Computing at the VUV-FEL

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1 Introduction

A "Free Electron Laser" for wavelengths down to 6nm in the vacuum-ultraviolet and soft X-ray regime (VUV-FEL) is under construction using the unique electron beam properties of the Tesla (TeV-Energy Superconducting Linear Accelerator) Test Facility at DESY (Hamburg). It is operated in the "self-amplified spontaneous emission" (SASE) mode and delivers sub-picosecond radiation pulses, with gigawatt peak powers and wavelength tunability.

The light of the VUV-FEL is expected to be provided for the first user experiments in year 2005. The collection and analysis of the data from these experiments strongly depends on the software used not only at the experimental stations but also at the VUV-FEL facility, requesting comunication between the different computing systems in use. Information from the experiments must be correlated with that from the linear accelerator and electron and photon beams. The characteristics of the radiation generated at the VUV-FEL request this correlation to be done in a single bunch basis (with 9MHz frecuency).

This report describes the computing systems used at the VUV-FEL. The first section gives an overview of the main information that the VUV-FEL facility will provide to the users. The description of the computing systems and the interconnection between them will follow.

2 Information provided to the VUV-FEL users

The information provided to the VUV-FEL users coming from the facility can be divided into three blocks: parameters concerning the linear accelerator, properties of the electron beam submitted to the SASE proccess and properties of the photon beam generated by this proccess.

2.1 The Linear Accelerator (LINAC)

The MVP group at DESY is on charge of the control system for the Linear Accelerator at the Tesla Test Facility. The accelerator is foreseen to work in different operation modes, differing on the electron energy and bunch duration. In any of the modes the train repetion rate is intended to be up to 10Hz, with up to 7200 bunches per train and a 111 ns bunch separation (9MHz).

The information about any of these bunch trains will be packed using a 8 channels 10MHz ADC system with 14 bits resolution and 4 Bytes data words. This system will be mounted on VME crates read-out via Solaris SBCs (standard VME crates at the VUV-FEL). The data acquisition will be started by an external trigger controlled by the VUV-FEL timing system. The number of samples to take is programmable, typically 2048 samples will be taken with 1μs separation and 10Hz repetition rate, corresponding to 2ms reading every 100ms. The information packed at the ADC system contains a train identifier, a time stamp, the train repetition rate, number of bunches per train and bunch separation.

The full data sample recorded via the ADCs will be available online for the machine operators and the experiment users for every single bunch. This information can be used for control, display or calculations. Part of this sample (configured via a run controller) will be permanently stored on tape and accesible via dCache by local or remote users.

The above features make use of the VUV-FEL control system described in section 3.

In parallel to this, a train number, for unambiguous identification of every train, and an adjustable train trigger will be generated and provided to all the experimental stations via output registers. The train trigger will be distributed as a TTL signal (± 1ns jitter) and will make accessible the timing information for every train. Figure 1 shows the timing sequence at the VUV-FEL. All the shown timing signals are available to the user, being also possible a delay up to 20 ms of the main trigger. Events *A1* and *A0* will also contain information about the LINAC running mode, the first one determining if there will be no beam, or beam with a single bunch, interrupted bunches or a full bunch train, and the second one confirming or not this expected running mode.

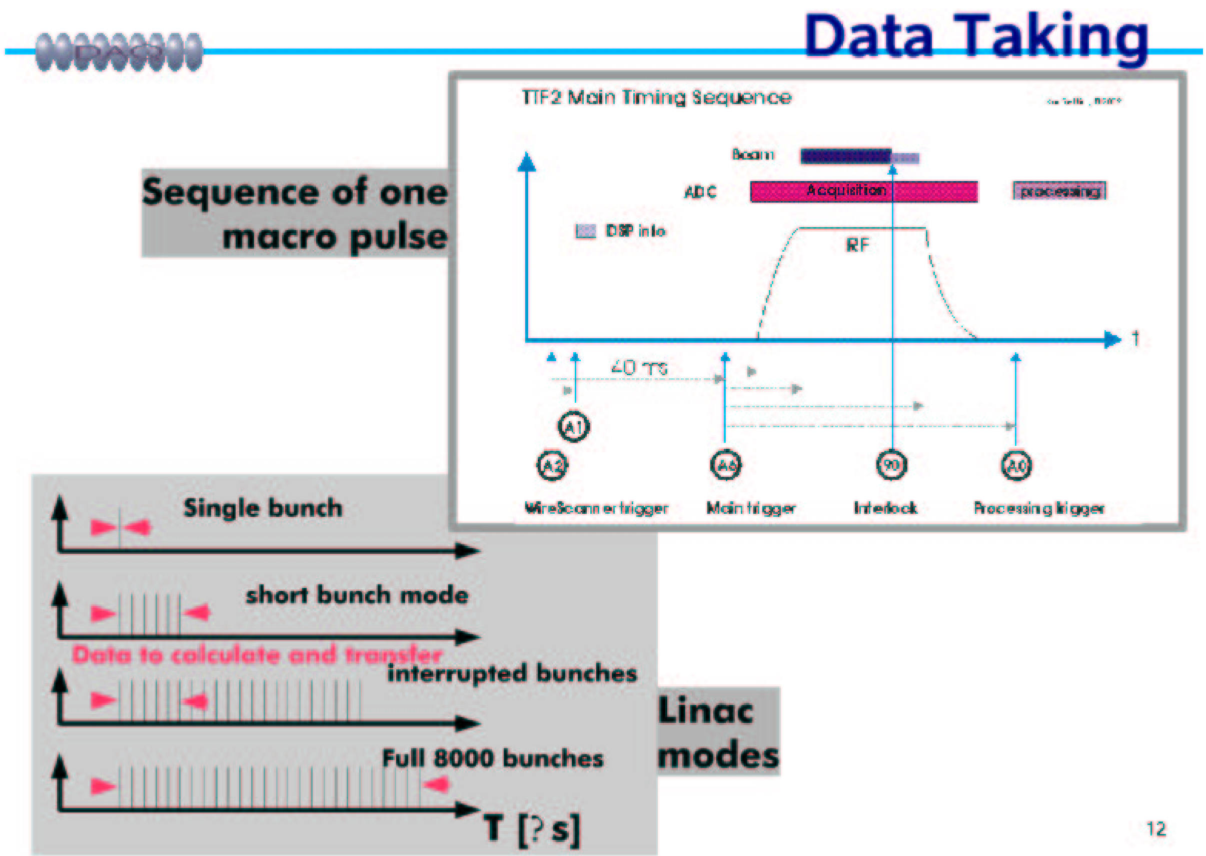

Figure 1: Timing sequence at the VUV-FEL.

A bit pattern generated by the VUV-FEL users can be added to the rest of the bunch information via an input register, and it will be read-out, provided and stored with the rest of the train parameters.

2.2 Electron Beam Diagnostics

A set of devices is installed along the LINAC in order to characterize the electron beam and contribute to the control and understanding of the accelerator operation. These devices allow absolute measurements of the electron beam and lattice properties, as well as, relative measurements for monitoring the accelerator stability and setting-up the injector in a reproducible way. The measured electron beam properties include beam charge and transmission, beam position, beam transverse density and profiles, energy and energy spread and bunch length.

The Electron Beam Diagnostics system makes use of the same ADCs described in the previous section, hosted in VME crates, and of the same computing facilities developed by the MVP group. The total number of ADC channels is about 800. In addition, several hundred slow values will be stored on tape.

2.3 Photon Beam Diagnostics

A new concept of Photon Beam Diagnostics has been developed in order to measure the unique properties of the VUV-FEL radiation from the SASE on a single bunch basis. The performed measurements will be packed in the so called Photon Beam Diagnostics Record. This record will contain the electron signal and ion current coming from a gaseous detector, the beam position in both transversal coordinates, the spectrum and wavelength, as well as timing information for pump and probe experiments. The electron signal (changing in a single bunch basis) allows a relative measurement of the photon intensity, while the slower ion current will allow the calibration of this signal for getting the absolute intensity.

The Photon Beam Diagnostics will be mainly hosted in VME crates of the LINAC control system but it will also make use of the computing system developed at the Hamburger Synchrotronstrahlungslabor (HASYLAB) in DESY-Hamburg, described in section 4.

The electron signal will be also optionally provided for every single bunch via output register to every experimental station.

3 VUV-FEL control system

The MVP group is in charge of the control system for the VUV-FEL. The VUV-FEL is an international project, using different hardware and software components provided from the collaborating institutes around the world. This requires a common control system, which enables the integration of the different software protocols. In addition to the operation and control of the VUV-FEL, contributing to the improvement, better understanding and maintenance of the LINAC, the control system should also satisfy the requirements of the experiments that will make use of this laser facility. From this point of view, the main aims of this system are:

- Collect and store all relevant parameters of the LINAC, Diagnostics systems and optionally of the user experiments.
- Provide this data online for LINAC operators, expert/accelerator physicists and users.
- Provide the stored information to local or remote users.
- Provide the tools to retrieve the information online and offline.

- Provide the offline analysis tools to local and remote users.
- Allow experiments to correlate their data with the LINAC.

The information has to be, moreover, provided and correlated in a single bunch basis (9MHz) due to the characteristics of the radiation generated by a SASE proccess. A VUV-FEL Data AcQuisition system (DAC) based on DOOCS (a Distributed Object Oriented System developed by the MVP group at DESY and run on Solaris and Linux, and has an interface to Windows) is under development to satisfy these requirements.

Figure 2 shows the architecture of the DAQ. Every particular hardware device at the VUV-FEL is handled via a so called DOOCS device server. This single software unit controls the device, retrieves the device data and provides it to the network. The collection of the data from the hardware is triggered by events from the VUV-FEL timing system. Data from these servers are collected for being transfered to a central DAQ server. This collection can be done by "fast collectors", for every single bunch, or by "slow collectors", in case of properties not changing in single bunch basis. The collectors are storing the data in a shared memory for further processing. A data rate of $\approx$ 100MB/sec is expected at the DAQ collector. From the shared memory a portion of the data is send via TCP stream to a event builder for the offline storage. These data in the shared memory are also accessible for on-line displays (DOOCS clients, which can request data directly from device or middle layer servers), and for control loops or calculations (DOOCS middle-layer servers, which can also send data itself for storage).

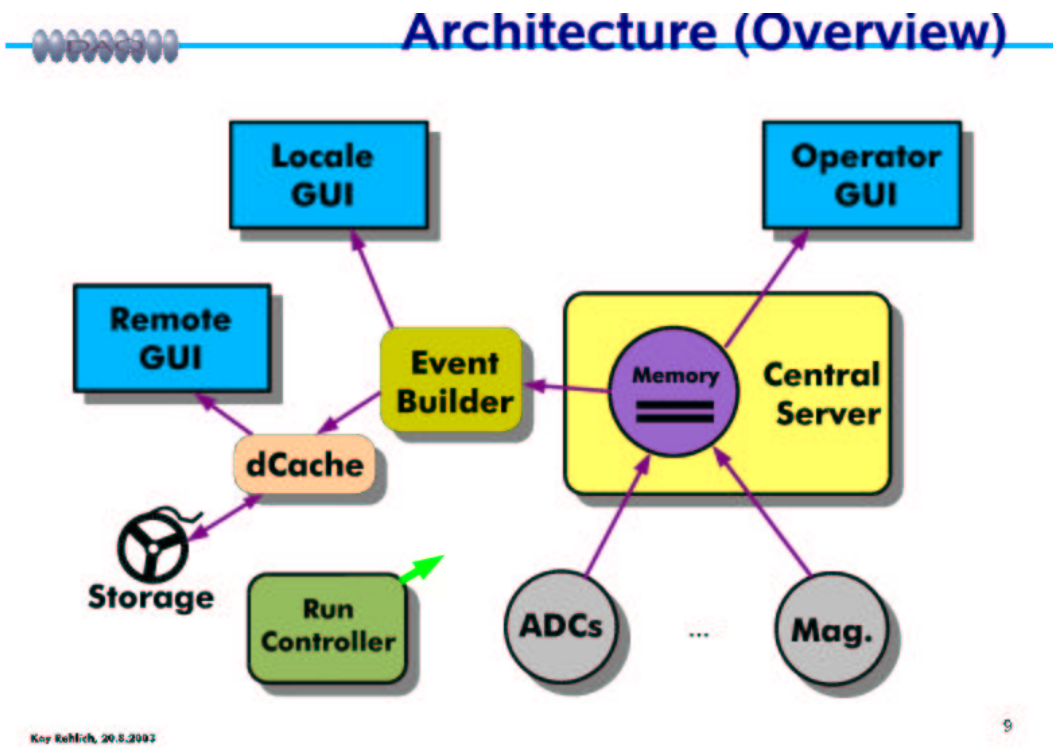

Figure 2: Architecture of the DAQ at the VUV-FEL.

The dCache will take care of storage and retrieving of the data, with a common interface for local and remote users (via dCap, GRID, Ftp and pnfs where applicable). It connects to the eventbuilder through a distributor which provides the event data stream in ROOT file format, being this the only storage format. ROOT is an Object Oriented Data Analysis Framework developed at CERN and extensively used by the HEP community. It provides a C++ class library and interactive C++ interpreter for commands. The dCache has a ROOT interface, being possible to link its library directly to ROOT tools. The data rate transfered to the dCache after filtering will be $\approx$1.2MByte/sec and the dCache will also provide an online disk for the most recent data ($\approx$ 500GByte).

The parameters for configuring this system are set and distributed via a Run Controller, allowing to select the maximum number of possible bunches in a train, the ADC sampling rate (1 or 9 MHz), the repetition train rate (1 ... 10 Hz), the increment of samples, samples for calculating a mean value and the samples to be read before and after the bunches. It also specifies the amount of data to be sent to the central server for the online monitoring and storage. The Run Controller communicates with the central server, the device servers and also with the Linear Accelerator.

A DAQ Browser will be provided by the MVP group for accessing the stored data. It will read the operation overview from status/index files in order to select a time range of interest, allowing also filtering of the selected data. The defined channels from these selected data sets will be read from ROOT files, making them accessible for analysis and generation of different plots (time domain, correlations, histograms, ...).

It is also foreseen to create a Quality Monitor for reading permanently a certain fraction of the data, check the LINAC performance and alerts the operator on deviation from "normal" status.

4 The HASYLAB computing system

The VUV-FEL will make profit of the software developed at HASYLAB, that is already in use in many of the experimental stations at the PETRA and DORIS accelerators at DESY (Hamburg).

The standard HASYLAB online system consists of Linux PCs, VME crates and GPIB and CanBus interfaces. This software allows controlling the devices and retrieving data from them, with the following PC interfaces avalible to the user:

- Command line, Perl and PerlTk graphical interfaces for interactive sessions.
- Communication via sockets.
- DOOCS server. The communication with the hardware will be done using the HASYLAB software integrated into a DOOCS server, taking profit of the advantages of the VUV-FEL control system related to provide, store or display information. This alternative is required for those devices controlled via the HASYLAB software that has to be accessed for the LINAC operators or to be included in the general DAQ.

At the VUV-FEL, the mirrors, the PGM monochromator and part of the devices performing the Photon Diagnostics will make use of the HASYLAB software. This software will be also available for controlling additional hardware at the experimental stations.

5 The VUV-FEL experimental users computing system

The users of the VUV-FEL facility will develope their own software for controlling their experiment, collecting and storing the data. The trigger signal and train number provided by the MVP group in output registers can be integrated to their own systems for starting the data collection and synchronize the experimental data to the data collected by the general DAQ, respectively. The users can also send a bit pattern that will be collected and included in the VUV-FEL DAQ system.

The online access to the data from the VUV-FEL can be done by DOOCS clients (or using the offered DAQ Browsers). The MVP group will provide examples of these clients for Windows and Linux operation systems. DOOCS supports interfaces to Lab-View, Matlab and ROOT.

Information from the experiments can also be included in the DAQ system by developing DOOCS servers, or using servers already developed by the MVP group for the own experiment devices (severs for different device types are available).

6 Services offered to the VUV-FEL users

As it was already shown in the previous sections, different services will be provided by the DESY groups to the researchers to make efficient use of the VUV-FEL facility:

- A central DAQ server, together with specific DOOCS device servers, provide all the LINAC parameters and the information from the Electron and Photon Diagnostics to the users. The access of the full sample can be done online for every bunch via DOOCS client (API). Examples of DOOCS clients for Linux and Windows, will be provided. The offline access to the stored data for local or remote users can be done via DAQ (dCache). A DAQ Browser will be also available for that purporse.
- A `train number`, for unambiguos identification of every bunch train, will be distributed via output registers in VME crates.
- A `train trigger`, providing timing and LINAC mode information, will be distributed as TTL signals.
- A user generated bit pattern (`user marker`) can be fed into input registers and read by the common DAQ system..
- A mass storage on tape OSM for user collected data available (DESY IT group).
- The possibility of integrating and storing data from the user experiments via the common DAQ is also offered, implying the development of DOOCS servers for the own devices or by using ADCs with a standard DOOCS server.
- A Switched Ethernet network (local bandwidth 100Mb, 2Gb to central switches in the DESY computer center) is available at the experimental stations.
- The data for analysis (at home institutes) can be transfered via the WAN (bandwidth: current 155Mb, future 622Mb) or recorded on DVDs or CDs.

7 Conclusion

A control system for the VUV-FEL facility is under development based on DOOCS, a distributed object oriented system developed at DESY mainly for the TTF. This system offers a high flexibility for the integration of different hardware devices and software protocols. It handles the control of every particular devices and provides and stores the parameters from them retrieved. The synchronization of the different data sets (LINAC, diagnostics and experiments) in a single bunch basis is enabled by this system. The VUV-FEL will make also use of the Hasylab computing system, already in use at the experimental stations at the PETRA and DORIS accelerators in DESY.