TIME JITTER MEASUREMENT FOR THE NSRRC PHOTO-INJECTOR DRIVE LASER

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Abstract

The 266 nm UV drive laser for the NSRRC 2998 MHz photo-injector system is generated from a nonlinear optical crystal that is driven by a 798 nm, 3.5 mJ Ti:Sapphire laser amplifier system. Synchronization of the seed laser pulses with the master oscillator of the photo-injector high power microwave system is done by locking the laser to the rf clock signal with time jitter of less than a picosecond. A detector circuit is being built to measure this jitter at sub-picosecond time resolution. Preliminary results of this jitter measurement electronics that have been tested with artificial signals are presented.

INTRODUCTION

The technology of high brightness photo-injector is being developed at NSRRC for accelerator and light source R&D. A 266 nm, 300 μJ laser system has been setup to excited photo-electrons from the 2998 MHz rf gun cathode surface. Arrival time jitter of laser pulses on the photo-cathode with respect to rf phase is crucial to the photo-injector operation. Excessive laser time jitter may degrade pulse-to-pulse reproducibility of beam energy spread and normalized emittance [1]. Timing and synchronization electronics have been implemented for precise control of laser time jitter and trigger signals. It is therefore desirable to have an independent measurement setup for the laser jitter with respect to the rf master clock for system characterization purpose.

In this report, we briefly describe our drive laser system and its synchronization electronics in the following sections. The design of laser time jitter measurement electronics will be discussed afterward. This measurement setup has been tested in the electronic shop with an artificial fast pulse signal from an rf comb generator to simulate the ultrafast UV photo-diode output signal. Finally, the test results are discussed.

THE LASER SYSTEM

The 266 nm UV drive laser for the NSRRC 2998 MHz photo-injector system was purchased from Coherent Inc. The UV light is generated from a nonlinear optical crystal that is driven by a diode-pumped 798 nm, 3.5 mJ Ti:Sapphire laser amplifier operating at 10 kHz repetition frequency for high stability. However, one Pockels cell at the amplifier output is triggered at 10 Hz pulse repetition rate to meet our photo-injector system requirement. This amplifier is seeded by the Coherent Mira 900 Ti:Sapphire laser oscillator operating at 74.95 MHz repetition rate (its 40^{th} harmonics would be the operating frequency of the photo-injector system). A UV stretcher that delivers pulses with adjustable durations ranging from 1 to 15 psec pulses has been installed after the third harmonic generator (THG). The Coherent Synchrolock module is used to tune the optical cavity of seed laser according to external reference at 74.95 MHz. The UV stretcher is useful for pulse rise time control in laser pulse stacker to minimize normalized emittance of the electron beam. Figure 1 depicts the block diagram of the NSRRC photo-injector drive laser system. Details of this drive laser and relevant optical design for laser beam transport and pulse shaping are reported elsewhere in this conference [2].

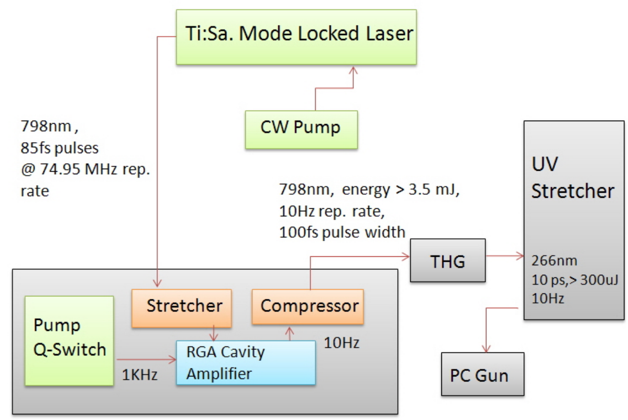

Figure 1: Block Diagram of the NSRRC Photoinjector Drive Laser System.

TIMING AND SYNCHRONIZATION ELECTRONICS

Timing and synchronization electronics developed in house and is shown in Fig. 2.

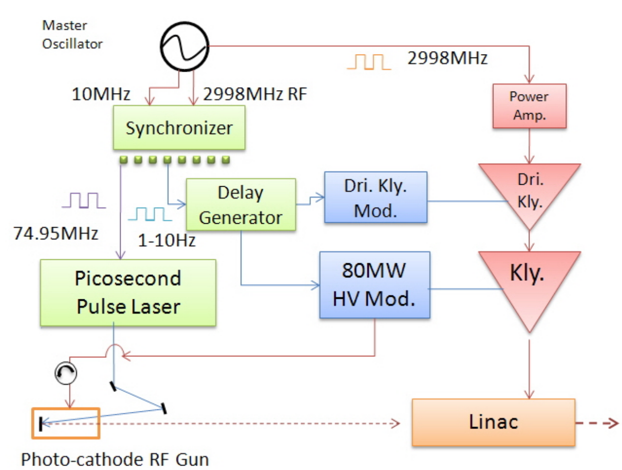

Figure 2: Timing and synchronization electronics for the NSRRC 2998 MHz photoinjector system.

A 74.95 MHz reference signal for the Mira 900 seed laser is derived from the master oscillator. Several channels of 1-10 Hz timing signals originated from the 10 MHz time base of the master oscillator are available as the trigger signals for the Pockels cells in the laser system, main klystron pulse forming network and scope etc. A Stanford Research digital delay generator DG645 is used to provide delays among trigger signals.

LASER TIME JITTER MEASUREMENT

Layout of laser jitter measurement setup is showed in figure 3. ALPHALAS ultrafast UV photodetectors (UPD-40-UVIR-D or UPD-200-UD) will used to convert the picosecond laser light into electrical signal for back-end signal processing. Figure 4 depicts a typical output pulse signal from the UV photodetector. A stripline comb filter operating at ~ 3 GHz is used to reproduce the psec output pulses from photodetector by 10 times [3]. An optional 2998 MHz narrow band cavity (Q ~ 1000) can be used to filter out harmonics or other unwanted rf signals. A standard phase detector equipped with double balanced mixer is used for phase jitter measurement of pulsed rf signals. An analog-to-digital converter may be required for data acquisition in the future.

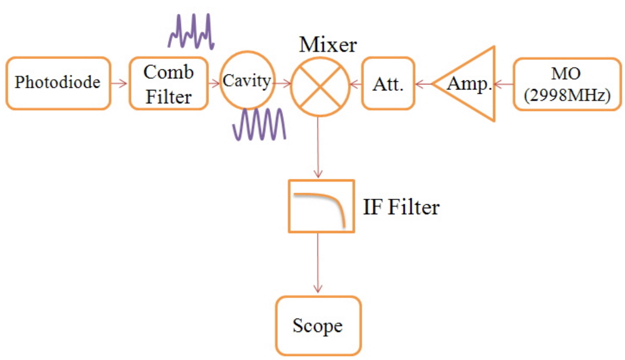

Figure 3: The laser time jitter measurement setup.

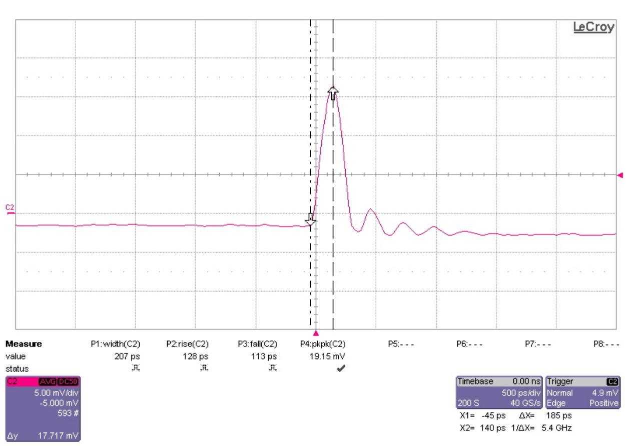

Figure 4: typical output pulse signal from the ultrafast UV photodetector.

TEST RESULTS WITH ARTIFICIAL PULSE SIGNALS

To simulate a laser pulse signal, a comb generator driven by 250 MHz rf is used to produce repetitive picosecond pulses for a test in the electronic shop. Figure 5 is the output signal of this 250 MHz comb generator. Driven by these sharp pulses, pulse trains can be obtained from the comb filter output (Fig. 6). The linearly decreasing amplitude of the pulse train is due to circuit loss in the stripline comb filter. Typical output signal from the double balanced phase detector for rf pulses without time jitter is shown in figure 7. The periodic 250 MHz waveform is due to the dependence of mixer output voltage on amplitude of rf input signal.

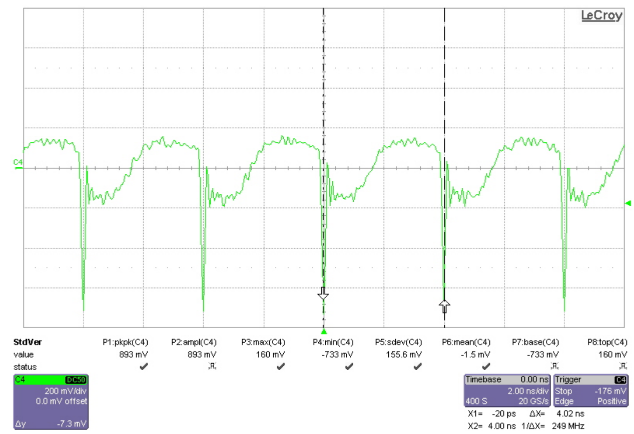

Figure 5: The output signal of a comb generator

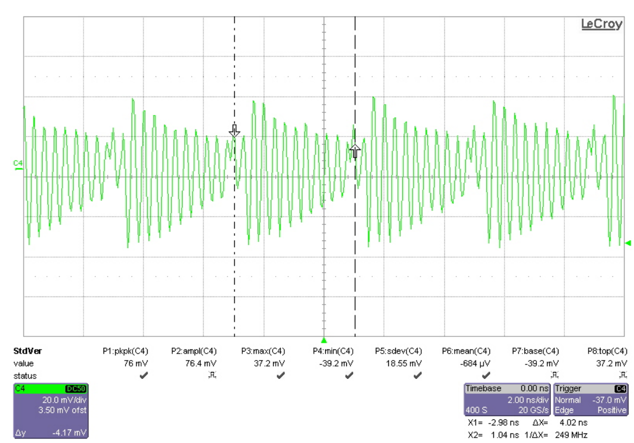

Figure 6: The output signal of the 2998 MHz comb filter.

By modulating the 250 MHz carrier signal frequency at 400 Hz, voltage fluctuation that is proportional to the time jitter can be observed. Proper calibration of mixer output voltage is required for a precise measurement. It is worth noting that the output voltage of the double balanced mixer is also a function of rf signal amplitude. However, the intensity fluctuation of laser pulses is not likely to fluctuate much with temperature control within +/- 1° C.

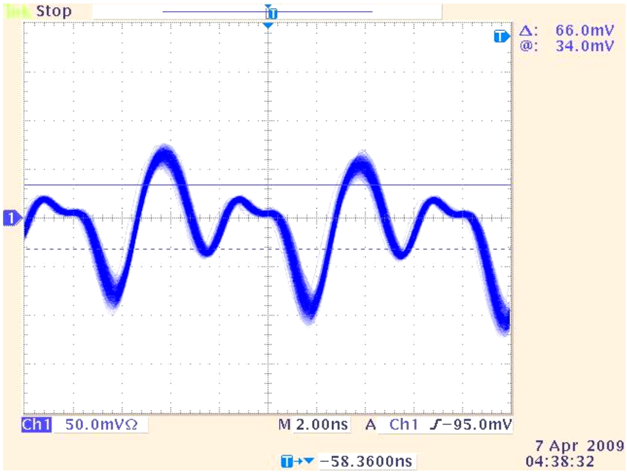

Figure 7: Typical output signal from the double balanced phase detector with the 250 MHz simulation signal.

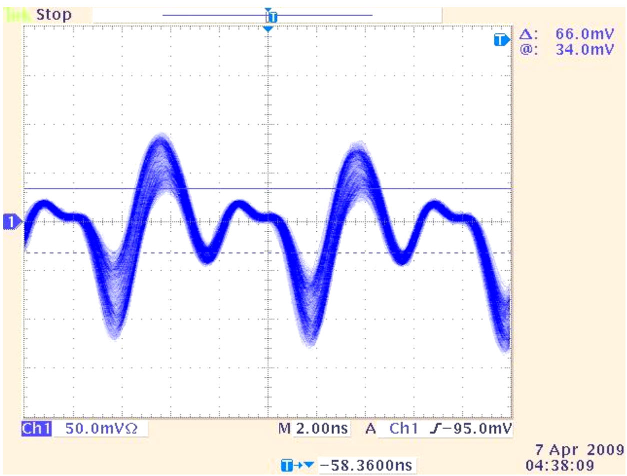

Figure 8: Voltage fluctuation that is proportional to the phase jitter of the carrier can be observed.

SUMMARY

Timing and synchronization electronics for the photo-injector system are implemented and are ready for use in the system. Detector for laser time jitter measurement of photo-injector drive laser with respect to the master clock has been built. Preliminary measurement with artificial modulation on the 250 MHz carrier has been used to test the validity of the detector circuit. Careful calibration of detector output voltage is required and fluctuation of pulse-to-pulse laser amplitude should be avoided during time jitter measurement.

REFERENCES

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