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Pyapas: A NEW FRAMEWORK FOR HLA DEVELOPMENT AT HEPS

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Abstract

The High Energy Photon Source (HEPS) is a 6 GeV, 1.3 km, 4th generation storage ring light source being built in Beijing, China. Compared to third-generation light sources, HEPS, as a fourth-generation light source, has a one to two orders of magnitude reduction in emittance. The number of magnets correspondingly increases by an order of magnitude, and there are higher demands for control precision. All of these pose new challenges for the development of HLA. The development of high-level applications (HLAs) for HEPS started in early 2021. A brand new framework named PYthon-based Accelerator Physics Application Set (*Pyapas*) was developed for HLA development. This paper will introduce the design of *Pyapas* and its application at HEPS.

INTRODUCTION

The High Energy Photon Source (HEPS) is a 6 GeV, 1.3 km, fourth-generation light source [1]. The construction started in Beijing, China, in the middle of 2019, and upon completion, it is expected one of world's brightest light source. The beam commissioning of Linac began in March 9 of this year, and the process acceptance of Linac completed three months later. Upon completion of a brief interlude for adjustments, the beam commissioning of booster started. The energy of booster successfully ramped to 6 GeV two weeks later [2]. As a fourth-generation light source, HEPS adopts a compact multi-bend achromat lattice design for the storage ring and uses a large number of combined magnets [3, 4]. The cross-talk effect between magnetic fields is significant, and the number of magnets has increased by an order of magnitude compared to the third-generation light sources, which introduce new challenges and requirements for tuning beam parameters.

Existing HLA development frameworks are mostly monolithic and not easily scalable [5, 6], which cannot meet the needs of HEPS' complex parameter tuning. And porting the existing framework is almost as much work as building it from scratch. In order to meet the requirements of HEPS, we decided to design a new HLA framework based on Python named *Pyapas* [7]. It adopts modular design philosophy to increase overall scalability. A dual-layer physical model module has been designed to meet the replaceability of online calculation models. In addition, the communication module, database module, and server module have all been specially designed to meet the needs of adjusting a large amount of parameters.

Based on *Pyapas*, we have completed the development of HLAs for the Linac [8] and successfully applied them to beam commissioning [9], verifying the practicality and reliability of *Pyapas*. The development of HLAs for the booster and transfer lines [10, 11] has also been completed, and the development for the storage ring is nearing completion. This paper will briefly introduce the design of *Pyapas* and the progress of the development of HLAs for HEPS.

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FRAMEWORK DESIGN

For a framework to develop HLA, the basic abilities include hardware communication, user interface development, database connection et.al. But for the high level physical application (HLPA), physical model and physical algorithm are more crucial part. Therefore the core of *Pyapas* is a dual-layer physical module. As shown in Fig. 1, there are two independent layers: device mapping layer and physical model layer. The device mapping layer corresponds to the real machine and is responsible for communicating with the machine, while the physical model [12] layer is responsible for online calculation based on the information read from the device mapping layer. The device mapping layer and the physical model layer are deeply decoupled and connected by connector, which only need to specify information such as the calculation model class name, unit conversion, and parameter name that needs to be called in the connector. This makes it very convenient to switch between different calculation models to meet the online calculation needs in different scenarios.

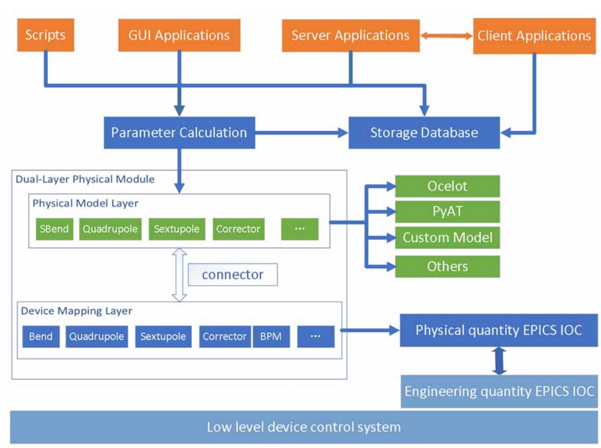

Figure 1: Pyapas framework.

In addition, to improve the scalability of the framework and reduce the development difficulty of developers, we adopt a modular design. Specifically, we analyze the functions involved in HLAs, and divide them into different modules for separate development. The modules are loosely coupled and specific application development is carried out through simple interface calls, which increases

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the overall maintainability and scalability of the framework. For a framework to develop physical application, *Pyapas* is based on physical quantities, all the variables are physical quantities which make the applications more intuitive for physicists. To complement the use of physical quantities-based applications, a conversion system utilizing SoftIOCs has been implemented. In the communication module, singleton factory pattern is used to avoid duplicate creation of channel connections. In combination with Qt's signal-slot mechanism, non-blocking communication connections are established, greatly improving the ability to handle large parameter scales. Moreover, the design of C/S architecture modules and database rapid creation and management modules can help developers in physics to quickly develop complex HLAs, further enhancing the applicability of *Pyapas*.

HLAS DEVELOPMENT

Before the commencement of the specific HLAs development, a multi-user virtual accelerator (MUVA) was developed as the testing platform. As shown in Fig. 2, this is the snapshot of Linac MUVA, it can simulate the beam profile, orbit, energy, Twiss parameters etc. All the information were disseminated via a full feature EPICS IOC, acting as a real machine environment.

The MUVA system can add virous errors and unexpected scenarios to meet the testing requirements of specific HLAs. Another novel function of MUVA is the multi-user feature, that means on the same network or same server lots of VA could be launched without conflicting with each other. One HLA can connect to different VA instance with the special prefix name. This feature is very useful when a team develops HLAs on the same network area or same cluster.

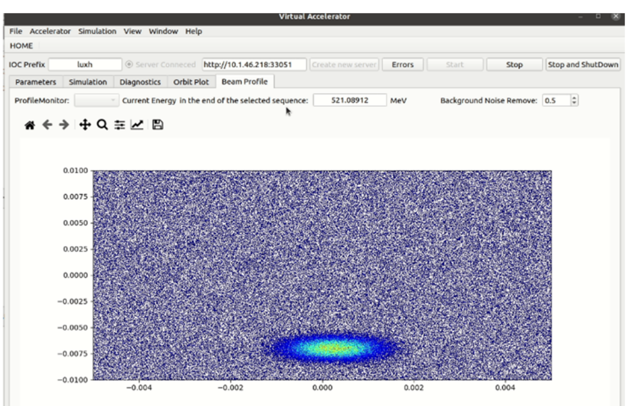

Figure 2: The virtual accelerator for testing the HLA.

The beam commissioning of the Linac started in the middle of March, 2023. All the HLAs for the Linac are based on *Pyapas*, including orbit correction, emittance measurement, energy spread and energy measurement, phase scan, and physics-based control application [13]. As a result of the previous comprehensive preparations, full beam transmission was achieved quickly, and the design energy was reached. The physics-based control program played a crucial role in this achievement.

After a brief respite, we started the beam commissioning of booster. After three days of concerted effort, we got the synchrotron light signal, two weeks later, the beam energy was ramping to 6 GeV. The beam commissioning is still underway, moving towards the machine's design objectives.

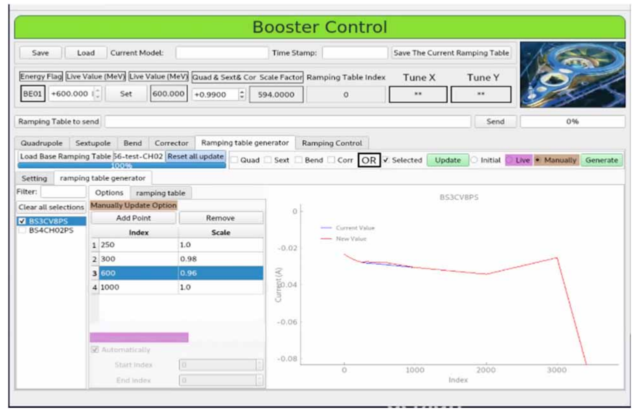

Figure 3: Booster Control based on physical quantities.

The HLAs play import role during the beam commissioning, including global orbit correction, local orbit correction, dispersion measurement, physics-based booster control (Fig. 3), chromaticity measurement, first-turn beam analysis, and more.

The HLAs for the storage ring are currently being developed and soon to be completed.

CONCLUSION

To meet the beam commissioning requirements of the HEPS, a brand framework *Pyapas* had been designed for HLA development. It is a full-featured development framework specifically designed for high level physical applications, which can significantly enhance development efficiency. Based on this framework, we have completed the HLAs development for the Linac and the booster, respectively. The HLAs for the Linac and booster have been successfully applied to beam commissioning and have achieved excellent performance, assisting beam commissioning operators in quickly achieving beam transmission throughout the entire system. The successful application of *Pyapas* demonstrates its reliability and practicality. Currently, we are developing the HLAs for the storage ring, which has a magnet data volume one order of magnitude larger than the booster and a significantly increased level of control complexity. To ensure the availability of the HLAs, more technologies need to be added to *Pyapas*, such as asynchronous communication technology and multi-process development functions.

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