ORBIT DATA PROCESSING USING THE DATA ACQUISITION SYSTEM (DAQ) AT THE TTF VUV-FEL

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Abstract

At the Vacuum Ultraviolet Free Electron Laser TTF VUV-FEL located at DESY 66 Beam Position Monitors (BPMs) registrate the deflection of the electron beam. To make the huge amount of these *orbit* data manageable for the operator a server program processing the orbit data (*Orbit Server*) is implemented. As a part of the TTF VUV-FEL DAQ it reads the data from a central data pool, the Shared Memory (SHM). Besides this, it computes on request other parameters of the beam, for example temporal trends or the beam position scattering at the BPM locations. The application of the SHM concept is an example, which proofs the benefits of using the SHM technology for accelerator controls.

A corresponding *Orbit-Display* acts as the operator's graphical interface. It mainly shows the orbit data, provides zoom functions in all three spatial dimensions and enables the operator to adjust the pre-processing done by the Orbit Server.

INTRODUCTION

The TTF VUV-FEL at DESY is a linear electron accelerator with an undulator system to produce laser pulses of never reached qualities. In addition it is a test facility for future linear accelerators as the X-ray Free-Electron Laser XFEL [5] or the International Linear Collider ILC.

Besides the complexity of the TTF VUV-FEL setup, high demands on the qualities of its laser pulses require sophisticated beam analysis. Especially the diagnostics of the beam trajectory (*orbit*) plays an important role. This diagnostics has to be fast, detailed but nevertheless easy and flexible to adjust by the operator.

To meet this goal, an *Orbit Server* program processes the BPM data. It provides the orbit of single bunches, spatial correlations, temporal orbit developments etc. to the operators and represents a middle layer module of the TTF VUV-FEL Distributed Object-Oriented Control System DOOCS. For fast data transfer it reads the BPM data from the central SHM (a unix interprocess communication facility) of the DAQ and performs on request different averaging procedures.

REQUIREMENTS

Following the approach to use the TTF VUV-FEL as a test stand for accelerator modules as well as an operational light source the entire setup has to provide flexibility as high as possible. In addition, the electron beam has a timing of high complexity. It consists of charge packets (*bunches*) with ≈ 1 nC charge, generated with a *bunch frequency* of currently 1 (later 9) MHz. However, a sequence of bunches is restricted to time intervals of a few hundred μs duration due to RF power limits. The frequency of these *macropulses*, the *repetition rate*, is adjustable up to 10 Hz. Each combination of the bunch - and the macropulse frequency may be selected. In addition, the linac of the TTF VUV-FEL can be operated in several modes, corresponding to the usage of different sections of the vacuum pipe. It has two sections for reducing the longitudinal bunch length (*bunch compressors*). Furthermore a line parallel to the undulator section is installed (*bypass*) to avoid unnecessary load of the undulators if no lasing is required. Each of these lines independently may be used or not. Fig. 1 gives an overview of the TTF VUV-FEL setup.

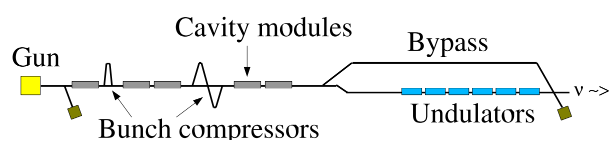

Figure 1: Sketch of the TTF VUV-FEL linac. The length from the gun to the main dump is 255 meters. A total of 66 BPMs are mounted.

All these cases of usage of the accelerator have to be covered by the control system. Especially the orbit has to be measured and handled very flexible where preservation of the accuracy has to be kept in mind at the same time.

THE ORBIT SERVER PROGRAM

To meet the demands described in the previous chapter a dedicated program, the *Orbit Server*, has been implemented. Located between the hardware serving layer and the user interface layer of the control system it represents a DOOCS *middle layer server* (see also Fig. 2 and [1]). A further example of a DOOCS middle layer server which uses the DAQ can be found in [4].

The Orbit Server is based on three main conceptual approaches:

- It is a standard *DOOCS server* program to allow easy exchange of auxiliary data as the current linac operation mode or the status of the BPMs.

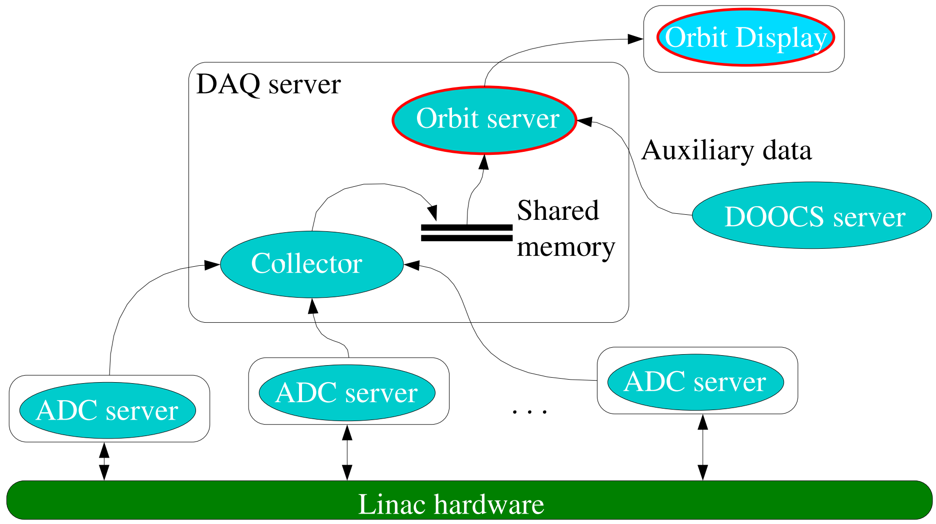

Figure 2: Data flow of orbit data at the TTF VUV-FEL.

- It reads the BPM signals from the *Shared Memory* data pool of the TTF-DAQ for fast access. As soon as the data are ready to read they are already synchronized. The reading is *event-driven*, no polling is necessary.

- It can be steered from outside by a build-in *Finite State Machine (FSM)* to allow its coordination with the other actors of the control system. This enables a central instance (*Run Control*) to coordinate the process with the other actors of the control system an thus for example to perform management of the computer resources.

In that way it undertakes the task of treating the data in the following ways:

- It *stores* the data of previous macropulses in a ring buffer.

- It provides *flexible averaging* of the data in the manner shown in Fig. 3 to reduce the data amounts.

- It calculates *temporal developments* (*trends*) of the orbit.

To save CPU time the calculations are only done on request of client programs. The parameters specifying the subset of measurements to be averaged are transmitted to the Orbit Server together with the request.

Fig. 3 shows a scheme of the averaging algorithm, which is the main charge of the Orbit Server program. `M1, M2` and `N_A` are names of standard DOOCS server properties to put in the values for the position and size of the averaging window. `X, X_MEAN, X_BT_MEAN` are names of standard DOOCS server properties which are read by a client after processing. They symbolize the orbit of the first bunch in the last macropulse (`X`), the average over the last macropulse (`X_MEAN`) or the average over the sliding window containing also measurements of the recent macropulses (`X_BT_MEAN`).

A diagram to illustrate the integration of the Orbit Server process in the DAQ of the TTF VUV-FEL is shown in Fig. 2. The data flow reaches from the DOOCS ADC servers, operating the linac hardware, via a DAQ collector process receiving the data. The collector process writes the data into a memory area shared by different processes. Since several processes share the data kept in the memory the network traffic is reduced significantly. In addition, the processes using the data are only

triggered when all data they are particularly interested in are available. Hence, no polling is necessary.

A detailed description of the DAQ can be found in [3].

THE ORBIT DISPLAY

Fig. 4 shows a screenshot of the *Orbit Display* acting as the user interface to display the results of the Orbit Server. There are a number of options to steer the appearance of the orbit plots. The operator can exclude single BPMs from being displayed or may zoom in to show only parts of the linac in a higher resolution. Furthermore, the operator can select the position and size of the averaging window, see Fig. 3, hence, steer the Orbit Server. In addition the scale and region of the orbit plots vertical axes can be adjusted, showing the transversal position of the beam. The Orbit Display is written in *ROOT*, a collection of C++ classes for data handling and graphical user interfaces [2].

CONCLUSIONS & OUTLOOK

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To process the orbit data of the TTF VUV-FEL an Orbit Server program as well as an Orbit Display have been

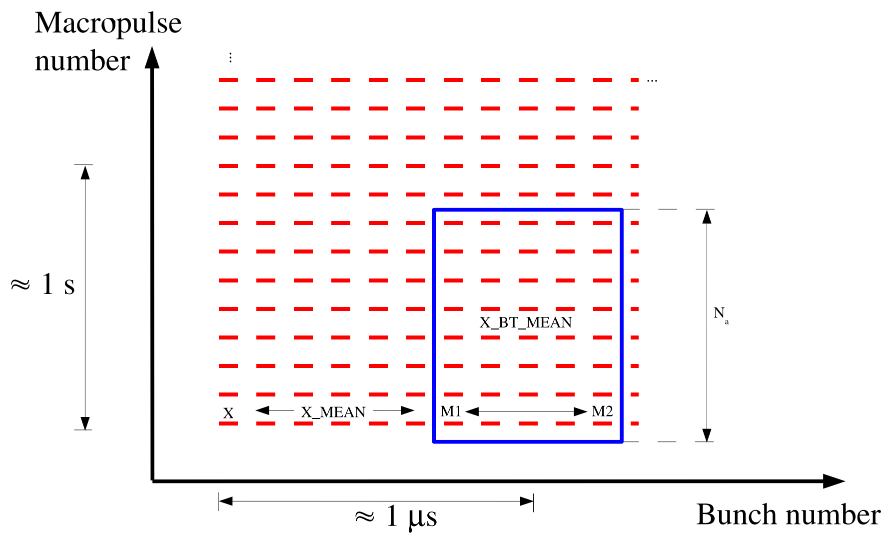

Figure 3: The main function of the Orbit Server program. It shows the processing of one beam position dimension (x or y) measured at one BPM. On the horizontal (time-)axis the sequence of the single bunches of a macropulse is symbolized where the vertical (also time-)axis shows the progression of the macropulses. Upon request, the average of the sliding window containing a subset of all stored data is calculated and provided to the requesting client program.

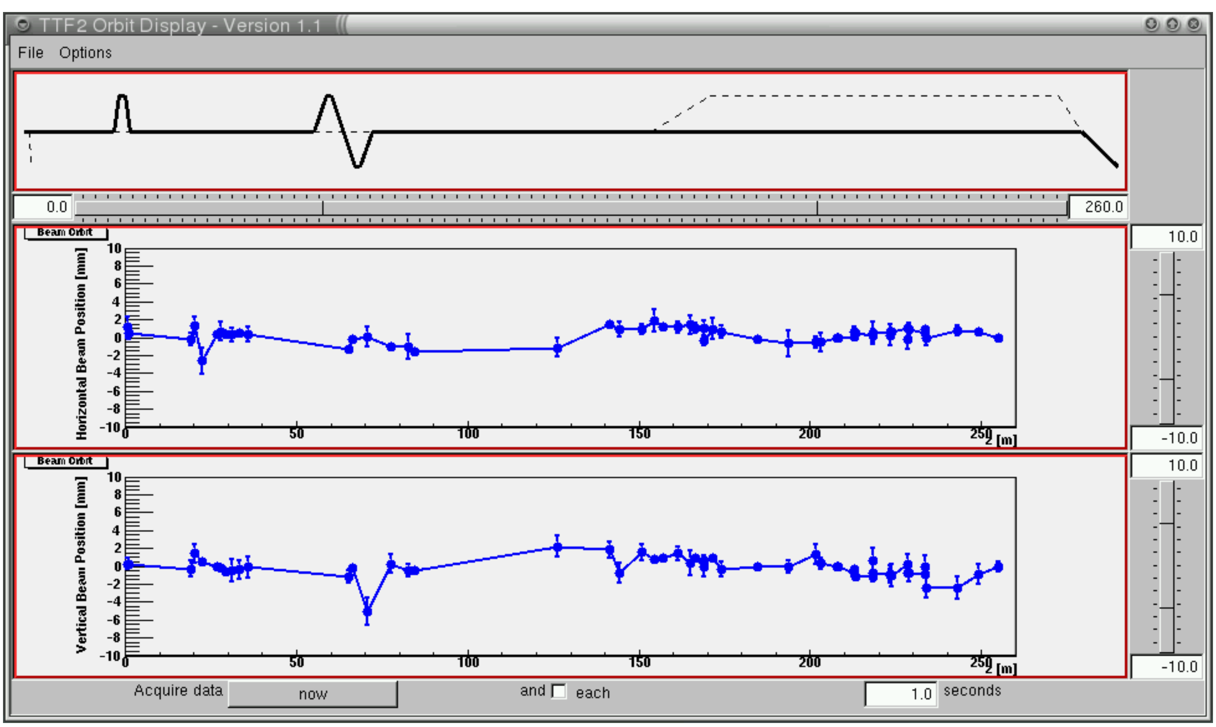

Figure 4: Appearance of the Orbit Display. The upper part shows a sketch of the TTF linac while the lower two graphs show the horizontal respectively vertical beam positions at the BPM longitudinal positions. In all dimensions (longitudinal, vertical and horizontal) the sliders allow flexible selection of regions the operator is interested in. In this case the bunch compressors are switched on and the undulator section of the linac is used (marked with the bold line).

designed and implemented as an integral part of the control system DOOCS. The Orbit Server reads the data from the shared memory pool of the Data Acquisition System of the TTF VUV-FEL and performs an on-line adjustable averaging of the orbit data. In that way data reduction is done while at the same time the flexibility for the operator is preserved. In addition the Orbit Server computes other parameters as the temporal trend of the orbit. This is done by analysing the data of the previous macropulses stored in the Orbit Server's buffer.

The Orbit Display, as the interface to the operator, shows the orbit data, allows adjustment of the region of interest in all dimensions, in the longitudinal as well as both transversal dimensions (*zooming*). Additionally, it can be used to set the parameters of the averaging process done by the Orbit Server.

OUTLOOK

There are a number of useful algorithms which are planned to be implemented in the Orbit Server respectively the Orbit Display. For example a calculation of the correlations between the BPM signals can help to find sources of disturbances. In that manner the sources of possible fluctuations of the beam energy could be found by correlation of the orbit data in dispersive sections. The requirement for these calculations, the availability of the orbit data of the recent seconds or minutes, is already met by the Orbit Server as it already buffers these data for averaging.

A major extension of the Orbit Display is the planned introduction of storage and reloading of reference orbits. By this means, the operator is enabled to store the orbit when the linac runs in an optimal state (*golden orbit*) which then can be used as a reference after changes of the linac. The golden orbits might furthermore be a base of orbit correction methods.

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