ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPRB107

A NOVEL DESIGN OF A LASER PHASE MONITOR FOR AWA RF PHOTOCATHODE ELECTRON GUN*

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Abstract

It is critical to maintain a stable laser phase for a RF photocathode electron gun to achieve high beam stability. In order to achieve a higher beam stability for AWA (Argonne Wakefield Accelerator) beamline, a novel laser phase monitor has been designed to allow us to monitor and feedback on. Both the design and its applications at AWA are presented in this paper.

INTRODUCTION

AWA beamlines all started with a 1.5 cell RF photocathode electron gun. The characteristic parameters of the electron beam coming out of the electron gun strongly depend on the injection phase(the injection time of laser beam measured in the RF phase of 1.3GHz RF) of the laser beam. Depending on what the injection phase is set to, the beam quality could be very sensitive to the phase instability. But in general, we would like to keep the injection phase instability as small as possible. In order to control the injection phase instability, we have upgraded our low level RF (LLRF) system to instrument a RF phase monitors and feedback system. The LLRF phase monitor and feedback system picks up RF signals from electron gun and linacs and measures their phase against the 1.3GHz reference signal from master oscillator. The results are then used to feedback control LLRF of RF modulators. With the LLRF phase feedback system, the RF phase drift has now been eliminated but the drift in beam phase is still observed during experiments and confirmed with phase jitter scan. A laser phase monitor is thus needed to further stabilize the beam phase.

AWA LASER SYSTEM

AWA laser system uses Spectra-Physics Tsunami ultrafast Ti:Sapphire oscillator which offers two photodiode output for its controlling electronic modules. One for the mode lock electronic module and another one for the Lock-to-Clock electronic module (LTC box). Both photodiode signals are sine wave corresponding to the laser output. The LTC box takes 81.25MHz from our master oscillator as reference clock and control the Tsunami laser head to phase lock the laser to the reference clock. This 81.25MHz reference clock coming out from master oscillator is phase locked to the 1.3GHz LLRF reference signal generated in the same master oscillator. Ideally, the laser output from Tsunami should be have been phase locked to the 1.3GHz LLRF reference clock.

In order to measure the laser phase in terms of the 1.3GHz LLRF clock using phase detector circuit, one have to find a way to generate a 1.3GHz signal associated with the photodiode signal. For our case here, the photodiode signal is a nearly clean sinewave as showing in Fig. 1.

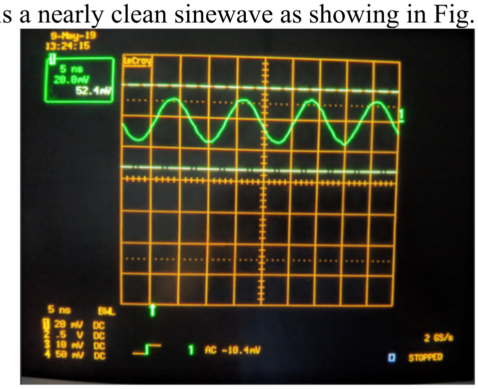

Figure 1: Photodiode signal from Tsunami laser head.

Since 1.3GHz is the 16th harmonic of 81.25MHz, with a nearly clean 81.25MHz sine wave from the laser photodiode output, it is quite straightforward that frequency multipliers should be used to generate the 1.3GHz signal associated with the laser.

AWA LASER PHASE MONITOR

Hardware Configuration

Once it is clear that the photodiode output from the laser head is an 81.25MHz sine wave, the easiest way to generate the laser associated 1.3GHz signal is to double the frequency up using frequency multipliers. As frequency multiplier are usually lossy and noisy, amplifiers and band pass filters are also used in the process of generating laser associated 1.3GHz signal. A block diagram of the design is given in Fig. 2.

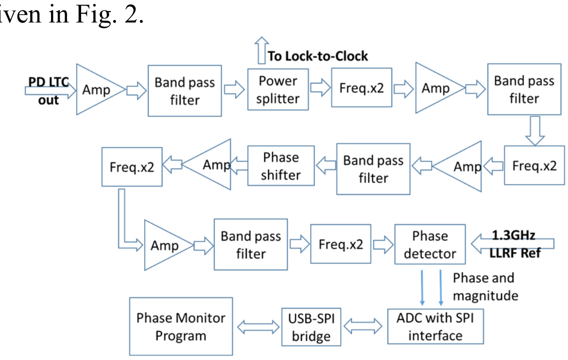

Figure 2: Function block diagram of laser phase monitor.

All frequency multipliers, amplifiers, band pass filters, power splitter and phase shifter are connectorized circuit unit from Mini-Circuits [1]. An AD8302 evaluation board [2] is chosen to be used as the phase detector while

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MCP2210 evaluation kit [3] is chosen as the interface between the computer program and the laser phase monitor. All the parts are commercially available and no PCB layouts and fabrication is involved.

Laser Phase Monitor Software

Based on the AD8302 datasheet, the phase and magnitude output signals are 30mV to 1.8V corresponding to 0-180° in phase and -30dB to 30dB in magnitude. These two signals are connected to channel 3 and channel 4 of the MCP3204 (A 4 channel, 12 bit ADC) which comes with the MCP2210 evaluation kit. A computer program developed using MSVC is used to communicate with MCP2210 to read the signals back and convert them into corresponding phase and magnitude values using the calibration data from the datasheets.

The LTC box controlling the Tsunami laser has offered a RS232 interface for a computer to query status and control some parameters. This RS232 interface basically offered us a way to use the phase monitor results to feedback control the laser.

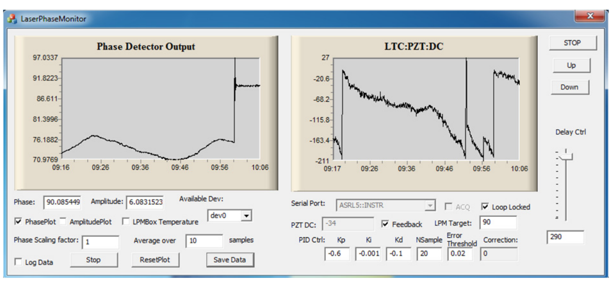

Figure 3: Screenshot of the LPM program.

AWA laser phase monitor program queries the status of LTC box and will try to keep the piezo-electric transducer (PZT) DC voltage in its mid-range by moving the stepper motor. When the feedback is enabled, it will also lock the laser phase read back value at a given target value by changing the delay setting in LTC box.

As shown in Fig. 3, a screenshot of AWA LPM program, the program will plot both the PZT DC voltage and the measured laser phase as a function of time. As shown in the phase detector output plot in Fig. 3, the measured phase was drifting at the beginning and moved to the target phase quickly after the feedback is enabled and stays locked to the target phase. As shown in the LTC:PZT:DC plot in Fig. 3, the program will move the stepper motor when the DC voltage of PZT is out of the range between 10 to -200, which is equivalent to keeping the lock status bar on LTC box stays in the middle.

Results of LPM Measurements

At AWA we usually set the laser phase with a phase scan routine which plots out the charge vs LLRF phase curve by changing the LLRF phase and measuring the charge of resulting electron beam. We call the LLRF phase the zero phase when the charge of electron beam starts increasing on the LLRF phase vs charge curve.

In order to study the phase instability, another program called phase jitter scan is created. What it does is keep scanning LLRF phase around the zero phase and record the zero phase of each scan.

After both the LPM hardware and software were commissioned, a set of phase jitter scans were done while the LPM was monitoring the laser phase. The results are shown in Fig. 4. As shown in the plot, the LPM reading matches well with the phase jitter scan.

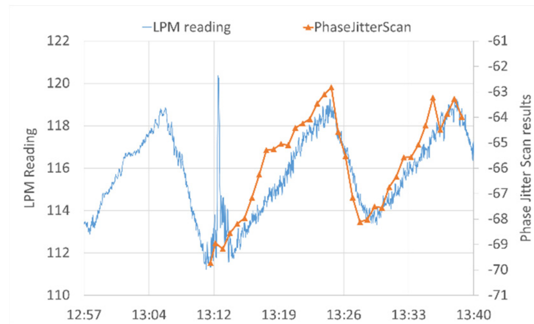

Figure 4: Comparing LPM with phase jitter scans.

There is another way that most other facilities use to generate the needed signal from laser photodiode which involves the using of high speed photodiode, amplifiers and band pass filters. We did not go down that road because we don't want to install laser power splitter to divert the already low laser energy. But just for the sake of sanity check, we temporarily installed a high speed photodiode at the output of Tsunami laser and set up a direct filtering based laser phase monitor. Tsunami laser phase was monitored simultaneously using both monitors and the readings are recorded and plotted in Fig. 5 for comparison.

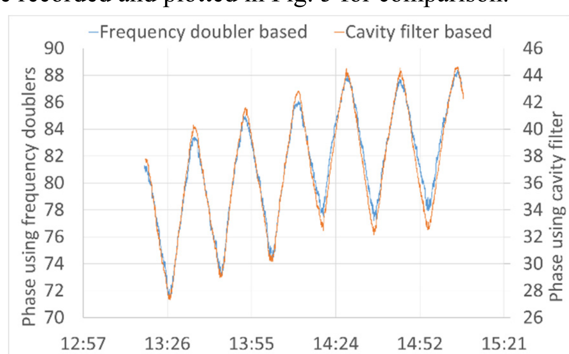

Figure 5: Comparing with high speed PD based monitor.

As shown in Fig. 5, our phase monitor design agrees very well with the conventional method using high speed photodiode, band pass filter and high frequency LNA.

CONCLUSION

Our novel economical laser phase monitor design is successful and it works perfectly with our Tsunami laser head.

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