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UPGRADE OF TIMING SYSTEM AT HZDR ELBE FACILITY

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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 timing system, that is currently in operation, has been modified and extended in the last two decades to enable new experiments. At the moment parts of this timing system are using obsolete components which makes maintenance a very challenging endeavour.

To make the ELBE timing system again a more homogenous system, that will allow for easier adaption to new and more complex trigger patterns, an upgrade based on Micro Research Finland (MRF) hardware platform is currently in progress. This upgrade will enable parallel operation of two electron sources and subsequent kickers to serve multiple end stations at the same time. Selected hardware enables low jitter emission of timing patterns and a long-term delay compensation of the distribution network. We are currently in the final phase of development and with plans for commissioning to be completed in 2022.

SYSTEM DESCRIPTION

Hardware

The new timing system uses hardware from Micro Research Finland [1]. MRF hardware allows a modular approach with highly flexible topology with event master modules (EVMs), which are responsible for timing event generation and distribution, and event receiver modules (EVRs), which are responsible for setting the state of a physical outputs based on the received event.

For the majority of the system hardware used shall be of the MicroTCA form factor wherever possible, but certain user/experiment stations will use PCIe cards, which allow for up to 10 trigger outputs in a smaller package and are more cost effective.

Each of the two ELBE injectors will have an EVM, which will be responsible for generating independent timing pattern, allowing for both independent operation in separate beamlines and also common emission into ELBE accelerator.

Beam diagnostics, low level frequency control (LLRF) and other devices that need coordinated triggering will be connected to the EVRs via MicroTCA backplane trigger lines (if device lives in the same crate as EVR and supports triggering on a backplane signal), front panel output (if TTL level is needed) or through any of the Universal Modules that provide variety of optical and electrical level triggers.

As the number of outputs is limited to 8 per EVR, 4 front panel TTL trigger signals and 4 signals from Universal Modules, MRF offers to extend the number of trigger signals via rear transition module (RTM), where 10 additional trigger output signals can be configured and routed. Type of the input or output signal from the RTM is determined by the type of the Universal Input/Output (I/O) module selected as shown in Figure 1.

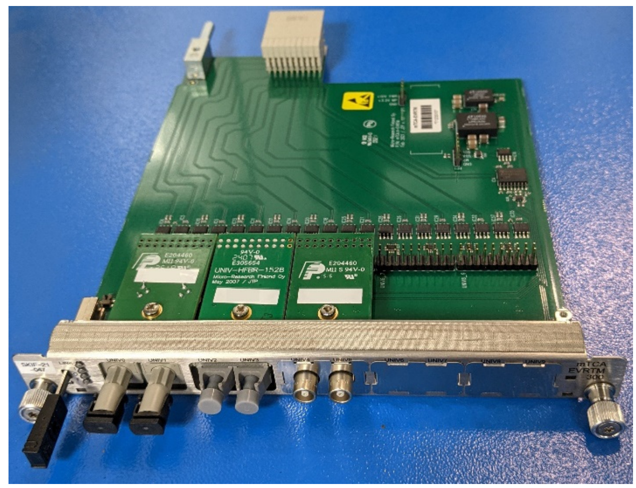

Figure 1: Micro Research Finland timing receiver rear transition module equipped with universal output modules.

All MRF boards (EVMs and EVRs) from the 300 series provide a delay compensation feature, where event propagation delay through whole distribution network is continuously measured and EVRs adjust their internal delay to match a programmed desired target delay. Each of the EVRs can have a different target delay setpoint, but adjusting target delay on an EVR will hold you back for approximately 15 minutes while the measurement and the loopback mechanism stabilizes.

To synchronize new timing system with the accelerator RF we plan to lock the internal oscillator of the master EVM to an externally provided frequency of 130 MHz through the dedicated input on front panel of the master EVM. This external reference frequency will be locked to both 1.3 GHz RF frequency and 26 MHz thermionic gun master oscillator and it will provide a 130 MHz event clock rate with which timing events will be distributed from the EVMs to the EVRs.

ELBE has multiple beamlines (as shown at Figure 2) but at the moment only one kicker is used to split the beam into two beamlines. For each beamline branch a dedicated bunch pattern has to be generated and sent to appropriate gun. A combined interlock and logic block interleaves the pulse trains and allows the machine interlock system to disable individual gun clock signals. As an upgrade to the machine protection system (MPS), an upgrade is foreseen where it will be able to react on interlock events after the kicker and only disable the corresponding pulse train.

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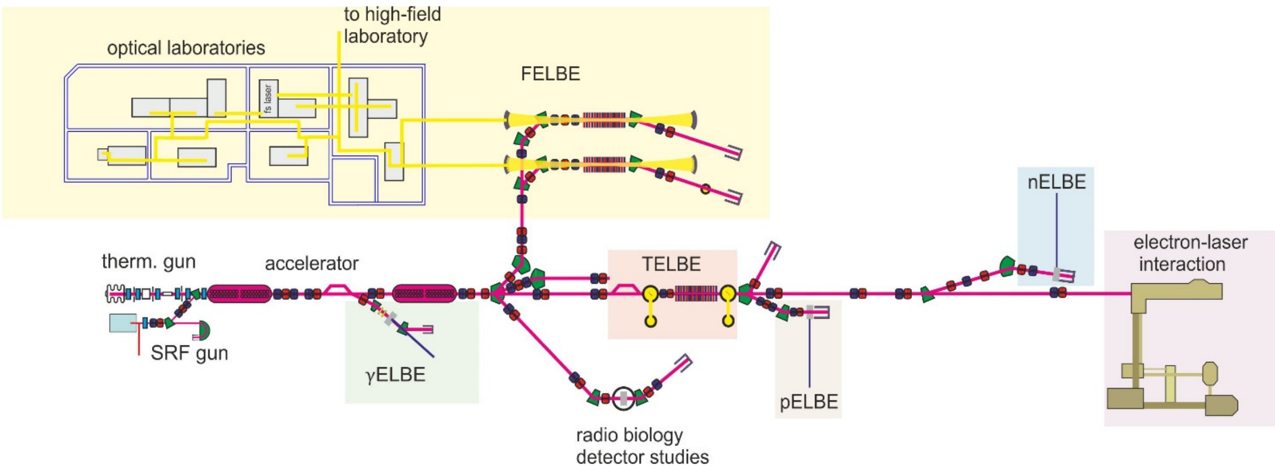

Figure 2: Topology of ELBE beamlines.

A possible ELBE upgrade scenario is to extend capabilities for simultaneous multi-user experiments; new timing system has a requirement to support parallel injection of the two electron sources. Selected timing hardware already has these capabilities. To make use of this feature to its full potential, injector sections of ELBE have to be modified to be susceptible for beams at different energy.

Software

Software for the new timing hardware is implemented in EPICS [2] control system framework with support of the mrfioc2 [3] and s7plc [4] modules. It allows a creation of required timing event patterns based on a requested operation mode, like continues wave (CW), macro pulsed or single pulsed beam. These predefined operation modes simplify the operation of the timing system for the end users, and allow for high level of automated parameter settings which is the core part of development effort.

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

All user entered machine parameters and operation mode dependent derivatives are checked by verification part of the timing software and by a master programmable logic controller (PLC) which is the main interface for MPS.

While in development a simulator written in Python is used to test connection and interaction between the timing system software and master PLC.

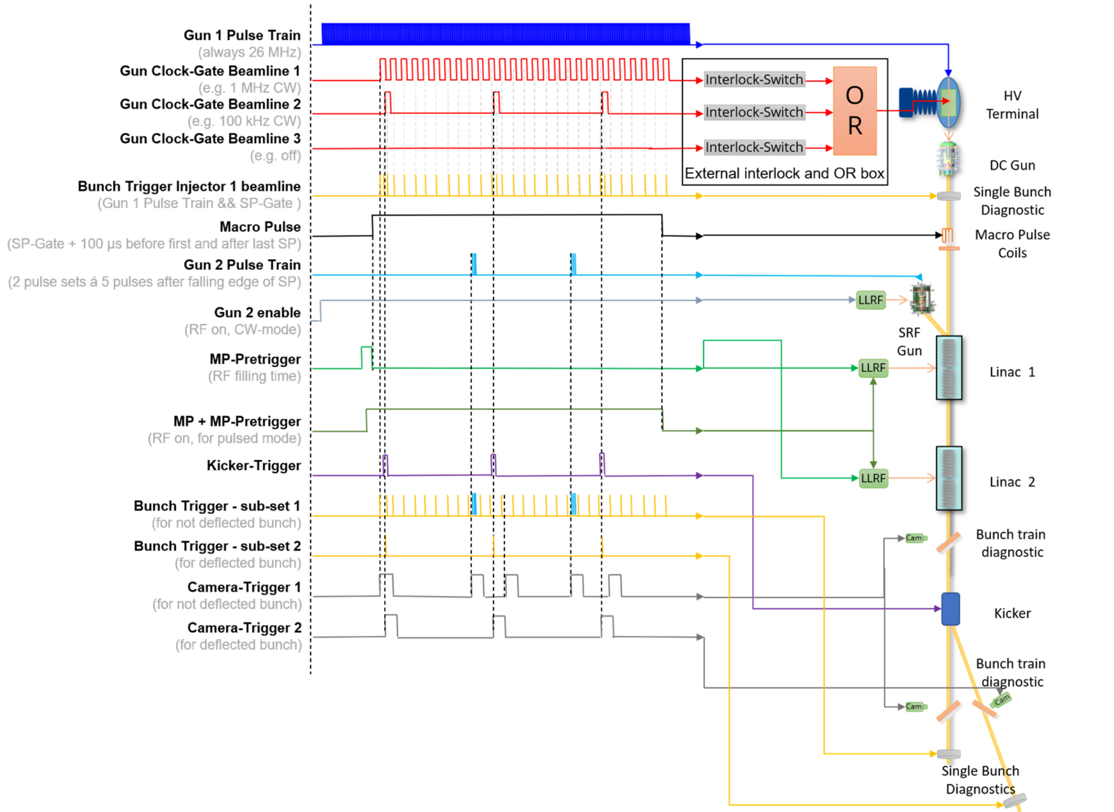

Figure 3: Example of a timing structure at ELBE using two guns and a subsequent kicker to generate bunch pattern.

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Figure 4: Output performance of a UNIV-LVPECL-DLY output module.

Pattern Generation - Example

Figure 3 illustrates an example of a more complex operation mode than 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 was measured with two different MRF Universal I/O modules, one with UNIV-LVTTL and second with UNIV-LVPECL-DLY module using a Rohde & Schwarz FSWP8.

Measurements with UNIV-TTL module show jitter of 4.5 ps rms in an interval of 1 Hz to 1 MHz, while measurements with UNIV-LVPECL-DLY module show jitter of 7.8 ps rms in an interval of 1 Hz to 1 MHz as shown in Figure 4.

WORK IN PROGRESS

The system is currently under development on a test bench. 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 analysed by three oscilloscopes.

The last of the main operation modes (dark current suppression, combination of macro pulse and single pulse) is being implemented and debugged at the moment. For stand-alone operation a GUI in Control System Studio GUI has been developed over many iterations and will serve as an expert GUI when the system has been commissioned at ELBE.

Main part of developed GUI is shown in Figure 5 and it enables the user to set up the timing system parameters through set of EPICS variables and also check what parameters are configured through WinCC GUI and under which what parameters timing hardware is currently operating. It also enables configuration of individual outputs on EVRs with selection of the predefined logic pulse patterns or with a pattern based on individual event, delay and width.

Status of the individual timing system hardware components is monitored and also displayed in dedicated GUI.

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

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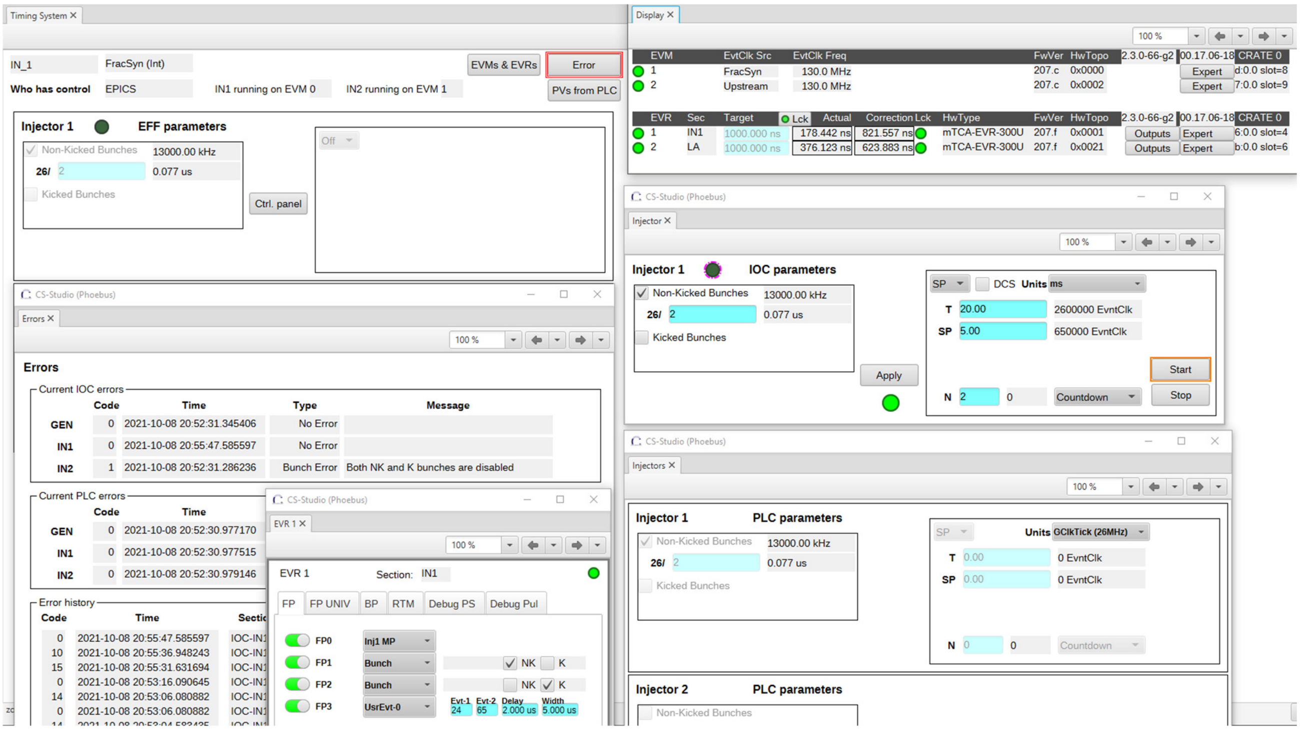

Figure 5: Timing system expert GUI.

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 beginning of next year which will then follow by a stepwise transition from the legacy timing system to the new timing generation and distribution.

REFERENCES

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

[2] EPICS – Experimental Physics and Industrial Controls System, `https://epics-controls.org`

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

[4] EPICS module s7plc, `https://github.com/paulscherrerinstitute/s7plc`