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UPGRADE OF THE ELBE TIMING SYSTEM

M. Kuntzsch, A. Schwarz, K. Zenker, M. Justus
Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany
Z. Oven, L. Krmpotic, U. Legat, U. Rojec, Cosylab, Ljubljana, Slovenia

Abstract

The ELBE center for high power radiation sources is operating an electron linear accelerator to generate various secondary radiation like neutrons, positrons, intense THz and IR pulses and Bremsstrahlung. The legacy timing system has been modified and extend over the last two decades to enable new experiments. Part of this system is using obsolete parts which makes the maintenance more complex and the heterogenous structure require a major revision of the timing signal generation and distribution at ELBE.

A new timing system based on the Micro Research Finland (MRF) hardware platform is being adapted to be used at ELBE. It will enable parallel operation of two electron sources and subsequent kickers to serve multiple end stations at a time. The hardware enables low jitter emission of timing patterns and a long term drift compensation of the distribution network. The development is currently in the final phase and the stepwise commissioning is scheduled for 2021.

SYSTEM DESCRIPTION

Hardware

The new timing system is using the Micro Research Finland hardware based on the MicroTCA standard for signal generation and distribution over optical fibers [1]. The modular system enables a flexible topology using event master modules (EVMs) for timing event generation and event receivers (EVRs) to drive physical outputs based on the received timing events.

At ELBE one EVM is set up per injector, allowing for independent operation in separate beamlines and combined emission into the ELBE accelerator. For machine timing receivers like beam diagnostics and low level frequency control (LLRF) MicroTCA EVRs are applied. User stations for users that are using MicroTCA hardware EVRs in the same standard are provided while others will receive a PCIe based receiver module which is more cost effective.

The receivers can be equipped with different universal output modules that are providing a variety of optical and electrical logic levels. MicroTCA receivers also use the backplane trigger lines to trigger LLRF and diagnostics. To extend the number of outputs a rear transition module (RTM, see Fig. 1) can be attached to the EVRs which can be equipped with the universal output modules mentioned above.

The latest revision of the boards have a drift compensation functionality included which reduces the temperature introduced timing drift of the fiber connections between EVMs and EVRs. The performance of this mechanism is currently evaluated.

Figure 1: Micro Research Finland timing receiver rear transition board equipped with universal output modules.

The master EVM is synchronized to the accelerator RF by locking the internal oscillator to the 1.3 GHz master oscillator of ELBE. The reference is divided by ten inside the EVM to get the event clock rate of 130 MHz. With this rate timing events are distributed from the EVMs to the EVRs that can in turn react to them in a predefined manner to generate the desired signal pattern on the physical outputs.

ELBE is using a kicker to split the beam into two. For each beamline branch a dedicated bunch pattern will be generated and sent to the gun. A combined interlock and logic block interleaves the pulse trains and allows the machine interlock system to disable individual gun clock signals. In future, the machine protection will be able to react on interlock events after the kicker by only disabling the corresponding pulse train.

The timing system is capable of handling parallel injection of the two electron sources at a time. To make use of this feature the injector section at ELBE has to be modified to be susceptible for beams of different energy. This is a possible upgrade scenario to extend the multi-user capabilities of ELBE and is therefore foreseen in the new timing structure.

Software

The software is implemented using EPICS mrfioc2 [2]. It has been adapted to map the required operation modes like continuous wave (CW), macro pulsed and single pulsed beam into the system. The predefined operation modes simplify the operation of the timing system for the users and allow a high level of automated parameter setting which is an integral part of this development.

In single pulse mode a flexible pattern of bunches with a predefined number of repetition rates can be configured. This allows for example to adjust the irradiated dose to a biological sample with high granularity as requested by the user groups.

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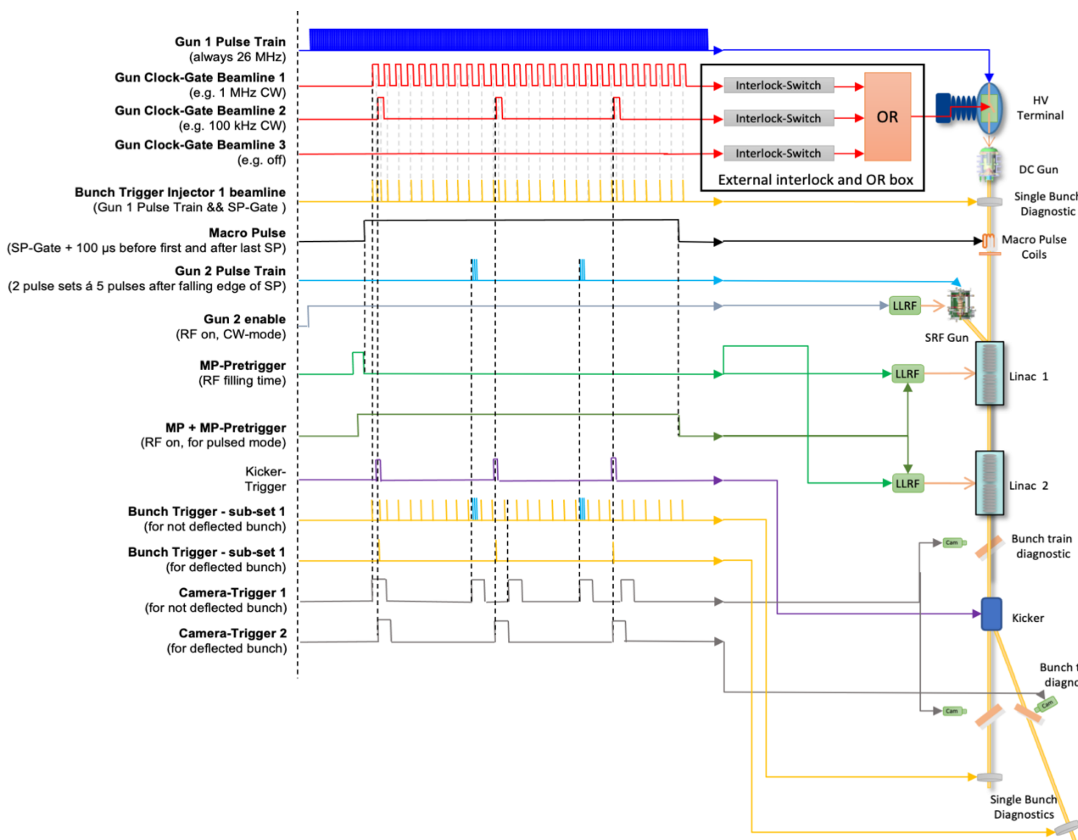

Figure 2: Example of a timing structure at ELBE using two guns and a subsequent kicker to generate complex bunch pattern.

The timing system can be configured using two graphical user interfaces (GUI). While the EPICS GUI is mainly for expert control and debugging, the main control is done by the WinCC SCADA system which includes all ELBE machine controls.

All machine parameters are checked by a master programmable logic controller (PLC) which acts as the main instance for machine protection. User commands and status signals from the timing system are processed and interlock signals are generated accordingly.

Pattern Generation - Example

Figure 2 illustrates an example of a more complex operation mode that could be applied after the timing system upgrade. Here both injectors emit electron pulses into the ELBE accelerator. A kicker is used to split the beam of the first gun into two beamlines. For each beamline section the corresponding gun emission triggers are generated and later the single bunch diagnostic triggers (e.g. for BPMs and ICTs) as well as the bunch train diagnostics (e.g. cameras).

The phase between the emission triggers can be set manually while the system automatically avoids gun emission triggers in the same RF bucket.

Output Jitter Performance

The output jitter of a universal TTL output module, installed in a EVR-RTM has been measured using an Rohde & Schwarz FSWP8. A jitter of 4.5 ps rms in an interval of 1 Hz to 1 MHz has been measured as shown in Fig. 3.

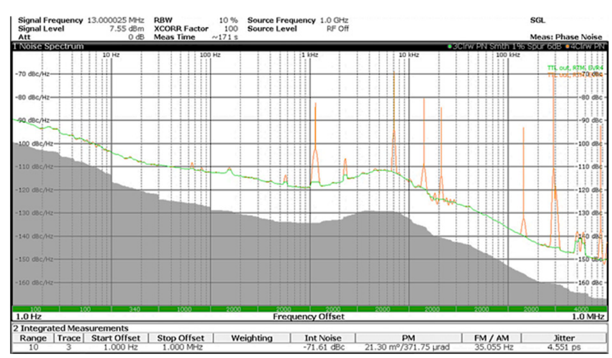

Figure 3: Output jitter performance of a TTL universal output module.

WORK IN PROGRESS

The system is currently under development on a test bench shown in Fig. 4. It consists of two MicroTCA chassis equipped with two EVMs and four EVRs. In addition, a computer system is set up to test the PCIe event receiver modules. The generated patterns are analyzed by three oscilloscopes.

The main operation modes are being implemented and debugged at the moment. For stand-alone operation a phoebus GUI has is constantly iterated which is used for the

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system development and will serve as an expert GUI when the system has been commissioned at ELBE.

Figure 4: Timing System test bench.

The GUI is shown Fig. 5 and enables the user to choose the gun injecting into ELBE, set up the bunch repetition rate and the three different operation modes. Output on the EVRs can be linked to the logic pulse patterns that have been defined. The system status is monitored and displayed for the individual hardware components.

In addition to the implementation of operation modes the hardware is being tested and the long term stability monitored.

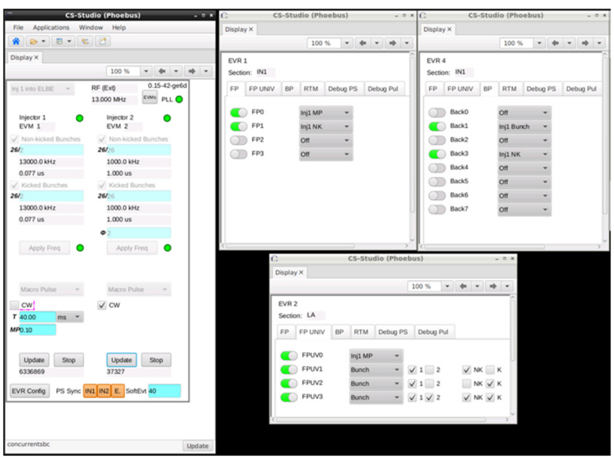

Figure 5: Timing System stand-alone GUI.

CONCLUSION

A new flexible timing system is being developed for the ELBE accelerator. The system allows flexible bunch pattern generation for two injectors operated in parallel.

The system is currently set up on a test bench which is used for performance tests and debugging. First tests with the ELBE accelerator are planned for later this year which will conclude into a stepwise transition from the legacy timing system to the new timing generation and distribution.

REFERENCES

[1] Micro Research Finlad Oy, `http://www.mrf.fi`

[2] EPICS mrfioc2, `https://github.com/epics-modules/mrfioc2/`.