Fast setup alignment of a highly mobile experiment with a Raspberry Pi and a Beckhoff PLC and the combination of the PLC to the DAQ.

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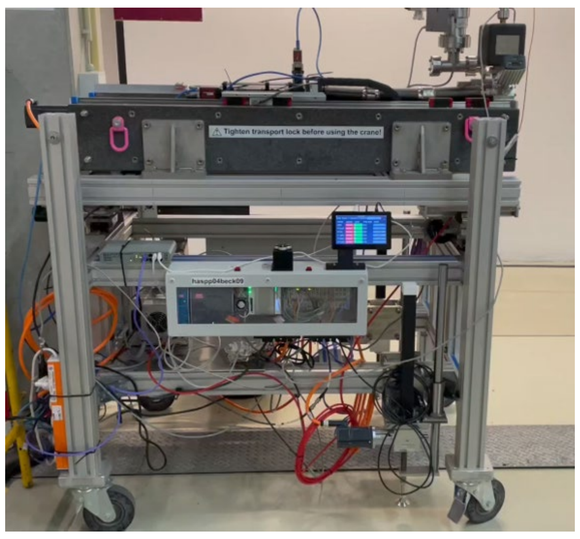
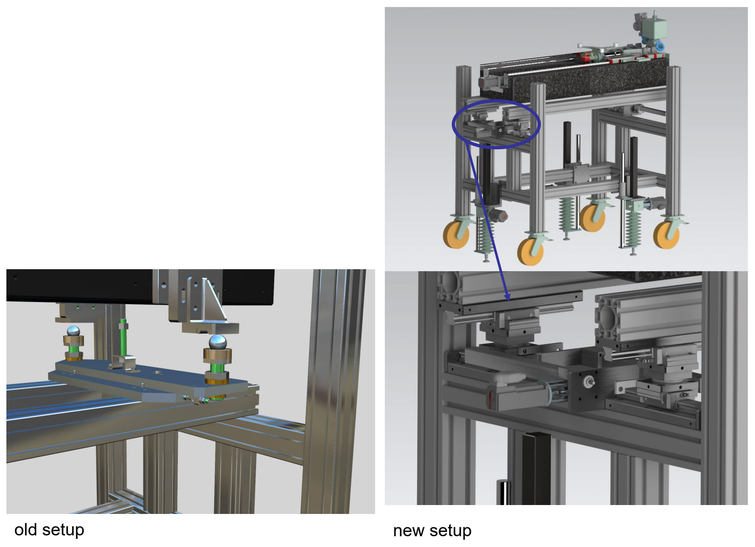
Motivation / Why Upgrade The Setup?

The **Focus Finder** (see QR code) is regularly used to check and optimize the beam parameters at our beamline. Therefore, we have to align this setup regularly as well. Unfortunately, in the beginning, the setup had no motorization for the alignment of the Focus Finder. This was done manually by adjusting the mechanics with screws, which was time-consuming and tedious. So we decided to upgrade our setup to a complete motorized support, with the goal that only the power plug needs to be attached to enable us to align the Focus Finder setup.

We upgraded the already-installed **Beckhoff PLC** system, which was used for the motorized measuring slide, with additional motors to align the complete setup via motors. To provide direct access to the motors at the setup itself, we also installed **a Raspberry Pi** with a 7-inch touchscreen for 'coarse' alignment by a fingertip. It now has six degrees of freedom (**DOF**). In the horizontal plane, it is more or less a kinematic mount built with three THK sliders and three Igus rotation axes.

The Beckhoff PLC system plays also a role in the **DAQ** system. While we **scan 'on the fly'** along the beam axis, the camera triggers the PLC and the encoder position will be stored in an array inside the PLC. After the scan is done, one can read out the array and has the images and position synchronized.



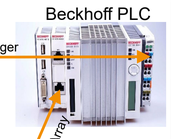


old setup

new setup

DAQ Implementation

Allied Vision Mako G-319B 1/1,8" CMOS Kamera, monochrom



Beckhoff PLC

TTL Trigger

Image Data / Settings

Position Array

Measurement PC

The measurement slide moves continuously along the beam axis and takes images of the Synchrotron beam via a YAG screen. The images will be stored and the TTL trigger from the camera goes into the PLC. The PLC will store the position at the moment where the trigger signal comes in. This array of the positions can be read immediately after the scan. This is faster than just read the position during the scan over our used Tango Control system.

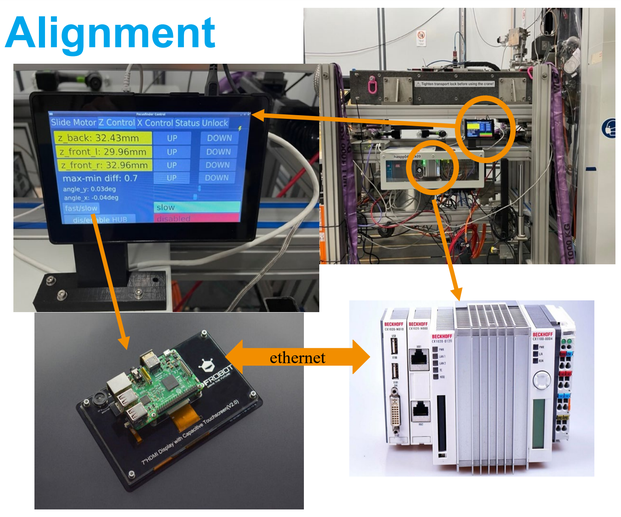
Fast Setup Alignment

The **Raspberry Pi** together with the **touchscreen** is used to control the motors of our **Focus Finder** to align the setup.

The motors are controlled by a Beckhoff PLC.

No additional PC is needed to control the motors.

The Raspberry PI and the Beckhoff are connected over an ethernet switch.



GUI

Behind the GUI with buttons and labels lays a python program which uses **PyQt**.

The python program communicates with the Beckhoff via **PyADS**.

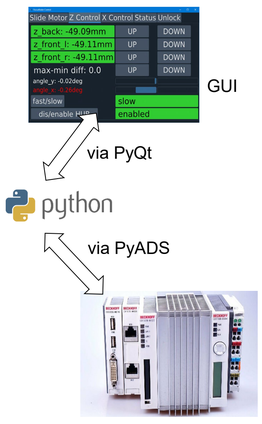
PyADS is a python library which is derived from the ADS (Automation Device Specification) protocol from Beckhoff.

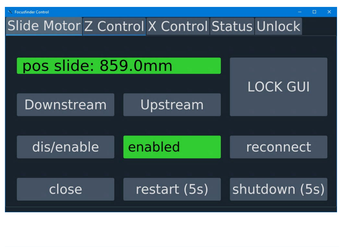
Example of reading a variable from Beckhoff:

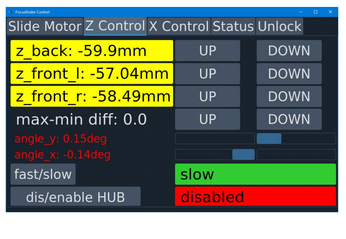
self.plc.read_by_name("MAIN.angle_y_out")

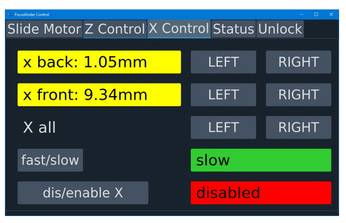
Writing a variable:

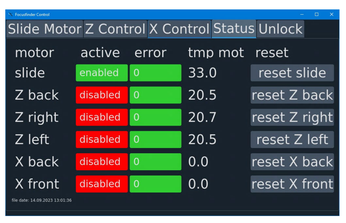
self.plc.write_by_name("MAIN.motor1", 10.5)











Used Hardware

Beckhoff CX1020
with Twincat 2 and PTP license

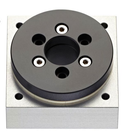
AM8131 Servomotor (Beckhoff)
1,35 Nm (M0), F3 (72 mm)
OCT (**O**ne **C**able **T**echnology)

THK HSR30A1M
280mm long
Dynamische Tragzahl: 40,5 kN
Statische Tragzahl: 53,7 kN

EL7211-0010 EtherCAT Terminal
1-channel motion interface servomotor, 48 V DC, 4.5 A, OCT (**O**ne **C**able **T**echnology)

AM8113 Servomotor (Beckhoff)
0,52 Nm (M0), F1 (40 mm)
OCT (**O**ne **C**able **T**echnology)

Igus Drehkranz PRT-01-20-SQ
Completely maintenance-free (no grease)
Axial load, static 15,000 N
Axial load, dynamic 4,000 N
Radial load, static 2,300 N



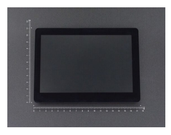
Raspbery Pi 3 B+
Price: now 130€ !
(normally around 80€)

NEFF SPINDELHUBGETRIEBE M0-VK
Hubkraft: 2,5kN

NEFF SPINDELHUBGETRIEBE M2-VK
Hubkraft: 10kN

Autosen AW002 Inclination sensor
2 axes
Interface: IO-Link

DFRobot 7" HDMI Display with Capacitive Touchscreen
Price: ~70€
The Raspberry Pi can be mounted on the screen



Allied Vision Mako G-319B
1/1,8" CMOS Kamera, monochrom
Pixel (h x v): 2,048 x 1,544

Mitutoyo ML Finite Brightfield 10x Objective

Magnification = 10x
NA = 0.21
WD = 51.0mm
Resolving Power = 1.31µm
Depth of Field = 6.2µm

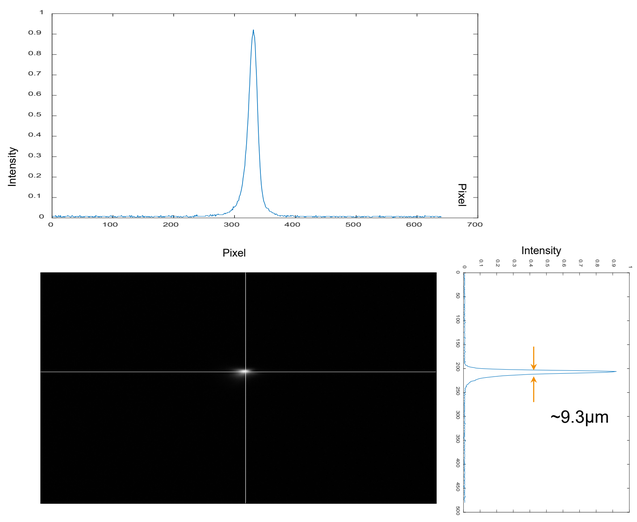
Results

Hers is an example of the measurement itself at the P04 beamline. This gives us the status of the focus at the P04 Beamline. As you can see (fig. a) we measured a vertical spot size of less 10µm and a horizontal spot size of less 17µm.

To find the focus the beam size is measured along the longitudinal axis. (fig. b). After fitting an polynomial function into the measured values we calculate the minimum position for the vertical and horizontal foci at 800.75 mm and 801.32 mm after the user valve.

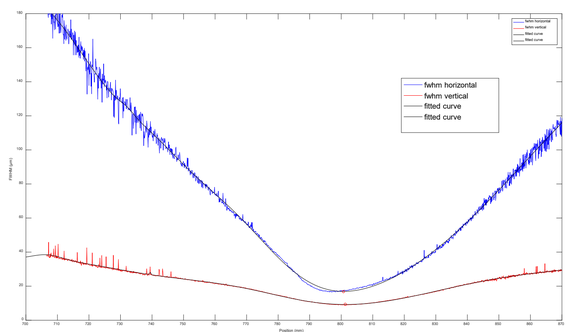
The position difference of 0.57mm for both foci are a good result.

With these results we can show that the 'Focus Finder' is a useful and versatile tool, which helps to characterize the beamline conditions.



(fig. a) Single Image at the minimum horizontal focus with the beam spot and the profile through the spot.

fwhm min (vertical, fit) :9.2567 µm minimum position (vertical, fit) :801.322 mm
fwhm min (horizontal, fit) :16.931 µm minimum position (horizontal, fit) :800.749 mm



(fig. b) The measured spot size (fwhm) along the beam axis. One can see the minimum and the small offset between the horizontal and vertical focus. In this scan nearly 2200 images where taken.

Conclusion and Outlook

After the full motorization of the Focus Finder, We could say that the setup time is drastically improved which really helps to save precious beamtime.

The next step will be to implement an automatic alignment with the help of the already existing scan software. This should also decrease the needed measurement time.

After all one can say that we have now an easy and fast to align setup which makes it easy for us to measure our beam focus parameters.

A 'Focus Finder' for Micro Focus and Beam Characterization.

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