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HIGH VOLTAGE RTM PIEZO DRIVER FOR XFEL SPECIAL DIAGNOSTICS*

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Abstract

High voltage RTM Piezo Driver (PZD) has been developed to support special diagnostic (SD) applications foreseen for XFEL facility. The RTM Piezo Driver is capable of driving 4 piezo actuators with voltages up to ±80 V [1]. The solid state power amplifiers are driven using 18-bit DACs and sampling rates of 1 MSPS. The bandwidth of the driver is remotely tuneable using programmable low pass filters. The 4-channel Piezo Driver unit provides the information of piezo output voltage and current. Three independent test setups have been built to test 4-channel Piezo Driver performance. In the paper we are presenting EOD laser lock to 1.3 GHz FLASH master oscillator using bipolar piezo stretcher (fine tuning). The piezo motor based course tuning has been applied for the long term laser stability measurements. The unipolar piezo actuator operation has been demonstrated for the Origami Onefive laser locked to 1.3 GHz LAB MO. The preliminary results of active stabilization of 3.6 km fibre link laboratory setup are shown.

INTRODUCTION

In accelerator facilities, especially free-electron lasers (FEL), the use of mode locked lasers is most common approach, e.g. for electro-optical diagnostics (EOD), as photo-cathode lasers, seeding, Beam Arrival and Beam Position Monitors (BAM, BPM) or pump-probe experiments [2].

The repetition rate of the laser train pulses is typically a sub-harmonic of the main RF synchronization signal. At European XFEL the main reference signal is at 1.3 GHz while the lasers run in a range between 54 MHz and 216 MHz. In order to synchronize the laser to the accelerator reference a piezo element within a laser cavity is applied. The main approach is to use a loop filter (digital or analog) driving a high output voltage and current power amplifier in order to minimize a phase difference between reference and the laser.

The accelerator reference signal needs to be also distributed over different places of the machine. The main idea is to encode the reference timing information in the precise rate of an optical pulse trains using master laser oscillator (MLO). The MLO optical signal is next transmitted to different accelerator locations (e.g. RF Gun, main linac or undulator sections) using fibre laser connections. The fibre lasers needs to be actively stabilized using stretcher in a fibre due to temperature drifts and microphonics. The typical active fibre link stabilization is done using balanced optical cross-correlator (OXC) that compares the optical signal of the transmitter (e.g. MLO) and receiver (e.g. Probe Laser) and minimize its phase difference using analog or digital feedback loop. The block diagram of the laser synchronization and special diagnostic applications foreseen for XFEL machine are shown in Fig. 1.

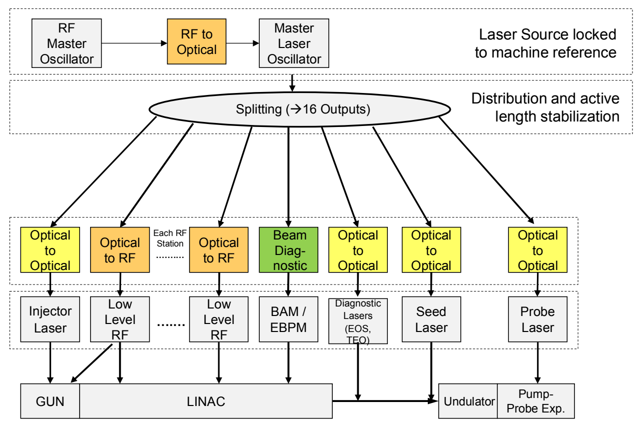

Figure 1: The block diagram of XFEL laser synchronization and special diagnostics.

The 2 laser sources locked to machine reference are foreseen for XFEL facility installation. The both MLO applications based on unipolar piezo actuator will occupy two 4-channel RTM Piezo Drivers (one channel per RTM). When considering optical signal distribution over XFEL accelerator a total of 24 fibre link connections with a length between 20 m and 3 km will be established. The bipolar piezo based fibre stretcher applications will consume 6 RTM Piezo Drivers (4 channels per RTM). The 4 electro-optical bunch length diagnostic (EOD) setups will use both bipolar (fine tuning) and unipolar (coarse tuning) piezo elements. The EOD lasers will occupy 4 Piezo Driver units. The 2 channels per module will be driven.

HIGH VOLTAGE PIEZO DRIVER APPLICATIONS

The 3 test stands have been established to check piezo driver performance for precise synchronization of optical lasers and special diagnostic applications [3].

MLO Synchronization

The Master laser oscillator application is based on Origami-15 onefive ultra-low noise femtosecond laser

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module of wavelength of 1553 nm and repetition rate of 216 MHz. The laser module consists of mode-locked erbium-doped fibre laser and a free space part supported by piezo stretcher and motorized stage (based on temperature stabilized controller). The unipolar piezo actuator (capacitance of 100 nF) of MLO laser cavity can accept voltages from 0 V up to 120 V.

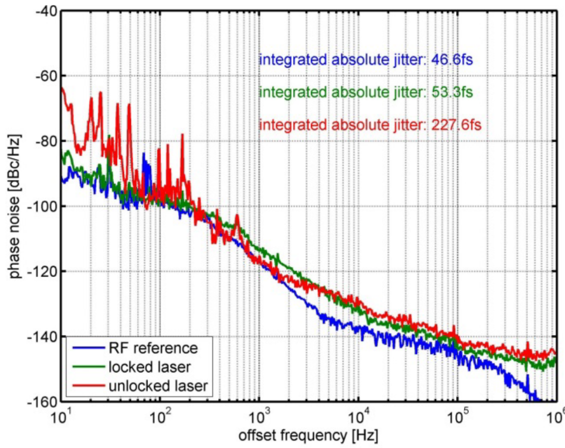

Figure 2: The in loop phase noise measurement of MLO laser.

The MLO application has been tested with the following hardware setup:

- RF front-end standalone box supported by photodetector and a set of band pass and low pass RF filters: 6^{th} sub-harmonic of 216 MHz laser repetition rate is taken into account and 1.516 GHz output RF signal is generated,
- DRTM-DWC10 MTCA.4 based analog downconverter module supported by a set of RF mixers and low pass filters: 1.516 GHz RF input signal is downconverted to intermediate frequency of 216 MHz according to 1.3 GHz reference input, low pass filtered and connected to fast ADC inputs (AC coupled), 81.25 MHz input clock frequency feedthrough circuit is also included,
- AMC-SIS8300L1 MTCA.4 based fast ADC digitizer board supported by power full Virtex 6 FPGA device from Xilinx, PCIe connection to the CPU (Generation 2) and low latency link connection over the backplane (throughput up to 3.125 Gbps),
- DAMC-FMC20 MTCA.4 based low cost FMC carrier board supported by power full Spartan 6 FPGA device, PCIe connection to the CPU (Generation 1) and low latency link connection over the backplane (throughput up to 3.125 Gbps), module also supports two FMC cards extension possibilities (e.g. FMC based step motor driver or optical module connections extender),
- DRTM-PZT4 MTCA.4 based piezo driver board supported by 4 solid state amplifiers (bandwidth up to tens of kHz) with output voltages up to ±80 V and output currents up to 1.5 A, internal high voltage power supply module generated from 12 V Payload Power, 18-bit DACs with sampling rate up to 1 MSPS and monitoring ADCs.

The proportional-integral (PI) control scheme has been applied to lock free running laser to 1.3 GHz RF oscillator (see Fig. 2).

Fibre Link Stabilization

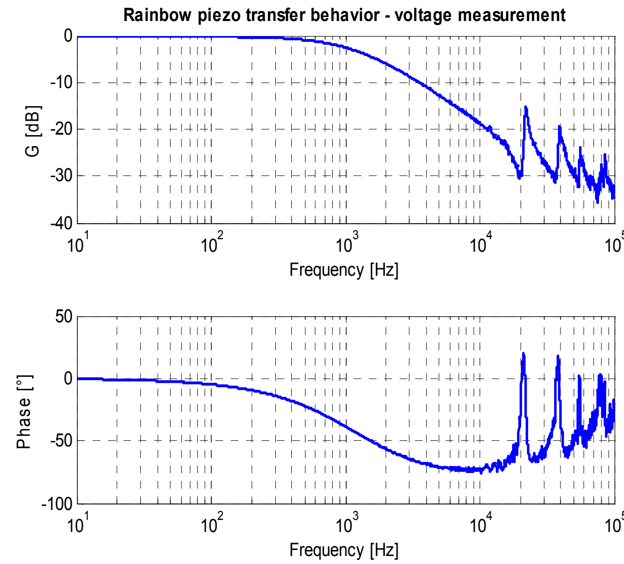

Figure 3: Typical piezo frequency response used for fibre link application.

The fibre link stabilization test stand is based on 3.6 km fibre laser equipped with bipolar piezo stretcher (±400 V), step motor based delay stage and balanced optical cross-correlator. The typical frequency response of used piezo actuator is shown in Fig. 3.

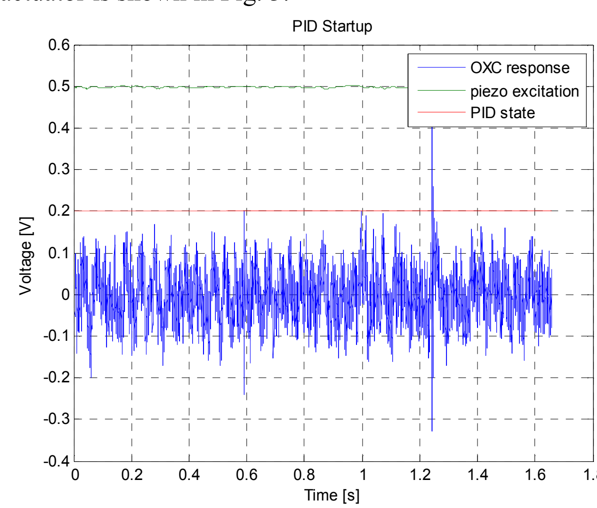

Figure 4: The 3.6 km fibre link stabilization.

Since the cross-correlator output signal is DC coupled with a frequency range of a few MHz, the 10-channel RTM-SIS8900 MTCA.4 based board has been connected to AMC-SIS8300L1 module. DAMC-FMC20 board functionality has been extended with FMC-MD22 step motor driver card connected to motorized delay stage. All

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other hardware components have been not changed when comparing to MLO test stand.

The fibre link stabilization procedure consists of:

- Course tuning stage (with step motor), where the OXC signal is searched by moving step motor device,
- Fine tuning stage (with piezo fibre stretcher), where the digital feedback controller (PI algorithm) is activated to drive fast piezo actuator (see Fig. 4).

EOD Laser Synchronization

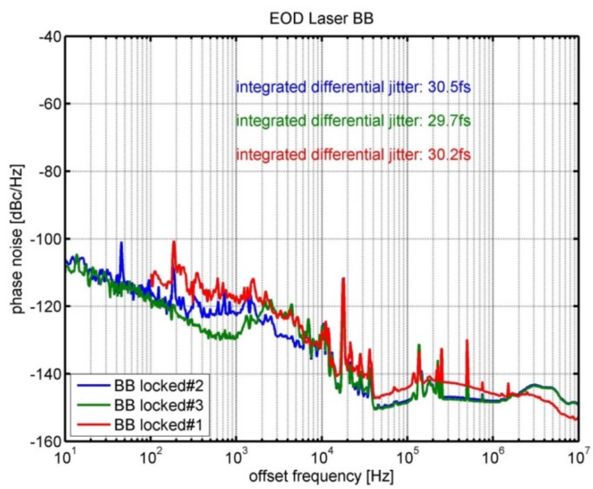

Figure 5: The out of loop phase noise measurement of EOD laser (base band).

The electro-optical bunch length measurement application is based on Ytterbium-Fibre Laser of 1030 nm wavelengths (electro-bunch length dimension) and repetition rate of 54 MHz. The laser module consists of a ring oscillator with a fibre, free space part supported by piezo stretcher and motorised stage based on piezo motor driver. From the hardware point of view the same setup has been applied as for MLO application. The only difference is that the RF front-end box has been modified to provide 1.354 GHz RF output (26^{th} sub-harmonic of 54 MHz repletion rate of the laser). One of the piezo driver channels has been connected to piezo fibre stretcher (bipolar piezo ±200 V, capacitance of 33 nF) for fine tuning purpose while the second one for the coarse tuning using piezo based motor driver (unipolar piezo with voltage range between 0 V and 120 V, capacitance of 64 nF). The fine tuning control scheme has been designed using PI algorithm. The course tuning controller has been implemented using saw tooth waveform generator of programmable frequency, amplitude and number of periods. The out of loop phase noise measurements of Ytterbium laser lock performance are shown in Fig. 5.

For the long term operation of the laser (over thousands of seconds) the relative piezo motor driver steps (coarse tuning) versus controller output steps (fine tuning) have been recorded (see Fig. 6).

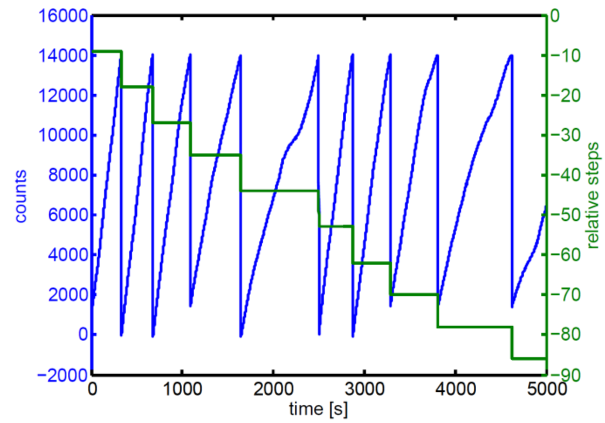

Figure 6: The piezo motor driver (coarse tuning) based voltage relaxation applied to piezo fibre stretcher (fine tuning).

CONCLUSION

The designed high voltage 4-channel RTM Piezo Driver has been successfully tested with different conditions (unipolar and bipolar piezo actuators) and various capacitance load (from 30 nF up to 100 nF). The MLO laser oscillator has been locked to 1.3 GHz reference with integrated differential jitter of 50 fs. The 3.6 km long fibre link has been stabilized to deliver fs optical pulses. The link lock has been noticed to be stable in time over several thousands of milliseconds (even if external disturbance has been applied after 1 second of operation). The electro-optical bunch laser synchronization performance to 1.3 GHz reference has been measured to be less than 30 fs of integrated differential jitter (out of loop). During long term laser operation it was noticed that several piezo motor driver steps have been generated to relax the piezo driver voltage whenever threshold condition has been reached. The designed RTM Piezo Driver module has been commercialized and its mass production for XFEL facility installation has been lunched.

REFERENCES

[1] K. Przygoda et al., “MTCA.4 Module for Cavity and Laser Piezo Operation”, THPRO100, IPAC’14, Dresden, Germany, June 2014, p. 3142 (2014); http://www.JACoW.org

[2] M. Felber et al., “Compact MTCA.4 Based Laser Synchronization”, TUPRI107, IPAC’14, Dresden, Germany, June 2014, p. 1823 (2014); http://www.JACoW.org

[3] U. Mavric et al., “Precision Synchronization of Optical Lasers Based on MTCA.4 Electronics”, TUPC34, IBIC’13, Oxford, UK, June 2013, p. 451 (2013); http://www.JACoW.org