

# A HIGH-LEVEL INTERFACE FOR THE ANKA CONTROL SYSTEM\*

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## Abstract

ANKA is a synchrotron radiation source located near Karlsruhe, Germany. While the control system has always provided access to technical parameters, like power supply currents or RF frequency, direct access to physical parameters like tune or chromaticity has been missing. Thus the operator has to change and monitor the technical parameters manually and to calculate the physical parameters using separate tools. Therefore effort has been made to integrate the monitoring of physical parameters and simulation tools into the control system. At ANKA the MATLAB-based Accelerator Toolbox is used for simulation purposes, however the control system framework ALMA Common Software (ACS) does not support MATLAB natively. For this reason, a software bridge has been created, which provides direct access to control system components from MATLAB. Thus operators can write their own MATLAB code simultaneously using simulation code and components from the control system. This system has already been used to automate measurements, thus allowing unattended long-term measurements, which have not been possible before. Future plans include creating a graphical user interface and various monitoring and stabilization loops.

## ABOUT ANKA

The ANKA facility is a synchrotron radiation facility located near Karlsruhe, Germany. A 2.5 GeV electron storage ring is used to generate synchrotron radiation for various X-ray and IR beamlines. The storage ring can be operated with different optics, in order to provide radiation for different purposes. A low emittance optic is used for normal user operation at a beam energy of 2.5 GeV [1]. A special “low alpha” optic is used to generate coherent THz synchrotron radiation for the IR beamlines in the so called “special user operation” mode [2].

## CONTROL SYSTEM

The ANKA control system [3] is based on the software framework ALMA Common Software (ACS) [4, 5]. ACS uses CORBA as a communication link between components. At the moment, components written in C++, Java or Python are supported by the framework. The central ACS manager provides a naming service which is used by clients to find a component by name. The ACS manager

also stores configuration information for components, thus centralizing all configuration information.

The ACS components represent technical components of the storage ring (e.g. power supplies, beam position monitors, RF generators) and are written in C++ and Java. The ACS clients (at ANKA they are all written in Java) provide a GUI for displaying data provided by the components as well as controls for changing the settings of the devices represented by the components. Apart from the lookup and configuration process, the ACS manager is not involved in the communication between clients and components. The architecture of the control system is shown in Fig. 1 (components within the box “Legacy Components”).

## Limitations of the legacy control system

The legacy control system is build around the hardware of the accelerator / storage ring. This means that it basically provides remote control and monitoring of all relevant devices, but it is not aware of the physics of the accelerator. The only exception is a software client specially built for performing orbit corrections. However, this client basically is just a special GUI and the code concerning physics is not part of the control system backend components.

As the ANKA storage ring has a flexible lattice and is often operated with different optics (a low-emittance, a low-alpha or a low-beta optics), having a good model for calculating the accelerator settings for different modes of operation is very important. However, without a direct connection between the model and the real acclerator, all changes calculated in the model have to be transferred into technical parameters manually.

## Features of the new high-level interface

The new high-level interface allows for an easy integration of new diagnostic components. As the diagnostic components can easily access all control system parameters, task like logging tunes against beam energy can be performed very easily. Even measurements that require the change of machine parameters (e.g. chromaticity measurements) can easily be automated using the new high-level interface as it also allows for write access to most parameters.

## ACCELERATOR MODEL

The Accelerator Toolbox for MATLAB (AT) provides tools to create a generic accelerator model [6]. This model

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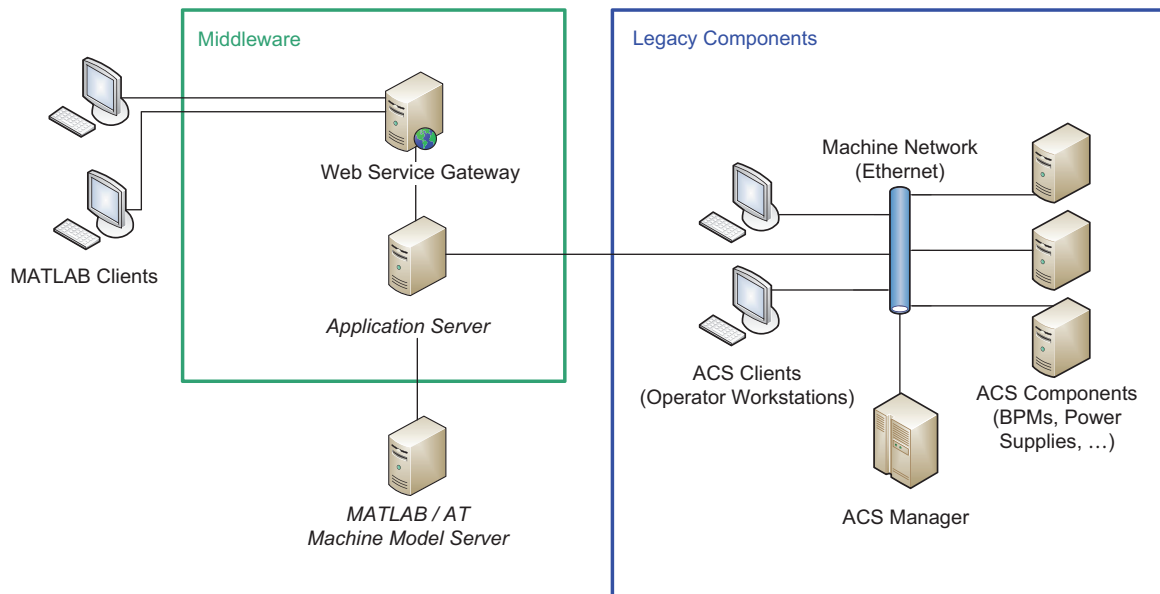


Figure 1: Architecture of the ANKA control system

can be used for many simulation tasks required in accelerator physics. However, real world accelerators always differ from the model because of effects which cannot easily be measured directly or change over time and can hardly be monitored automatically (e.g. small asymmetries, imperfect alignment of magnets, higher order effects in the magnet fields, collective effects).

Therefore, LOCO (Linear Optics from Closed Orbits [7]) is used to fit parameters (i.e. the quadrupole gradients) in the model to match the real accelerator [8]. This is done by measuring an orbit response matrix (change of orbit at beam position monitors against kick at corrector magnets) and then fitting the model to make the model's orbit response matrix match the measured one.

### Connecting the model with the control system

While the typical accelerator model parameters are magnet fields or kick angles, the parameters in the control system are magnet currents. Thus a conversion between model parameters and control system parameters is necessary. While an absolute conversion is error-prone, a relative conversion works quite well. Therefore a model that was fitted using a response matrix measured at a similar accelerator state (especially at a similar beam energy) is used as a base. For a magnet the current that was in effect when the model's response matrix was measured is compared to the present current and the difference is calculated. This current difference is then converted to a difference in the magnetic field, which is applied to the model.

This means the following process is used in order to get

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a model that matches the current state of the accelerator:

1. Load the accelerator model best fitting the current state.
2. Compare magnets' currents in model with currents from control system and calculate difference.
3. Convert current difference to field difference.
4. Apply field difference to model.

The model resulting of this process is a good approximation of the real state of the accelerator. It can be used to predict effects of changes in the magnets' currents or, what is even more important, to calculate changes in the magnets' current needed to attain certain changes in the accelerator optics. The results of these calculations can then be used to apply the changes using the reverse process:

1. Compare magnets' fields with fields from initial model.
2. Convert field differences to current differences.
3. Apply current differences to control system.

By using this process iteratively many small changes can be applied in order to finally attain a big change.

## TECHNICAL REALIZATION

As the control system cannot be directly accessed from MATLAB, a "Web Service Gateway" is used. This

software connects to control system components using CORBA and (from the view of the legacy control system) works like a usual ACS client. The gateway exposes the components of the control system using a simplified facade that can be accessed through a web service protocol (at the moment Hessian is used). This allows for a simple, lightweight client which can easily be integrated into MATLAB, using MATLAB's support for integrating Java components.

This approach allows for automation of measurements and integration of simulation methods without having to change or even rewrite the legacy control system. On one hand the complexity of the communication protocol of the control system (CORBA) is hidden from the high-level applications. On the other hand the control system can focus on its main task, the control of many hardware-devices in a reliable and efficient way. Thus the most important goals are attained with minimal effort and virtually all existing components of the control system can be reused by the high-level interface.

### EXAMPLE USAGE

The working point of the storage ring has a significant effect on the beam life-time. Therefore it is important to choose a good working point and take care of stabilizing at or near to this working point.

However, changing the gap of a wiggler in the storage ring has major impact on the vertical tune, thus moving the working point (see Fig. 2).

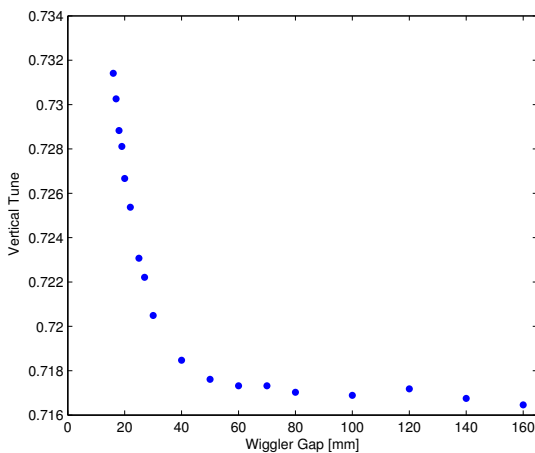


Figure 2: Change of vertical tune against gap of the SUL wiggler in the ANKA storage ring.

The new high-level interface can now be used to calculate changes for the quadrupole magnets in order to compensate the tune drift caused by the wiggler and stabilize at a chosen working point.

A similar problem occurs in the energy ramp: Different working points are chosen for different energies. Besides, the quadrupole power supplies have to be ramped in order

to account for the changed beam energy. This ramp uses a pre-defined table, so the working point is well-known for certain energies. However, between the defined data points the working point not controlled explicitly and therefore might move on a suboptimal path. Furthermore, the values for the ramping table, which is defined in the term of magnet currents, have to be changed manually.

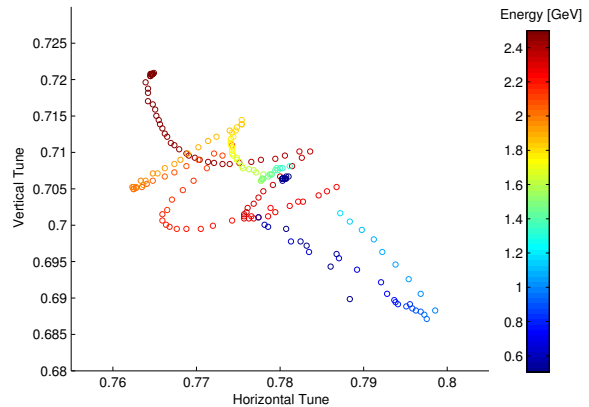


Figure 3: Working point of the storage ring against beam energy.

Fig. 3 shows the horizontal and vertical tune against the beam energy in the ramp from the injection energy of 505 MeV to the final energy of 2.5 GeV. In the future the high-level control system might be used to perform the energy ramp instead of using predefined tables for the magnet currents. This energy ramp algorithm could take care of choosing a working point that is not too close to one of the resonances or other instabilities.

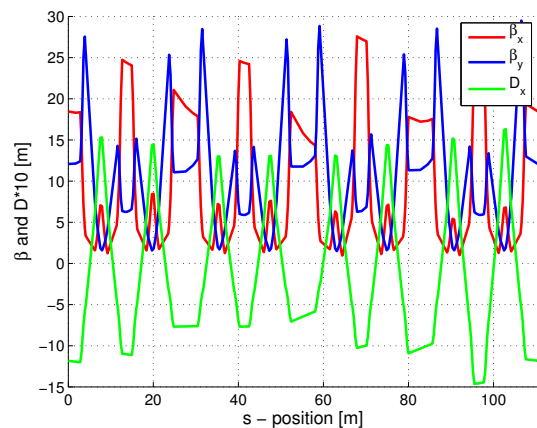


Figure 4: Betatron functions and dispersion along the ring for the low-alpha mode.

## BENEFITS FOR THE LOW-ALPHA MODE

The new high-level interface can be used to further develop and investigate the low-alpha optic. For example using the fitted model the optics functions (shown in Fig. 4) can be calculated, taking into account individual gradient errors of each quadrupole.

Another use of the model integration is the calculation of the momentum compaction factor  $\alpha$ . The bunch length correlates with  $\alpha$  and getting a short bunch length is the main goal of using the low-alpha optic. Therefore a good estimation of  $\alpha$  from the model can help in estimating the expected bunch length for a certain optic.

A more detailed description of the low-alpha optic can be found in [2].

## FUTURE PLANS

While the present solution is a good start for a more physics-aware control system, the architecture is not yet suitable for a long-term solution. As the accelerator model is integrated within the client applications, the synchronization between model and control system has to be performed for each client individually. Besides there is no abstraction layer between model and client code, thus the client software is tied to the model implementation.

Therefore a Java-based application server will be added to the system. This application server connects the clients to the accelerator model and the legacy control system. Due to the abstraction layer provided by the application server, the actual implementation of the model or the control system could be changed, without having to modify the client software. For example there are plans to try using MAD [9] instead of AT for the accelerator model.

Having only a single component for the accelerator model will also mean, that the synchronization between model and accelerator is performed at a single place and thus different clients are less likely to interfere with each other.

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