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THE ENHANCED LIQUID INTERFACE SPECTROSCOPY AND ANALYSIS (ELISA) BEAMLINE CONTROL SYSTEM PROTOTYPE

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Abstract

The Enhanced Liquid Interface Spectroscopy and Analysis (ELISA) beamline is a new instrument at BESSY II focusing on a novel, integrated approach for the high-fidelity preparation and investigation of liquid interfaces using soft x-ray radiation and infrared radiation light generated simultaneously from the BESSY II light source. As ELISA is part of the BESSY II+ upgrade scheme, it will be the first soft x-ray beamline at BESSY II to use new hardware motion control standards and a novel BESSY II EPICS deployment system.

This contribution focuses on workflows and tools we have developed for beamline control at BESSY II. We demonstrate their application at the ELISA beamline and finish with an outlook on scaling usage across the full experimental hall.

INTRODUCTION

The Enhanced Liquid Interface Spectroscopy and Analysis (ELISA) beamline is the first large instrument coming into operation in the context of the BESSY II+ project. The wider BESSY II+ project is the latest upgrade to the BESSY II synchrotron light source at Helmholtz-Zentrum Berlin (HZB) and aims to enable BESSY II to meet the growing demands of next-generation research in energy materials [1]. ELISA is currently under construction, and scheduled to see first light in 2026.

In addition to building new instruments, BESSY II+ aims to set new control system standards at the HZB. This includes new motion control hardware as described by Neu *et al.* [2], together with a novel approach on control system software.

This contribution focuses on a new approach towards control system software and motion control integration. The aim of the presented control system architecture is to automatise and simplify workflows for the end user by using a single tool for development, storage and deployment of all control system related software. ELISA is used as the environment for developing and testing this control system prototype, which will be used for both new and upgraded BESSY II beamlines.

BEAMLINE OVERVIEW

Figure 1 shows the beamline's optical layout. ELISA is designed as a dual-branch beamline covering an x-ray energy range from 40 to 3500 eV. An infrared (IR) radiation beam, ranging from 0.05 to 0.5 eV, can be used simultaneously with the x-ray beam. Both beams are generated by the BESSY II light source [3].

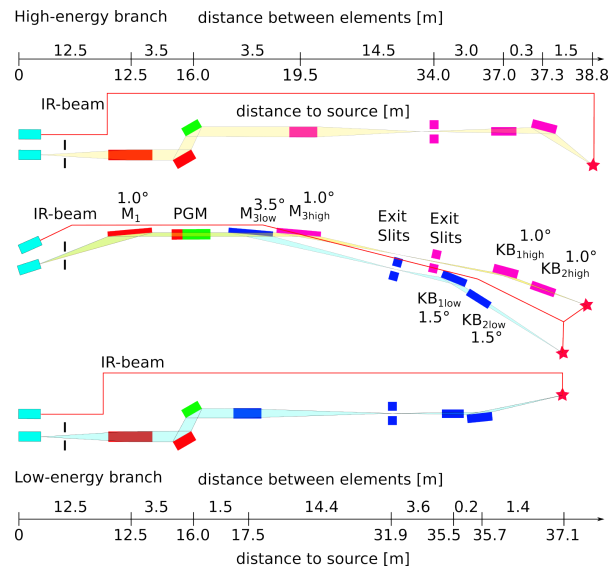

Figure 1: Sketch of the beamline's optical path [4].

The monochromator at ELISA will be fitted with three diffractive gratings. Next to a 400 l/mm laminar grating and a 1200 l/mm blazed grating, a multilayer coated 2400 l/mm blazed grating will be used. This will extend the energy working range up to 3.5 keV. Higher photon energies require the monochromator to work at shallow incidence angles. Keeping a fine energy resolution even at such high energies results in even higher demands in positioning precision for the monochromator. Most of ELISA's mirror units are positioned by hexapod based positioning systems. This combination of high demands in positioning precision for the monochromator and complex hexapod based positioning systems makes ELISA a challenging environment for the new motion control standard.

All beamline components are fully motorized and equipped with absolute encoder feedback. This brings the total to more than 70 motorized axes. To integrate these axes into the control system a highly automated approach is used.

CONTROL SYSTEM ARCHITECTURE

A sketch of the control system is shown in Fig. 2. To keep the architecture modular, a four-layer-based approach is used. The layers are defined as:

1. mechanics,
2. electronics,
3. communication, and
4. user interface (UI).

Technological solutions for layers two, three and four, have been recently developed and tested separately. ELISA is the

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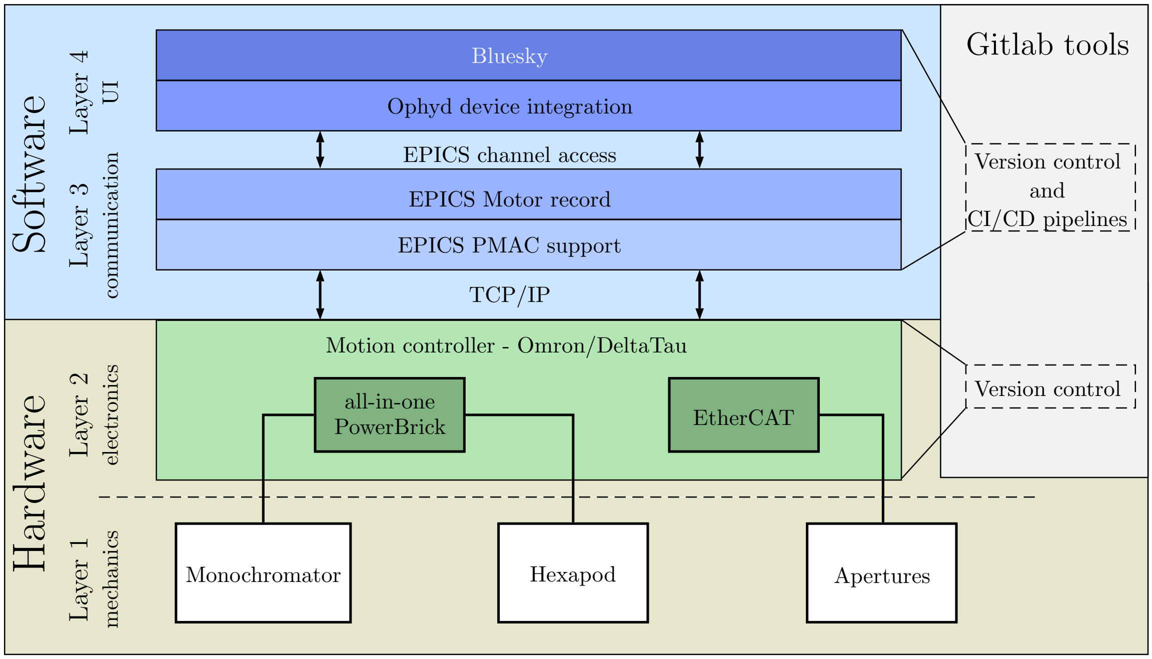

Figure 2: Sketch of the control system architecture.

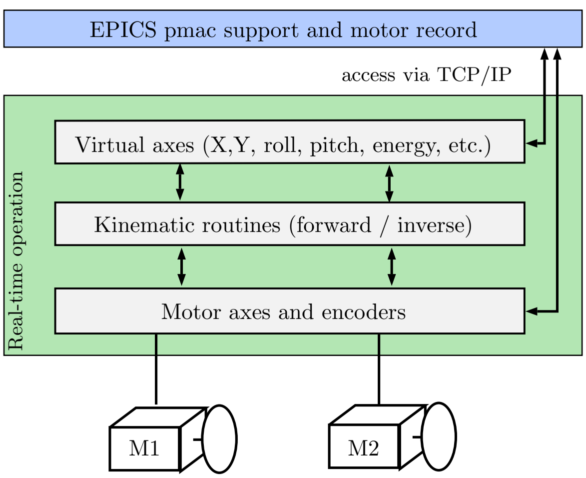

Figure 3: Motion controller setup.

first instrument where these individually designed systems will be combined into a complete control system. Each individual layer is designed such that the used technology can be exchanged with minimal effort.

The mechanical layer comprises of motors, sensors and other mechanical elements integrated in the beamline components. These elements are highly standardized and in most cases delivered by external suppliers following HZB standard interfaces. Hence this paper will not go into further detail on layer 1. The layers 2 to 4 will be discussed in more detail in the following subsections.

Electrical Layer - Motion Control

Figure 3 shows how the motion controller is set-up. As described by Neu et al [2]. most new beamlines at BESSY II will now be equipped with motion controllers from Omron/DeltaTau. This is also the case for ELISA. For simple individual motion axes, like aperture units or individual alignment motors, one EtherCAT Master controller with up to 32 EtherCAT motor amplifiers will be used. For the more complex axes of motion, like the multilayer monochromator and the hexapod-based mirror units, all-in-one PowerBrick controllers with integrated motor amplifiers are used.

The PowerPMAC motion controllers enable the usage of kinematic routines, so that physical motor axes can be transformed into virtual axes directly and in real-time inside the controller. It is then possible, for example, to drive a hexapod in either its joint coordinates (motor positions) or in its end effector's Cartesian coordinates (mirror position and orientation).

The setup of the motion controller is done via the PowerPMAC IDE and the PMAC script language. This text-based approach makes it easy to use GitLab for version control.

Communication Layer - EPICS Integration

Once the motion controllers are configured and motors can be driven, an EPICS Input/Output Controller (IOC) takes over the communication with the motion controllers.

Here, the EPICS IOC uses the pmac support module developed by Diamond Light Source, since this provides all features we currently need [5]. Instead of installing EPICS and all necessary support modules on a beamline control PC, we follow a novel highly automated approach. In lieu of a physical beamline control PC, virtual machines (VMs) are used, which are maintained and handled by a central service group. On these VMs all EPICS services run in containers. The schematic on how IOCs and other services run on the VMs is shown in Fig 4. The generation and deployment of

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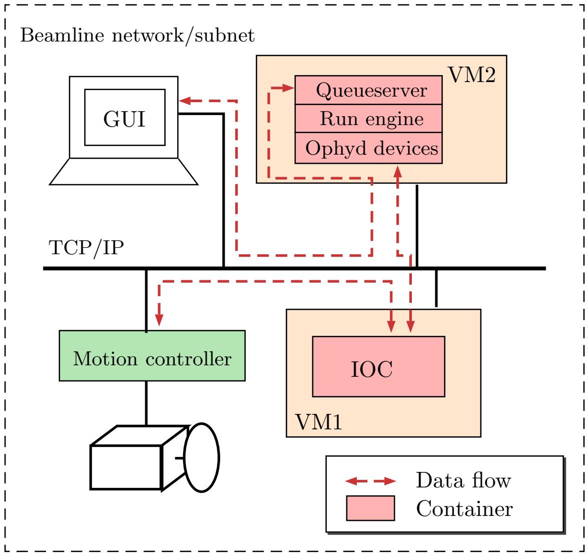

Figure 4: Network setup and containerized software distribution.

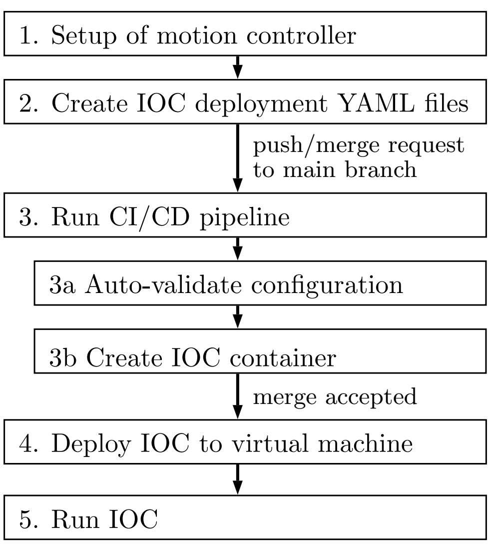

Figure 5: GitLab workflow for EPICS IOC deployment.

these containers is fully automated by GitLab pipelines and Ansible. The workflow for an EPICS IOC-deployment is shown in Fig. 5.

The control system engineer creates two YAML files in the GitLab environment. They contain all necessary information, such as which EPICS base and support modules should be used, and on which VM the IOC should be deployed. A merge request of these YAML files to the main branch then triggers a CI/CD pipeline, which validates the configuration and builds the image by fetching the required support modules. Once the merge request is accepted, the container image is deployed onto the VM via Ansible.

User Interface Layer - Bluesky

Similarly to the EPICS IOCs, the configuration of the services required for Bluesky [6] like the queueserver [7], as well as the user machine, is held in GitLab. Deployment and update of services is achieved with Ansible. The configuration of the machine is held on Gitlab, thus rolling out a new VM, which has exactly the same state can be easily achieved within minutes.

SUMMARY AND UPCOMING CHALLENGES

The control system architecture described here tries to standardise and automatise our beamline control system workflow as much as possible, while using tools which are not EPICS specific. Like this the control system engineer only needs minimal knowledge about EPICS itself. Everything, from the motion controller configuration files to the IOC configuration and the user interface, is handled by one single tool, in our case, GitLab.

The next challenge will be to bring ELISA into operation using the described control system. Afterwards this approach will be rolled out to more beamlines and experiments. Since the BESSY II+ project has a project horizon of 2029, the control system roll-out is aimed to be finished by then. To keep up with this tight timeline, we aim to start deployment of the presented control system architecture to existing instruments as early as possible and in parallel to the already existing control system. Like this the new system can be tested by instrument operators during commissioning and friendly user operation, while the established system remains available as a reliable backup for critical user operations.

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