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# A safe Bayesian optimization algorithm for tuning the optical synchronization system at European XFEL

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Over recent years, Bayesian optimization has become a widely adopted tool for fine-tuning and enhancing the operational performance of particle accelerators. While many Bayesian optimization (BO) algorithms focus on unconstrained optimization, constraints play an important role in accelerator operations. They ensure the safe functioning of the equipment and prevent damage to expensive components. Frequently, these constraints are not known and must be acquired through learning.
In Sui et al., a safe Bayesian optimization method was introduced. This method actively learns safety constraints during the optimization process, ensuring a safe operating environment. To tackle high-dimensional optimization challenges, LineBo was introduced to decompose the overall optimization domain into smaller sub-domains.
In this research, we present a modification of the SafeOpt approach that separates exploration and exploitation. This proposed strategy accelerates the convergence rate in particle accelerator applications, particularly at the European XFEL, the world's largest linear particle accelerator. The European XFEL is renowned for its capacity to produce intense and ultra-short X-ray flashes for investigating ultra-fast, time-resolved chemical processes. To enhance the quality of observations, the laser-based synchronization system is fine-tuned using PI controllers, employing a safe Bayesian optimization technique.
Given the high cost of machine time at the European XFEL, it is imperative for the algorithm to identify optimal parameters as fast as possible. In our contribution, we introduce a safe Bayesian optimization algorithm that not only ensures safety but also significantly improves convergence speed and noise robustness. We illustrate its application and present comparative results through simulations for the optical synchronization system of the European XFEL, as well as an experimental demonstration on a laboratory synchronization system.

## Primary Keyword

bayesian optimization

## Secondary Keyword

active learning

## Tertiary Keyword

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**Primary author:** LÜBSEN, Jannis (TUHH)

**Co-authors:** EICHLER, Annika (DESY); SCHÜTTE, Maximilian (DESY); SCHULZ, Sebastian (DESY)

**Presenter:** EICHLER, Annika (DESY)

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