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UPGRADES OF HIGH LEVEL APPLICATIONS AT SHANGHAI SOFT X-RAY FEL FACILITY

H. Luo, D. Gu, Z. Wang, K.-Q. Zhang, T. Liu,
Shanghai Advanced Research Institute (SARI-CAS) Chinese Academy of Sciences, Shanghai, China

Abstract

The Shanghai soft X-ray free-electron laser(SXFEL) facility has made significant progress in recent years with the rapid, upgraded iterations of the high level software, including but not limited to energy matching, orbit feedback and load, beam optimization, etc. These tools are key components in operation and experiment of free electron laser facility. Some key applications are presented in this paper.

INTRODUCTION

Based on the principle of the free-electron lasers [1], the output of the free-electron laser drifts and fluctuates with the instability of the electron beam energy, the instability of the angle and position of the electron beam, the instability of each device due to environmental changes, and the instability of the device itself. A stable electron beam is the key to obtaining a stable free-electron laser. The commissioning of the e SXFEL user facility started in spring of 2021 [2], and in 2023, the SXFEL facility has been opened to the public and user experimental research has been carried out, placing a higher demand on the stability of the entire device. In order to maintain the long-term high-quality operation of the SXFEL facility, with the joint efforts of our team, through the interaction and access of applications and hardware systems implemented by the Experimental Physics and Industrial Control System (EPICS [3]), we developed and put online a set of processed beam-tuning high-level applications (SXFEL HLA) written in python language in 2022. Based on these applications, we can achieve rapid recovery and long-term stable operation of SXFEL, and practice has confirmed the reliability and sophistication of this software, which has played an indispensable role in the tuning and operation of SXFEL. This article will report on some key applications. The main window of SXFEL's high level applications is shown in Fig. 1

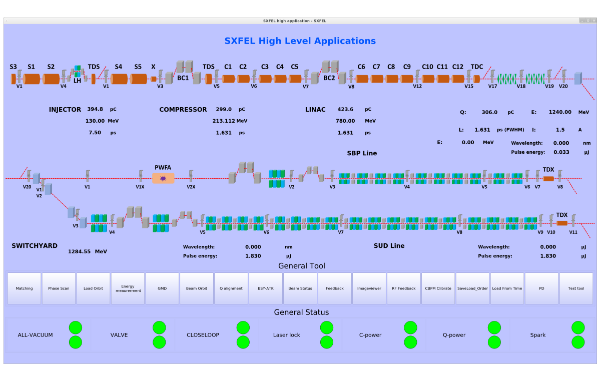

Figure 1: The main window of SXFEL's high level applications.

MATCHING

We all know that the focusing of the electron beam in the transverse direction is crucial to the stability of the beam and the amplification of the FEL, and through theoretical simulation calculations, we can get the target reasonable focusing state of the beam. Therefore, in order to get the focusing state we want, we design and develop the Matching module (shown in Fig. 2), which divides the matching of the beam into linear section, beam distribution section, SBP oscillator section and SUD oscillator section. The Energy Measurement module measures the energy and Emittance Measurement module measures the Twiss parameters, and the measurement results are placed in the background through the soft IOC for the Matching module to call. The inverse solution of the inlet parameters by this Twiss parameter is then solved by the theoretical simulation method of the Matching module.

Figure 2: Matching Window.

ORBIT CONTROL MODULES

Combined with these applications: LoadOrbit, Orbit, ImageViewer and BPM Calibrate, orbit feedback (shown in Fig. 3) is one of the key feedbacks to maintain high quality and long term stability of the SXFEL facility. For the consideration of the flexibility, ease of use and reliability of the application, we have linked the orbit feedback with the newly developed tuning tools: LoadOrbit, Orbit, ImageViewer and BPM Calibrate.

The BPM may drift in phase with changes in ambient temperature and humidity. In order to ensure the accuracy of the beam position measured by the BPM, we regularly use the high-level application BPM Calibrate (shown in Fig. 4) to detect and calibrate the phase drift of the BPM, which

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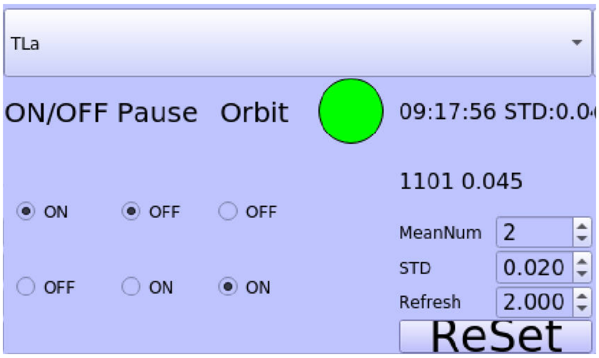

Figure 3: Orbit Feedback Window

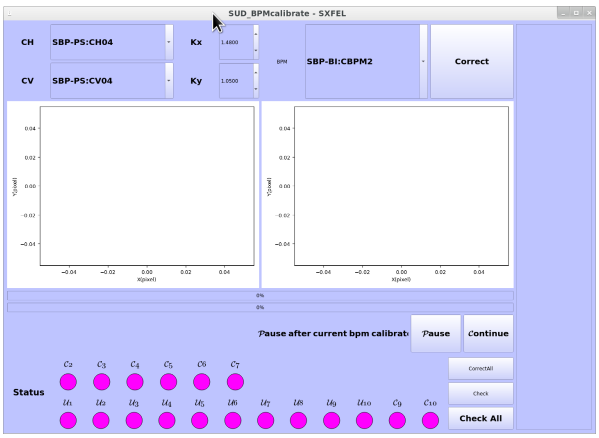

Figure 4: BPMCalibrate Window

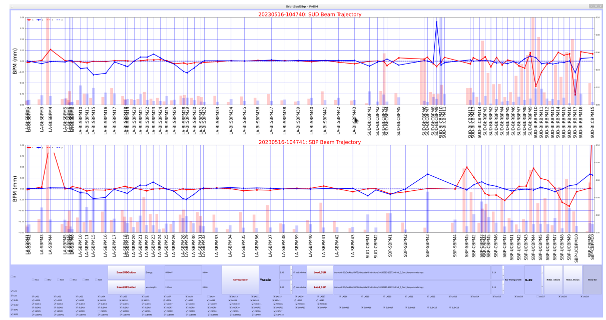
Figure 5: Orbit Window

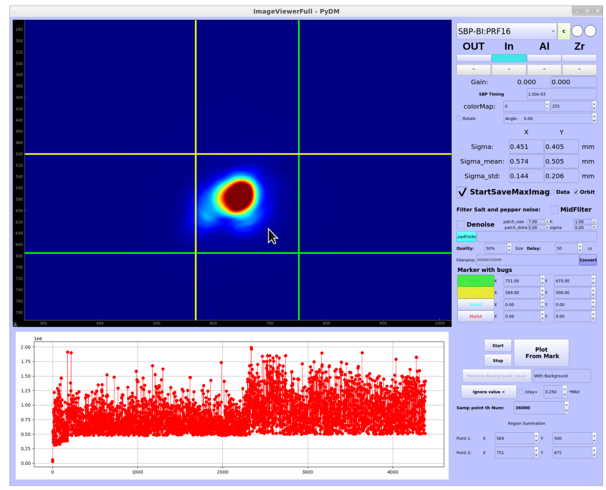

Figure 6: ImageViewer Window

provides a guarantee for SXFEL to carry out subsequent work related to the orbit.

SXFEL runs two oscillator lines SBP and SUD at the same time, according to the real distance of the BPM, we have developed a new version of high level application of Orbit (shown in Fig. 5) to display the beam's current orbit and jitter in real time, however, a BPM may be faulty during the work, and the position of the beam current can't be detected, so we have added the ByPass function for each BPM in the application. In the commissioning process of the FEL, the beam orbits and jitters are of great significance, and the light-emitting orbit saved by the Orbit app can not only be used as the reference orbit for the next FEL commissioning, but also be used for another high level app LoadOrbit to recover the orbit, and at the same time, it can be used as the target orbit for the orbit feedback.

Obviously, due to the dithering nature of the FEL, the beam orbit saved manually may not be exactly the light-emitting orbit, for this reason, SXFEL in the optimisation of the FEL as well as the commissioning process, the high level application of ImageViewer (shown in Fig. 6) will save the orbit corresponding to the value of the integral value that is larger than the previous one, as a more reliable light-emitting beam orbit.

The stability of the beam is different at different positions. In order to make the orbit feedback based on the response matrix algorithm more flexible and reliable, we have segmented the orbit and assigned the BPM and corrector to each segment as the default pairing for the response matrix measurements in the high level application LoadOrbit (shown in Fig. 7). Depending on the current state of the beam, the commissioner is free to replace the pairing in the application Loadorbit with the one he thinks is better, and the orbit feedback application and the LoadOrbit application default to use the latest measured response matrix. orbit Feedback and LoadOrbit are two high level applications that share a common set of segmentation, response matrix, and light-emitting orbit data, and LoadOrbit supports kicking the orbit to a light-emitting orbit or other custom orbit.

With the LoadOrbit module, we can easily find the radiated light and even restore it to the supplied light level by simple commissioning. In addition to expert commissioning for restoration, we can also use the General FEL Opimize module for algorithmic optimisation to restore the FEL. However, there is no guarantee that the commissioning and optimisation process is going in exactly the right direction, and using the application may also lead to worse results. As a result of this, we can use the LoadFromTime module (shown in Fig. 8) to restore the magnet parameters to the time we set by setting a historical time.

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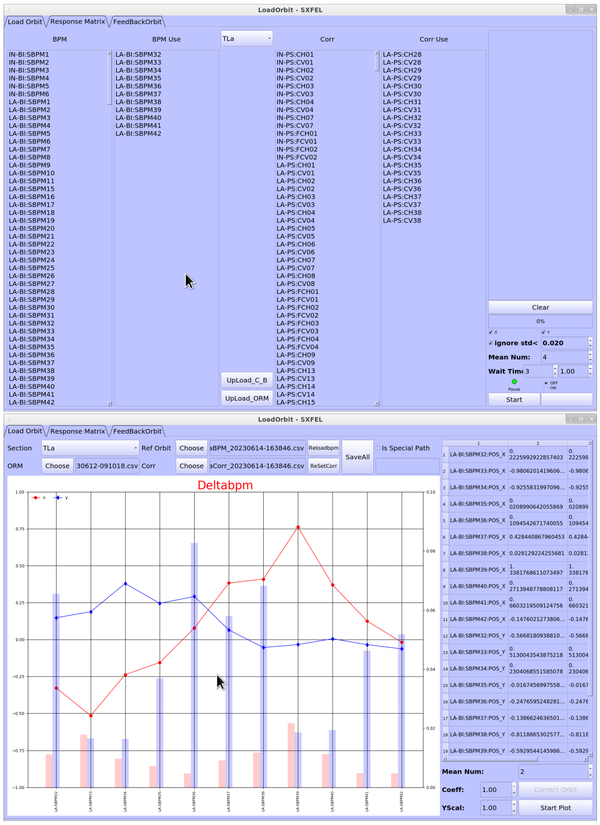

Figure 7: LoadOrbit Window

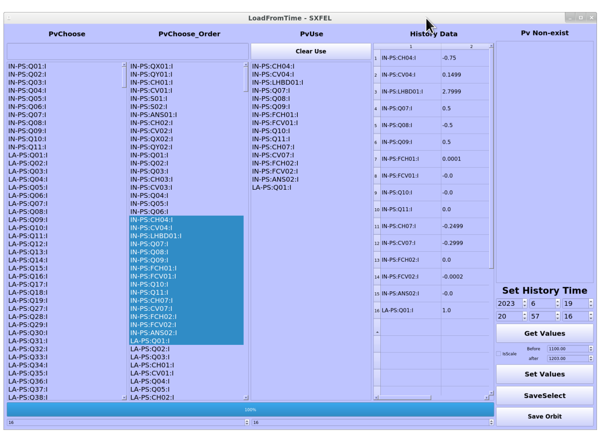

Figure 8: LoadFromTime Window

FEEDBACK

The output of the free electron laser will drift and fluctuate with the instability of the electron beam energy, the instability of the angle and position of the electron beam, the instability of each device due to environmental changes, and the instability of the device itself. Stable electron beam quality is the key to obtaining a stable free electron laser, and is also an important factor in maintaining the long-term high-quality operation of the SXFEL facility. In order to maintain the stable operation of the free electron laser facility, based on the response matrix algorithm:

$$\triangle Y = M^{-1} \cdot \triangle X \tag{1}$$

SXFEL has a lot of feedbacks (shown in Fig. 9), including feedbacks on charge, beam energy, beam length, injector energy, drive laser position, BAM and orbit, which play a vital role in the stable light supply of SXFEL.

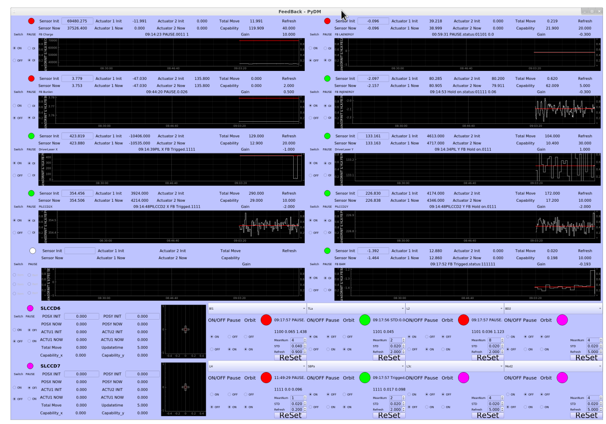

Figure 9: FeedBack Window

SUMMARY

After repeated verification in practice, the high-level application of SXFEL HLA has been able to achieve efficient and standardised FEL commissioning, which plays an important role in SXFEL's rapid commissioning recovery and long-term stable, high-quality running.

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REFERENCES

[1] R. Bonifacio, C. Pellegrini, L. M. Narducci, "Collective instabilities and high-gain regime in a free electron laser", *Optics Communications*, vol. 50, no. 6, pp. 373–378, 1984. doi:10.1016/0030-4018(84)90105-6

[2] Liu, Bo, Chao Feng, Duan Gu *et al.*, "The SXFEL upgrade: from test facility to user facility" *Applied Sciences*, vol. 12, no. 1, 176, 2022. doi:10.3390/app12010176

[3] https://epics-controls.org/