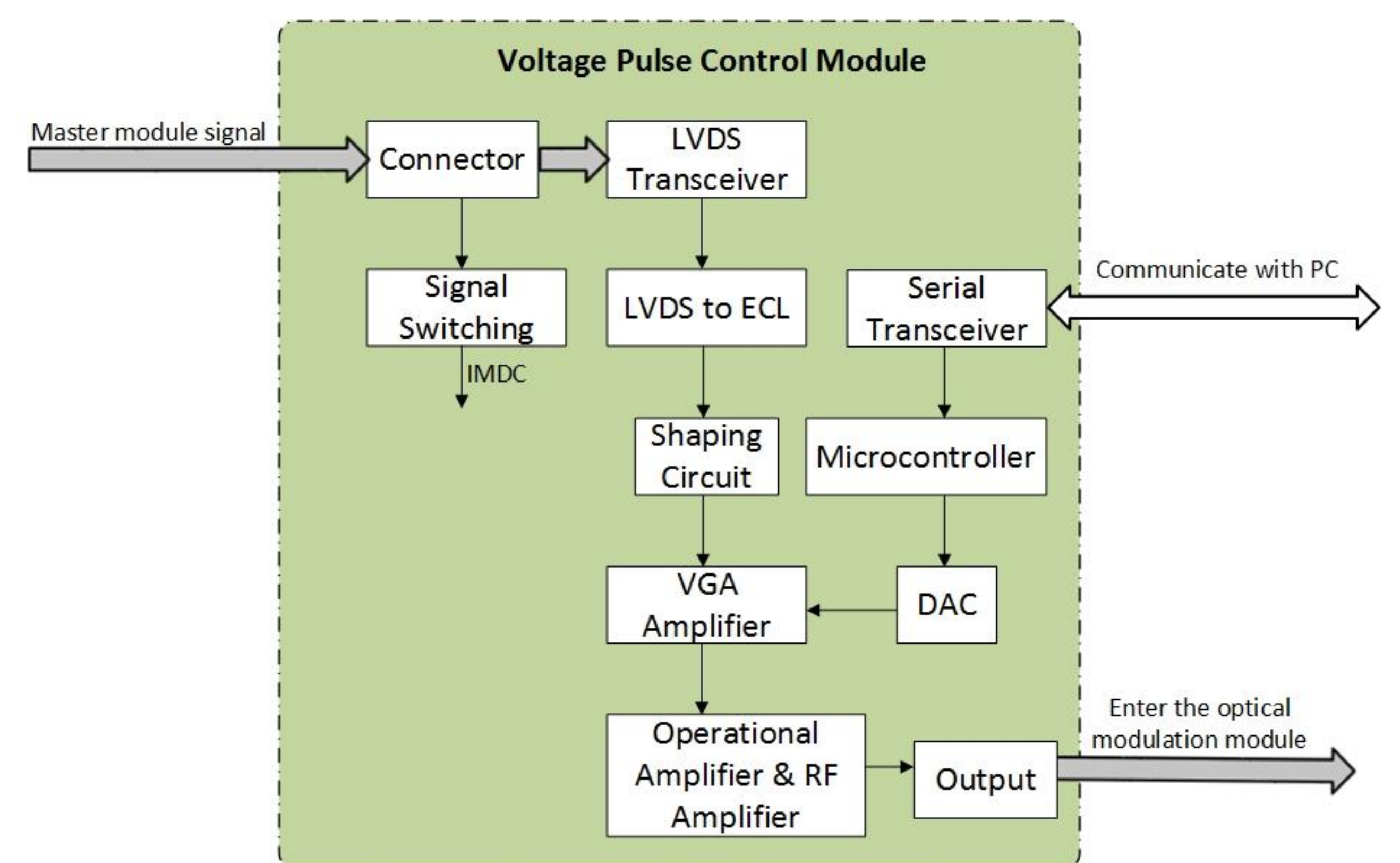


Fig.2 Block diagram of the voltage pulse control module

As is seen in the Figure 2, the Low Voltage Differential Signal (LVDS) enters the voltage pulse control module through the connector and then is transmitted to the LVDS transceiver after signal selection. After level shifting, the signal level is converted to Emitter Coupled Logic (ECL), and then the signal flows into the shaping circuit and Voltage-controlled Gain Amplifier (VGA) amplification circuit. The control system sends a command to the voltage pulse control module via the serial port to modulate the DAC outputs, which in turn control the VGA outputs, thereby modulating the output voltage pulse.

3. Test Results

The tests are in progress and the test method we used currently is that the input signal enters the voltage pulse control module from the master module of fiber channel system via the connector. Then the control system sends a command to the voltage pulse control module through the serial port, and the output signal is connected to the oscilloscope, which is the LeCroy WaveRunner 640Zi oscilloscope with a 4GHz bandwidth and a sampling rate of 40GS/s, for observing the output voltage waveform.

At present the preliminary test results is shown in Figure 3, and more detailed test results will be available in recent.

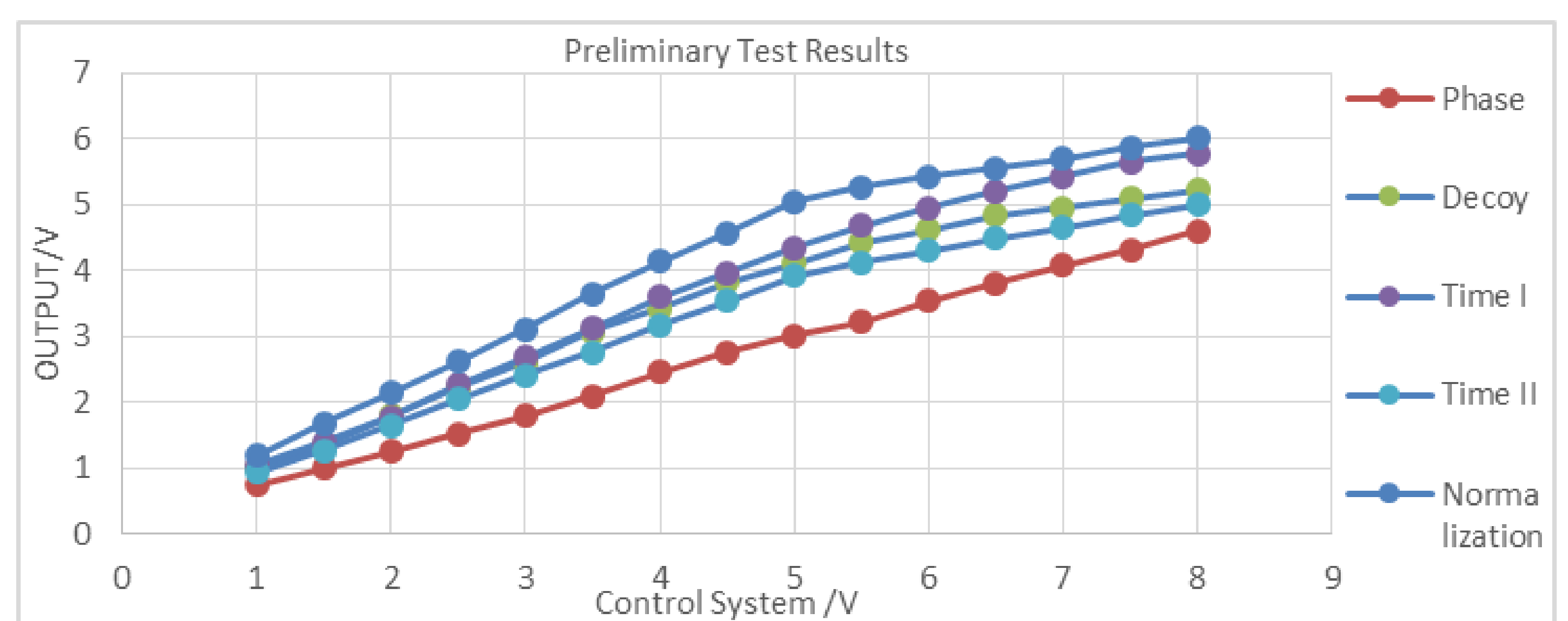


Figure 3 Preliminary test results

4. Conclusions

This paper describes the design of one electronic part for quantum cryptographic system - voltage pulse control module.

For the voltage pulse generator, although it has initially reached the working requirements and has been applied to the actual experiment through the system joint debugging, there are still some areas for improvement. The increase in voltage configuration speed and elimination of signal edge jitter is the requirement for the next step.