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BEAM DIAGNOSTICS CONTROL SYSTEM UPGRADE OF IPM LINAC

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Abstract

A series of upgrades has now begun to industrialize the applications of the experimental IPM electron LINAC. This includes upgrading the control system of the diagnostics tools and adding new tools and equipment to the system as well.

The aim is to build an integrated control system to collect and manage all diagnostics signals. This will allow us to continuously monitor and archive all of the beam parameters for LINAC performance analysis and improvement. It is hence decided to migrate from LabVIEW to an EPICS-based control system which has many advantages in this regard. In the meantime, it is also required to employ more modern equipment with better control interfaces and add some extra diagnostics tools to the system as well. So during this upgrade, most of the job would be developing new control interfaces and high-level applications accordingly.

In this paper, after a brief summary of the current diagnostics tools and our motivation for this upgrade, the scheme of the new control system and how different parts are integrated to the EPICS framework will be described.

INTRODUCTION

The experimental IPM LINAC has been in operation for a few years. Being first-of-a-kind project in the country, it was mainly intended to provide experience in accelerator science and technologies. However, over the past years it has gone well beyond this initial goal by serving as an X-ray source in several experiments as well.

After commissioning of the LINAC with 4 MeV beam energy, the original developers introduced a plan to reach higher energies in several phases. They installed a beam profile monitor system and a faraday cup (diagnostics station) at the most downstream of the LINAC in order to measure the beam properties at each phase [1].

Since then, the Iranian Light Source Facility (ILSF) has been cooperating with IPM in controlling and maintaining various LINAC subsystems. Now that it is decided to expand the applications of this LINAC, the ILSF control team was assigned to identify the hardware and software requirements and implement the required solutions afterward. In this paper, the preliminary steps to facilitate this process, with a focus on the beam diagnostics control system will be discussed.

MOTIVATION

Although an EPICS-based control system was initially considered for the commissioning of the LINAC, the original developers ultimately opted for a LabVIEW-based system due to their team's proficiency in it. While the LINAC has been operating successfully since then, there is a significant challenge ahead with the upcoming upgrades. The original source code of the LabVIEW design is not available at hand, and this poses a problem since without the source code, making upgrades or modifications can be difficult or nearly impossible. Since the current design also lacks some sort of standardizations, it is concluded that a complete redesigning based on a popular free open-source software is a necessary course of action. With this approach, we can make sure that the implemented solutions are previously tested, cost-effective, and reliable.

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THE EXISTING CONTROL SYSTEM

The layout of the existing beam diagnostics control system is depicted in Fig. 1. The so-called diagnostics station is located at the most downstream of the LINAC. Originally, it was consisted of a beam profile monitor and a faraday cup. Recently an in-house designed FCT has also been added to this setup as well. The output signals from these tools are visualized by an oscilloscope and a spectrum analyzer respectively. It is also possible to connect the spectrum analyzer to the LabVIEW control system for monitoring the RF input pulses.

The controllable components of the beam profile monitor system are the CCD camera and the screen mover system. The CCD camera is GigE Vision compliant. It is directly connected to a PC running LabVIEW NI Vision. This PC is dedicated to acquire and visualize the camera data. Similarly, the mover system is interfaced with another PC by a Moxa serial device server. This PC is running a Lab-VIEW application to control the screen position. This PC controls the whole LINAC except the camera GUI.

Unfortunately, the source codes of the applications running on these PCs are not available, and consequently, adding new tools to the GUI applications is impossible. The same issue arises with the custom designed boards of the timing system and the serial interface board (yellow parts in the Fig. 1). Self-developed codes running on these boards are not accessible either. So in order to tackle this problem, these self-developed hardware and software components will be replaced and an integrated control system based on EPICS will be built from scratch.

THE NEW CONTROL SYSTEM

Before proceeding with the upgrade, it is necessary to choose a standard based on our needs and requirements. This will help keeping consistency while designing different levels of the control system and working with different software and hardware platforms. For this reason, the first step was choosing the core software and corresponding communication protocol and network architecture.

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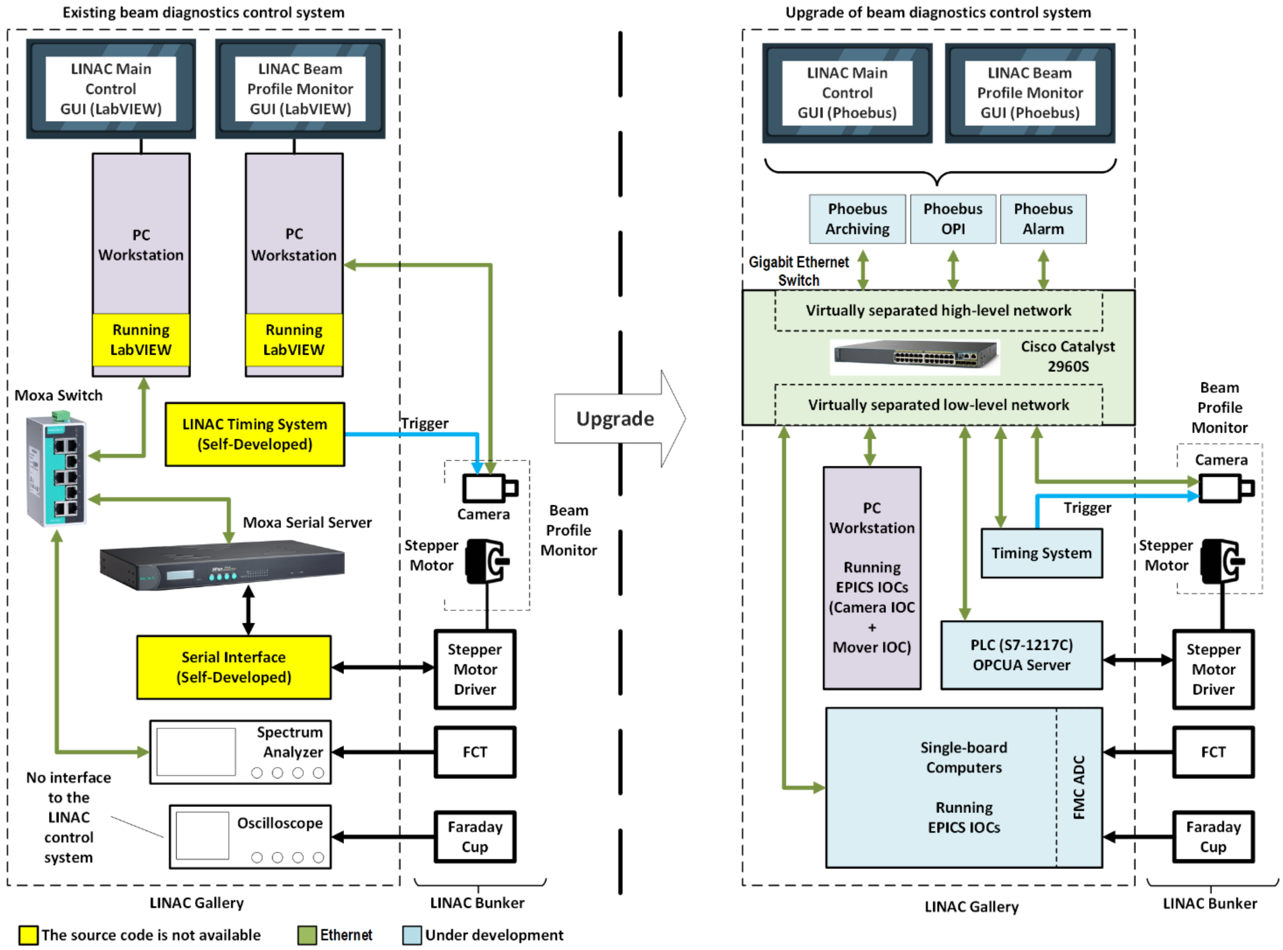

Figure 1: The architectures of existing beam diagnostics control system (left), and the planned upgraded control system (right).

Core Software

Among popular software toolkits, our preferred choice is EPICS, for which the expertise is already available. Since it is the same software tool envisioned for the ILSF control system, the workforce would be focused on a single path. The modularity of EPICS gives us more flexibility in making changes to both hardware and software during this upgrade and a variety of choices for developing high-level applications based on Qt, Python, etc. Furthermore, with the large and open community of EPICS, the technical knowledge would always be accessible and the maintenance and troubleshooting of the machine will no longer be dependent on the presence of a particular individual.

The EPICS version 3.15 has been the stable version for many years. However, there is an increase in the number of facilities migrating to EPICS 7 or choosing it for their projects in the first place. As stated by the developers, comparing to the classical one, EPICS 7 has more capabilities for implementing new features, and its communication protocol, pvAccess (PVA), has better performance specially in handling 2-dimensional image data leveraging the advantages of NTNDArray [2]. In order to avoid the complexities of later migration, it is more convenient to opt for the EPICS 7. This would give us the opportunity to get used to this version from the early stage of this upgrade while benefiting from the improved performance and its compatibility with newer technologies.

Network Architecture

In the new control system, the network is divided into low-level and high-level parts. This architecture has been implemented in many facilities and provides modularity, scalability and some levels of abstraction which will ease the process of upgrading and maintenance. A Cisco Catalyst 2960-S24PD-L Gigabit Ethernet switch is used to virtually separate the low-level and high-level network.

The low-level components include IOCs and all controllers that run I/O operations. These are connected to the field-level network.

The high-level components include CSS (phoebus [3]) services and applications such as alarm handling system, archiving system, and OPI runtimes, as well as other EPICS tools written in languages such as Qt, Python, and MATLAB.

Analog Devices: FCT and Faraday Cup

Currently analog diagnostics tools such as FCT and faraday cup are connected to a spectrum analyzer and oscilloscope respectively. While this solution has the advantage of being a stand-alone station to monitor the beam, it lacks

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modularity and flexibility in design. In large facilities, using standard platforms such as MTCA and cPCI to acquire and process the data is a popular solution, however, for this lean project with a few numbers of I/O signals, these are not optimal solutions in terms of both budget and personnel expertise. Hence, it is more likely that a single-board computer (SBC) with a multi-channel FMC ADC will be used for interfacing these tools to EPICS. The SBC would be connected to the ethernet switch and run an embedded EPICS IOC to put the data on the pvAccess network.

Beam Profile Monitor

The beam profile monitor consists of the scintillator screen mover system, which is connected to a PLC, and the GigE CCD camera, which is connected to the Ethernet switch. Connecting the camera to the Ethernet switch instead of PC comes in handy during the development, especially in cases where there is a need to connect to the camera from different locations.

For the screen mover system, the stepper motor is reused from the previous setup. Additionally, two limit switches are incorporated to the new system which provide more control over the setup and can be used for interlocking purposes as well. The stepper motor driver and limit switches are connected to a Siemens S7-1200 PLC system, which replaces the existing S7-300 PLC. The high performance 1217C CPU module has been chosen because this PLC controls other parts of the LINAC as well. Contrary to the existing one, this CPU features built-in supports for OPC UA and motion control I/O.

A high-performance PC workstation runs EPICS IOC applications to communicate with the PLC and the GigE camera. This PC handles the process variables (PVs) and communicate with other IOCs, as well as high-level clients using the pvAccess protocol.

Currently some preliminary EPICS IOC applications with S7NODAVE, OPCUA, and areaDetector support modules has been developed for evaluation (Table 1).

Table 1: Summary of the Developed EPICS IOCs

Controllable Device	**EPICS Support Modules**
GigE Camera	areaDetector
Screen Mover	S7NODAVE and OPCUA

For the camera system, an experimental setup has been built to test the procedure and develop applications of visualizing and measuring the beam size. The setup comprises of a laser, a movable aperture, a calibration screen, a moveable lens, and the GigE camera itself. The camera (jAi-BM-141 [4]) and the movable lens is shown in Fig. 2. The focal point of this lens is about 42mm.

Figure 2: jAi-BM-141 camera with the movable lens.

Since this camera is compliant with GenICam, the ADAravis driver from areaDetector is used to develop an EPICS IOC for communicating with the camera. By using pre-built areaDetector phoebus GUI panels, it is possible to control camera parameters, enable and configure the PVA plugin along with other necessary plugins, and start image acquisition. Finally, the image is visualized by the ImageJ [5] EPICS-NTND-Viewer plugin and its gaussian profiler.

A screen with 0.5 mm ± 10 µm grids is used to calibrate the setup as shown in Fig. 3. The horizontal projection of the laser beam is then plotted which gives the horizontal size of the beam as 39 µm ± 1 µm, taking only the error of the calibration screen into account (see Fig. 4). A microscope calibration slide with 10 µm divisions is used to validate this measurement.

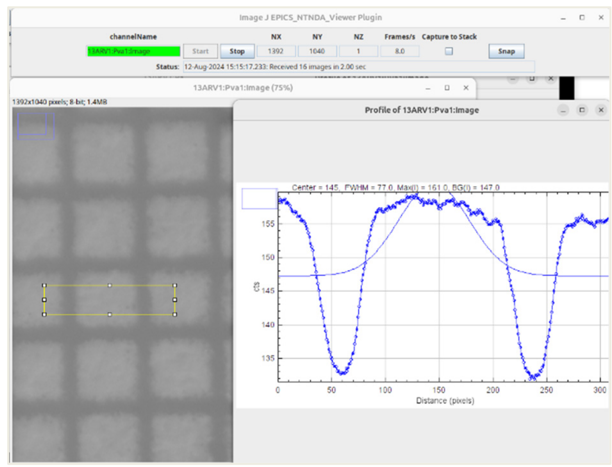

Figure 3: The profile of the calibration screen.

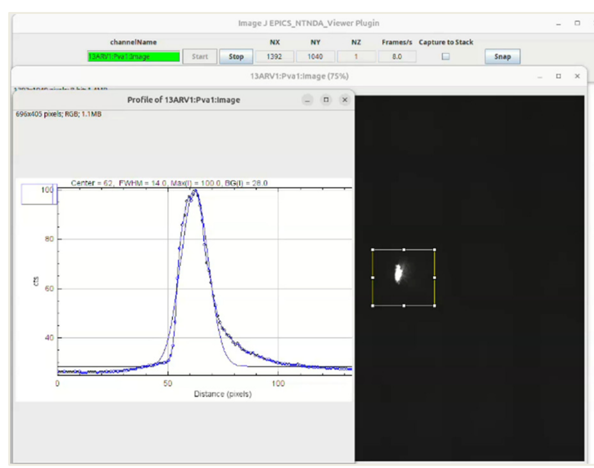

Figure 4: Measuring horizontal size of a laser beam that has passed through an aperture.

A phoebus GUI has been developed for this experiment as well (see Fig. 5). Among PVs available in the IOC database, there are two PVs which give the centroid and the corresponding size of the illuminated area in pixels (sigma). In order to find the actual size of the beam that is passed through an aperture in µm, a conversion factor that gives the object length per pixel should be found first. For this, the calibration screen is used as the reference. Then,

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the actual size of the beam in µm can be determined by multiplying the conversion factor by the sigma value in x and y directions.

While running the ADAravis IOC together with the required plugins and phoebus GUI panels, the resource usage of a PC with a Core i7-5500U CPU, 16 GB DDR3 RAM, and a 100 Mbps network card is monitored and noted as shown in Table 2. During this experiment, the required plugins are enabled one-by-one, while the following phoebus GUI panels are running:

- ADAravis
- commonPlugins
- IPM LINAC Beam Profile Monitor GUI panel (Fig. 4)

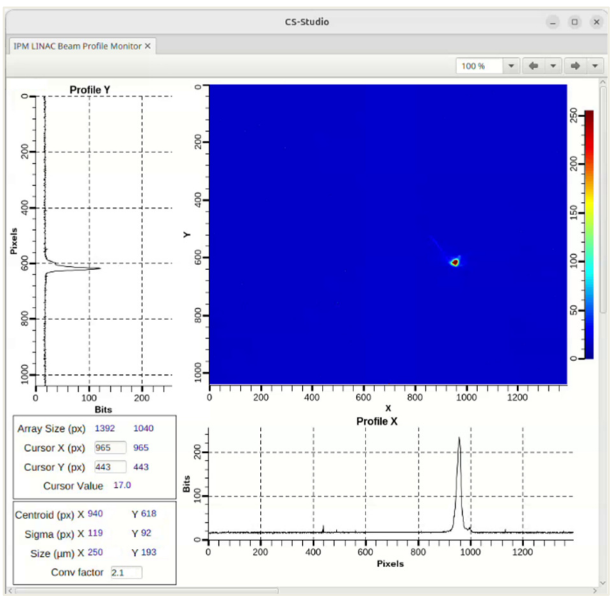

Figure 5: Developed phoebus screen for IPM LINAC beam profile monitor evaluation.

Table 2: Resource Usage of the ADAravis IOC and Phoebus

Plugins	ADAravis IOC	Phoebus
PVA	CPU: 4-5 % RAM: 257 MB	CPU: 7-9 % RAM: 1.1 GB
PVA + BADPIX	CPU: 14-15 % RAM: 282 MB	CPU: 7-9 % RAM: 1 GB
PVA + BADPIX + STATS	CPU: 18-19 % RAM: 286 MB	CPU: 9-12 % RAM: 1 GB

CONCLUSION

A review of the existing IPM LINAC beam diagnostics control system and the planned upgraded control system has been presented. In order to ease the way for the upcoming upgrades, preliminary steps to migrate from LabVIEW to an EPICS based control system has been taken. To begin with, EPICS IOC applications has been built to interface with the camera and the S7-1200 PLC for evaluation and testing purposes.

Our progress will continue in the future by enhancing the EPICS IOC applications, proceeding with the procurement of a single-board computer and a suitable FMC ADC for data acquisition of the analog devices, developing phoebus GUI panels, implementing phoebus alarm server and archiving system, and developing other high-level applications based on EPICS.

REFERENCES

[1] S. Sanaye Hajari *et al.*, "A Diagnostics Box for the Linear Accelerator of Institute for Research in Fundamental Science (IPM)", in *Proc. LINAC'18*, Beijing, China, Sep. 2018, pp. 581-583. doi:10.18429/JACoW-LINAC2018-TUPO119

[2] R. Lange *et al.*, "Five years of EPICS 7 - Status Update and Roadmap", in *Proc. ICALEPCS'23*, Cape Town, South Africa, Oct. 2023, pp. 1087-1092. doi:10.18429/JACoW-ICALEPCS2023-TH1BCO01

[3] Control System Studio, https://www.controlsystem-studio.org

[4] jAi, https://www.jai.com/products/bm-141-ge

[5] ImageJ, https://imagej.net/software/imagej