An orbit feedback for the Free Electron Laser in Hamburg (FLASH)

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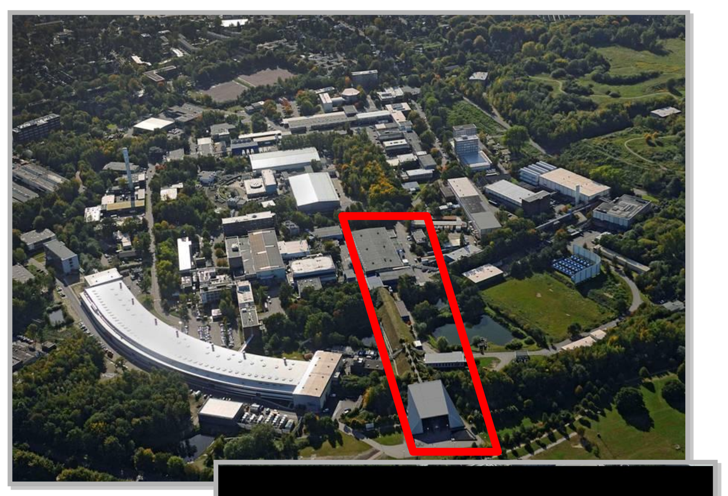
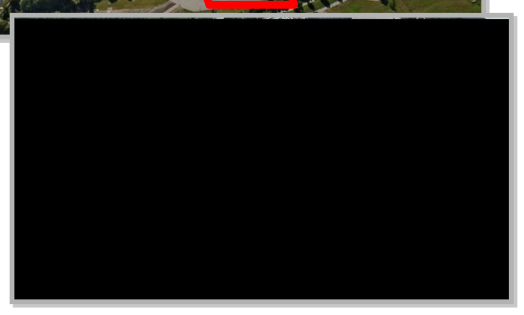
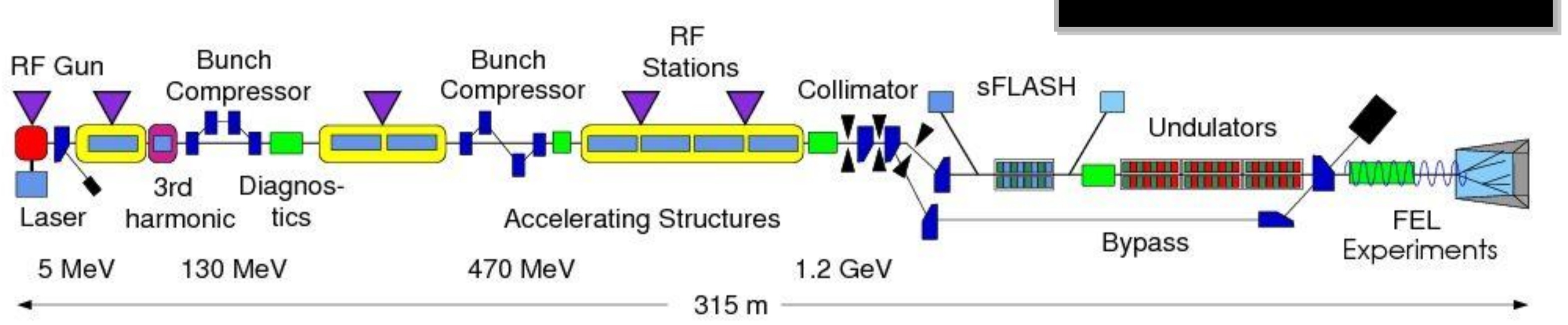
The Free electron Laser in Hamburg (FLASH)

FLASH the Free electron laser (FEL) in Hamburg at DESY (Germany) produces laser light of short wavelengths from the extreme ultraviolet down to soft X-rays. The reached peak brilliance is one billion times more intense than that of the best synchrotron light sources today.

FLASH is a high-gain FEL which achieves laser amplification and saturation within a single pass of the electron bunch through an undulator. The tolerances to achieve the lasing within the undulator structures are very tight so that precise energetic and spatial control of the electron bunch is the crucial step of the process.







Architecture and data flow

DOOCS as basic software infrastructure

Since the most widely used control system at the FLASH facility is the Distributed Object Oriented Control System (DOOCS) [2] the logic choice for the orbit feedback was to implement this software using C++ and the existing DOOCS application-programming interface (API). DOOCS offers a natural mapping of the monitors (BPMs) and correctors (steerers) to C++ objects, which significantly eases working with the multiplicity of devices, and thus understandability of the code.

Optics Toolbox

In standard operation the machine optics and hence the beam transfer matrix will not change. Therefore we excluded the determination and manipulation of the transfer matrix from the core feedback function and instead used the well-proven optics functions from the *optics toolbox* used at FLASH [3]. The Matlab functions of this toolbox are used to create the inverse response matrixes and stores these in files, which are read by the orbit feedback (see middle figure).

The orbit server

The actual beam position is not directly read from the front end servers, but instead from a server instance called *orbit server* as shown in the figure. This server is pre-processing the data to e.g. calculate the intra bunch train averages or statistical values for the BPMs.

The orbit server itself is embedded in the FLASH data acquisition system (DAQ), from where it collects the BPM readings (for details about the DAQ system see e.g. [4]).

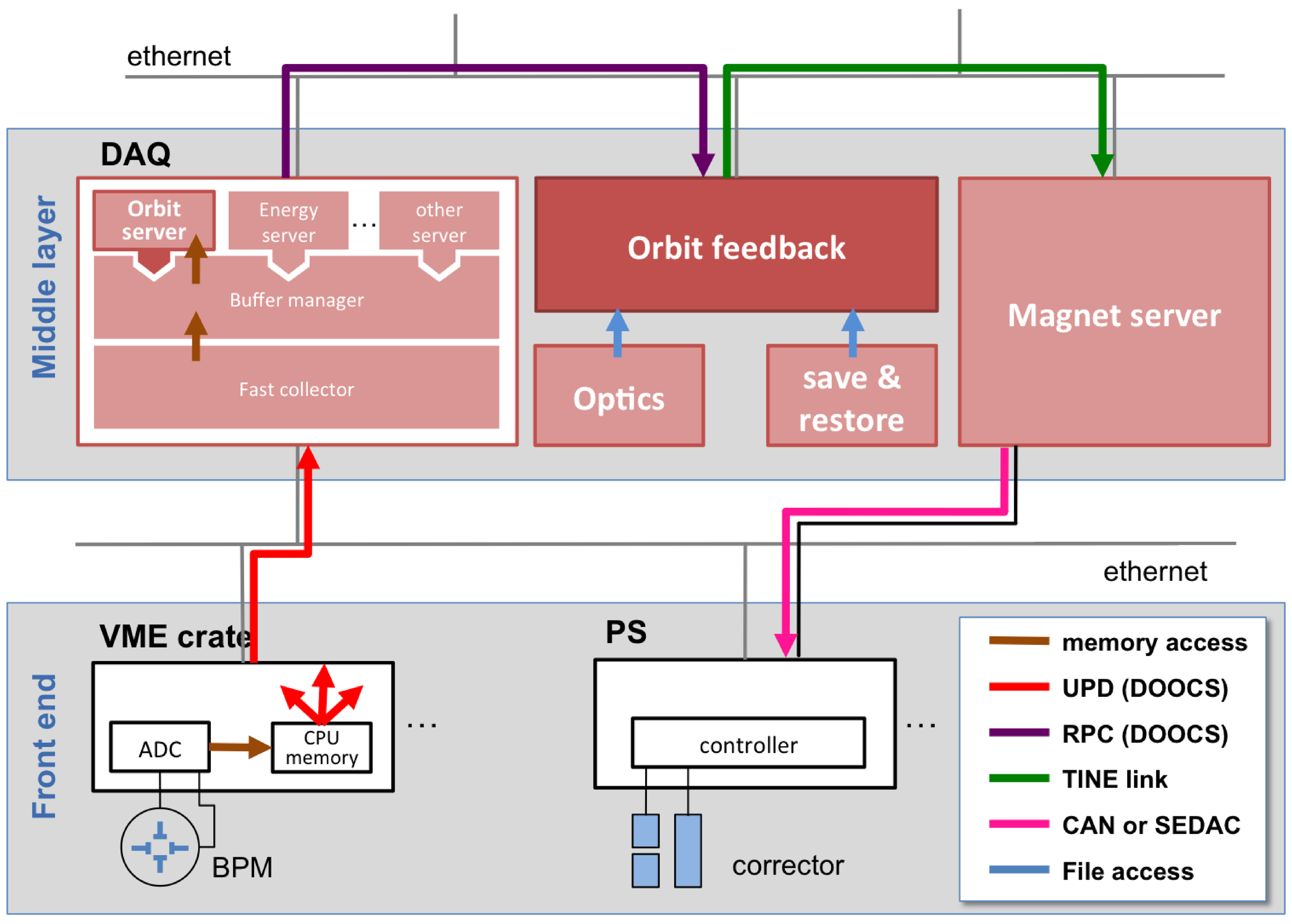
Motivation

The task of stabilizing beam jitter, as it is the case at most synchrotron radiation facilities, is of less importance for a linear accelerator.

Instead of this the main objectives for an orbit feedback at a linear accelerator are to:

- **restore** saved **orbits**
- **compensate** long term **drifts**
- **stabilize** the orbit **while tuning**
- making **localized** orbit **changes**

For FLASH it is even further envisioned to change the today practice of using individual steerers (dipole magnets) to tweak the orbit at a certain position along the machine, but instead of this modify beam positions using the orbit feedbacks target values at this desired position.



The orbit feedback

The response matrix provided by the optics toolbox are read from files into the orbit feedback.

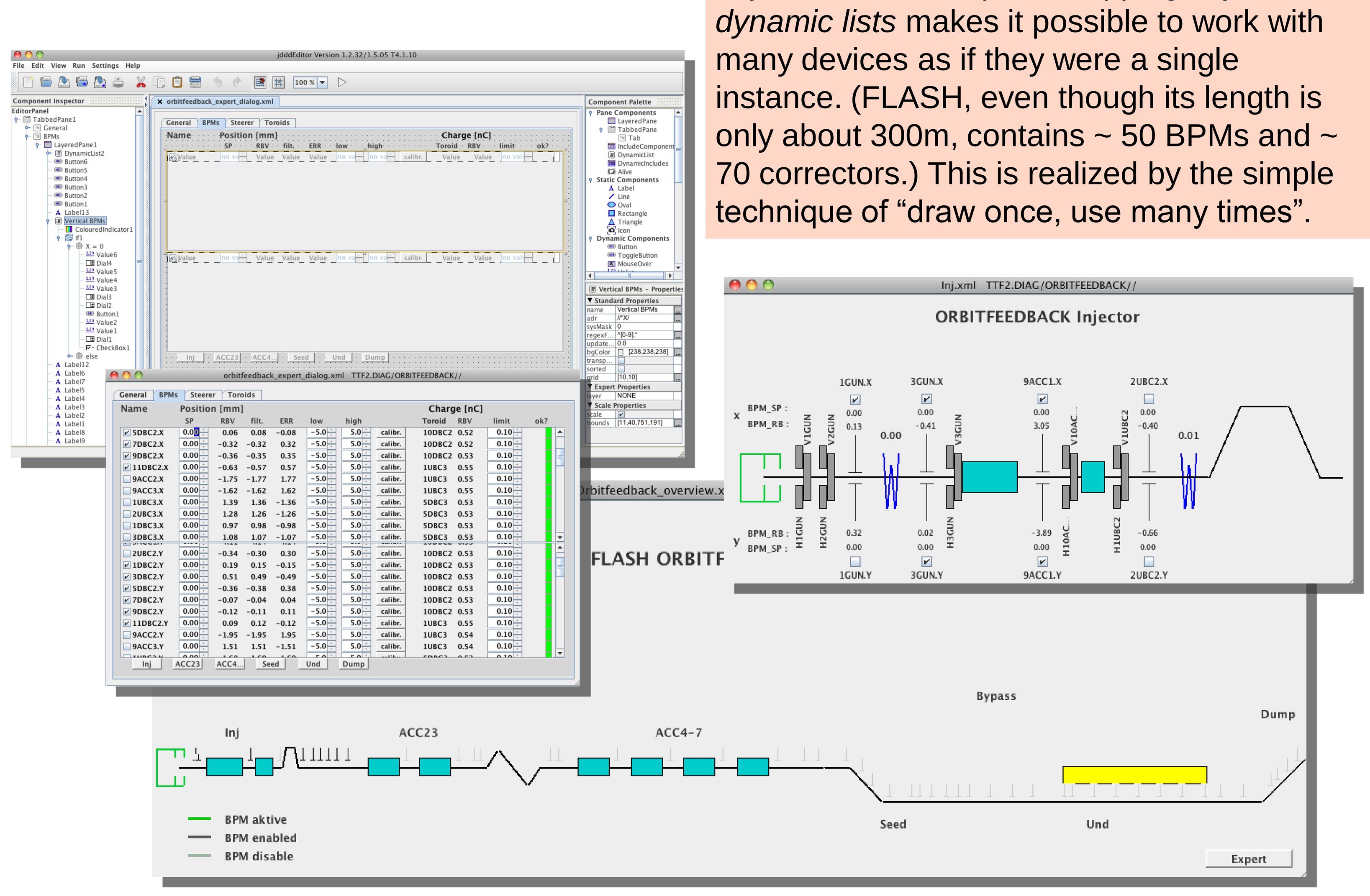
The orbit feedback uses standard DOOCS RPC communication to collect BPM data and perform the calculations needed to create the corresponding vector of corrector setpoint changes. The updated corrector setpoints are written to the TINE-based magnet server, which distributes them to the relevant power supply (PS) controllers (for TINE see [5]).

The management of the reference orbits (vectors of setpoint values) will be handled through the existing FLASH Save and Restore system.

The display level

Java DOOCS data display jddd [6] is used for monitoring and control of internal states of the orbit feedback server.

Defining BPMs and steerers as DOOCS objects and subsequent mapping to jddds *dynamic lists* makes it possible to work with many devices as if they were a single instance. (FLASH, even though its length is only about 300m, contains ~ 50 BPMs and ~ 70 correctors.) This is realized by the simple technique of “draw once, use many times”.



Basic schema for a linac attached orbit feedback

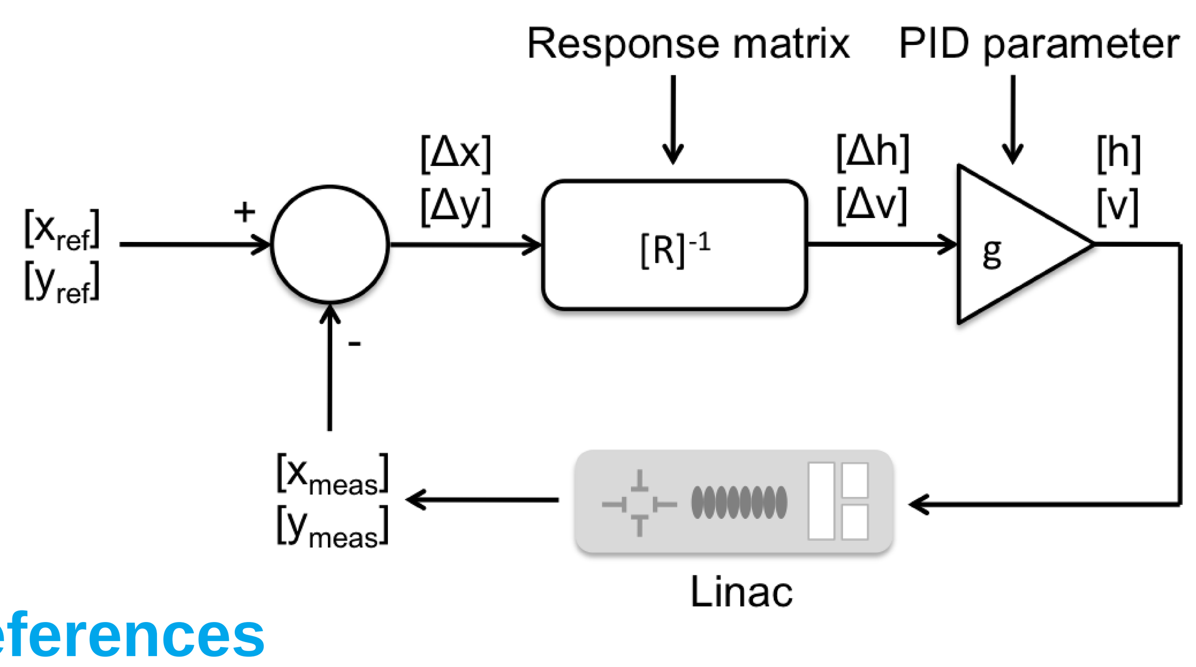
The basic principle of the FLASH beam based orbit feedback follows the standard techniques as e.g. described in [1]. A linear response matrix (**R**) describes the action of small changes ($\Delta\mathbf{I} = [\Delta\mathbf{h},\Delta\mathbf{v}]$) in the corrector magnet fields (dipoles) on the beam position ($\Delta\mathbf{X} = [\Delta\mathbf{x},\Delta\mathbf{y}]$) measured at the beam position monitors (BPMs).

$$\mathbf{R}\,\Delta\mathbf{I} = \Delta\mathbf{X}$$

Inverting the response matrix allows to derive the needed values to be applied to the correctors to yield a certain change in the beam position. In cases of unequal numbers of BPMs and correctors, the response matrix is non-square which can be inverted using the pseudo inverse or singular value decomposition.

$$\mathbf{I}_j = g\,\mathbf{R}^{-1}\,(\mathbf{X}_{ref} - \mathbf{X}_{meas}) + \mathbf{I}_{j-1}$$

With the gain factor g = 1 this would lead to a full correction of a given difference between the desired $\mathbf{X}_{ref}$ and actual beam position $\mathbf{X}_{meas}$, if the new current $\mathbf{I}_j$ will be written to the correctors in step j. One will usually work with a gain factor << 1 and also apply some filtering to the $\mathbf{X}_{meas}$ data to avoid ringing and overcorrection.



Status and conclusions

The basic software interface for reading the beam positions, writing the corrected currents has been implemented. Rough estimates for total loop times (150-300 ms) have been made and show that operation with the targeted operation frequencies of 0.5–2 Hz are well suitable.

First routines for accessing response matrixes delivered by the optics toolbox have been integrated and so the whole data flow chain is operational. First tests with beam are planned to take place in the end of 2010.

The combination of DOOCS object oriented approach and the dynamic generation of the displays and panels, have proven to ease the development. Such methods will be a must for working with the high device multiplicities, as one will have at e.g. the European XFEL.

References

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[5] P. Bartkiewicz, P. Duval, “TINE as an accelerator control system at DESY”, Meas. Sci. Technol. 18 (2007)
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