Users' Meeting 2025

Automation of facility sub-systems

Sarlota Birnsteinova on behalf of the Data Analysis group, CTRL, SXP, SPB/SFX, FXE

European XFEL GmbH, Schenefeld, Germany

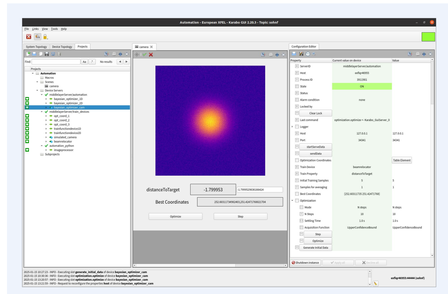
Motivation

- Large-scale facilities like European XFEL consist of a multitude of subsystems, many of which require frequent calibration critical to maintain stable and optimal performance
- The goal is to automate repetitive tasks to reduce operators' time investment and potentially increase the exploitation of allotted beamtime, both in quantity and quality

- As a result, many ongoing activities at EuXFEL are focused on automating various sub-systems with the aim of reducing human time investment needed during the operation.

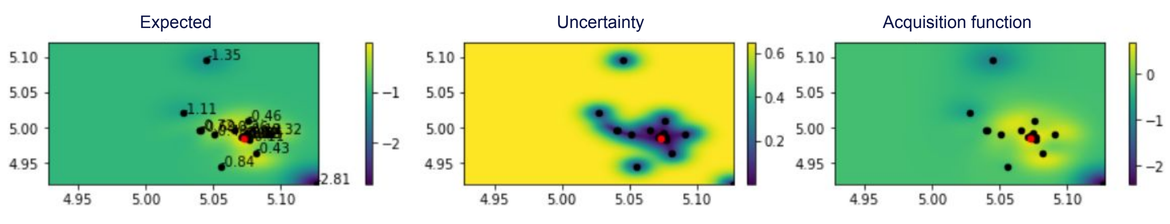
Methods & Tools

- Bayesian Optimization (BO)
  - a method for efficiently optimizing functions that are expensive or time-consuming to evaluate
  - uses a probabilistic model to make predictions about the objective function and guides the search for optimal solutions by selecting the next point based on previous results
- Karabo implementation of BO

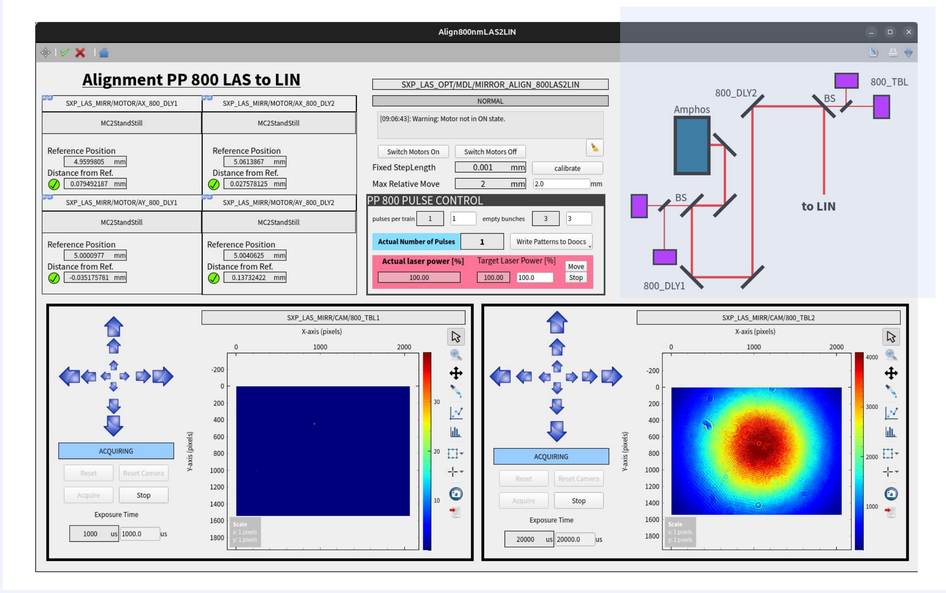


Usecase: Optical laser alignment

- SXP instrument
- Goals: Align the laser to the center of the camera, keep maintaining the alignment
- Method: Bayesian optimization to find the optimal positions of the motors for the laser alignment setup

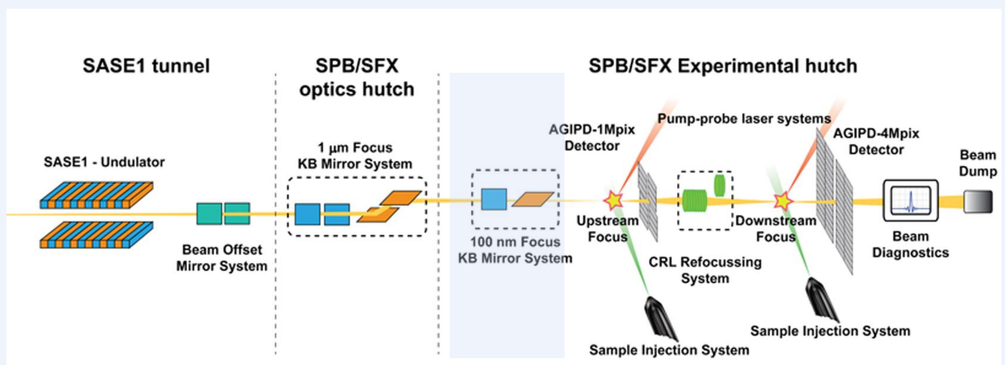


An example of expected value, uncertainty, and acquisition function guiding Bayesian optimization used for laser alignment. The expected value represents the model's current prediction, while uncertainty highlights regions of high prediction variability. The acquisition function identifies the next sample by balancing prediction accuracy and exploration of uncertain areas.



Usecase: Autofocusing of NKB mirrors

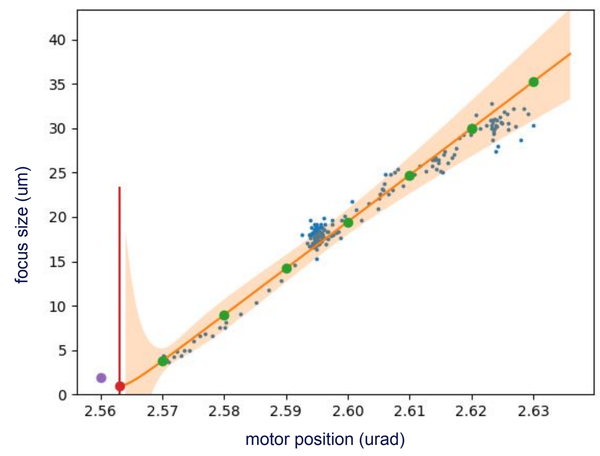
- SPB/SFX instrument
- Goal: auto-focusing the beam with NKB mirrors



- Method: the approximation to the V-Curve with a hyperbolic curve
  - the hyperbola describes very well how the focus size depends on the mirror angle:

$$S = \sqrt{b^2 + a^2(x - c^2)^2}$$

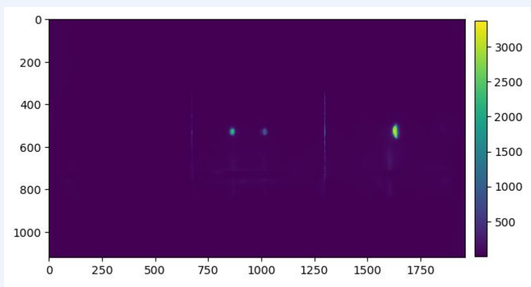
  - where b is focus size, c is focus position, a is an asymptotic slope, x is mirror angle.
  - ~ 5 steps for finding focus!



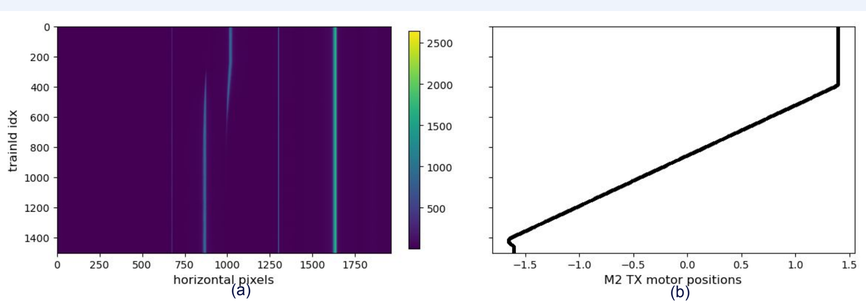
An example of optimization iterations for achieving an ideal focus based on hyperbolic V-curve fitting. This figure shows previously evaluated iteration points (green), the next iteration point (violet), and estimated ideal focus point (red) during the 5th iteration step.

Usecase: Beam alignment

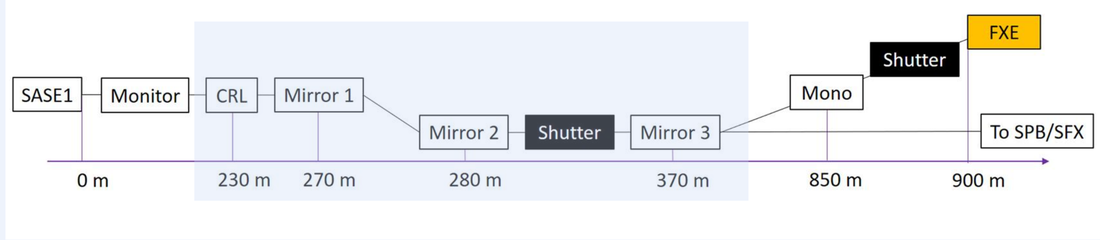
- FXE instrument
- Goal: adjusting multiple optical components such as mirrors and lenses to optimize conditions for start-of-the-shift alignment
- Methods: (in progress) BO to iteratively determine the optimal configuration by evaluating system performance metrics, such as beam intensity and position which requires reliable image processing.

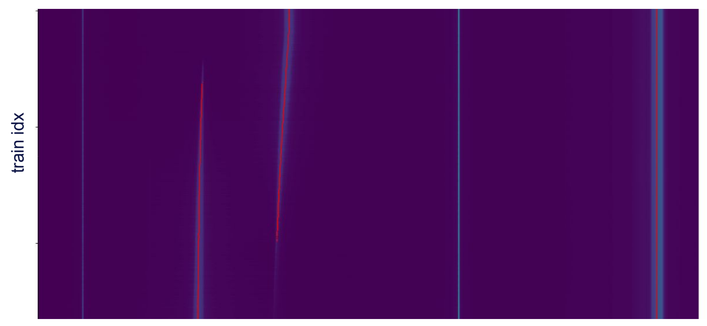


An average intensity of the image during a given step of beam alignment process



(a) An average intensity profile along the vertical axis showing changes in image intensity during the beam alignment process. Each row represents the vertical average of a single image. (b) Motor movements corresponding to the alignment steps and demonstrate their influence on the observed intensity variations (a).





An average intensity profile stacked along temporal axis with red points indicating the beam center detected by the developed software. Each row represents the vertical average of a single image, highlighting the software's accuracy in identifying the beam center on the acquired alignment dataset.

Related posters

"Interpretable Machine Learning at the EuXFEL", D. Ferreira de Lima