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Control System for JAERI Free Electron Laser

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Abstract

A control system comprising of the personal computers network and the CAMAC stations for the JAERI Free Electron Laser is designed and is in the development stage. It controls the equipment and analyzes the electron and optical beam experiments. The concept and the prototype of the control system are described.

I. Introduction

The Free Electron Laser (FEL) facility, SCARLET (SuperConducting Accelerator for Research of Light Emission at Tokai), is now under construction at JAERI[1-3]. It is a first step of the FEL program and the aim is the R&D of the superconducting accelerator (SCA) based FEL system in 10-50 μm range. The SCA is employed due to the suitability for the cw operation in the second phase of the project. The layout is shown in figure 1 and the main characteristics are described in table 1.

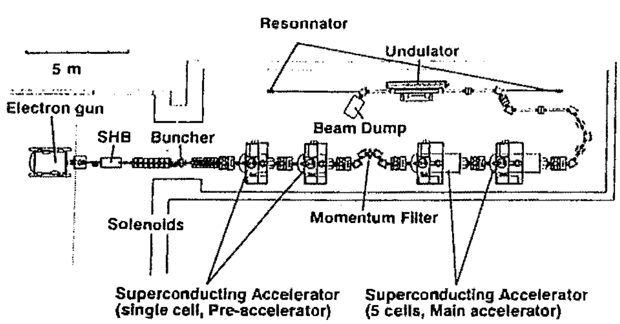

Figure 1. Plan view of the accelerator room of the JAERI free electron laser facility.

The accelerator itself is a small size with less than 20 m length, however, it would be expanded to 60 m in the second phase. In the design of the control system of the JAERI FEL, which will be also used in the next phase, the requirements were posed as:

1. Flexibility for evolving the system,
2. Reliability of hardware and software,
3. User interface for operator console,
4. Integrity of control and simulation,
5. Distributed control for fast response.

Table 1
Main characteristics of JAERI FEL
(first phase)

ITEM	SPECIFICATION
Electron Energy	14 – 23 MeV
Energy Spread	< 0.2 %
Peak Current	> 10 A
Pulse Width	40 ps
Repetition	10.4 MHz
Undulator Pitch	≈ 3 cm
Laser Wavelength	10 – 50 μm
Laser Peak Power	1 MW

II. Hardware Architecture

In this project, the flexibility has the highest priority to accommodate the frequent change and upgrade of the hardware devices in the development stage and at the next phase. The devices in the facility are divided into three subgroups: (1) the injector section (electron gun, sub-harmonic buncher, buncher, and injection beam transport line), (2) the accelerator section (superconducting cavities, rf power supply, refrigerators, momentum filter, achromatic bend line) and (3) the optics instruments (undulator, mirrors, optical detectors). They are well isolated by the locations and their functions.

Each subgroup is controlled by a local unit equipped with:

- a 32-bit personal computer (NEC PC 9801:cpu i80386 16/20MHz, 3-5 MB RAM, 14-in CRT) with minimal peripherals to control the local unit alone,
- a dedicated CAMAC crate system with parallel bus crate controller, which contains analog i/o, digital i/o and GPIB interface modules,
- an Ethernet interface.

The main console unit consists of two personal computers, one is used to control the tasks in the network and another is used to analyze and display the acquired data or on-line processed results in a 21-in CRT. These are connected by Ethernet and SCSI for accessing the common 300 MB hard drive and 600 MB magneto–optical drive. As the pointing devices, mice and a touch panel are used.

Fig. 2 shows the hardware configuration of the control system for the JAERI FEL facility schematically.

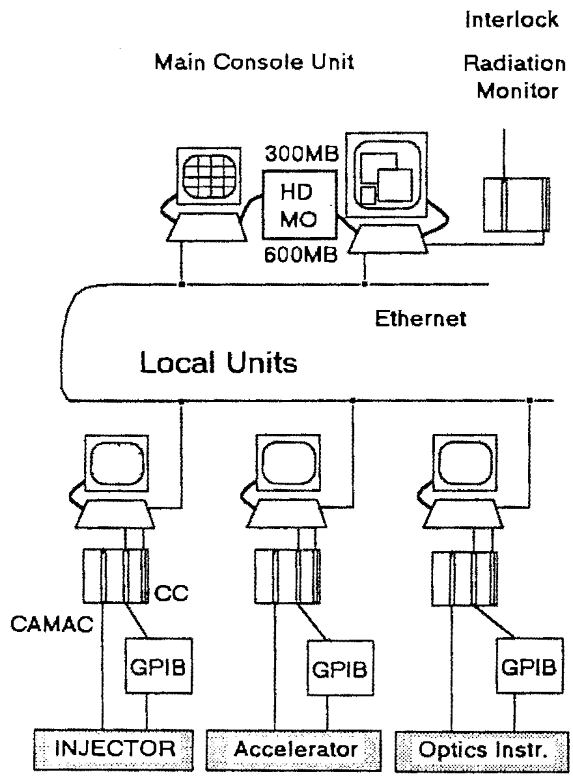

Figure 2. Schematic diagram of the hardware configuration.

The reliability of the hardware is important to maintain the laser oscillation, which is very sensitive to the electron beam quality. As the hardware considerations, we employ the modular approach in each layer: (a) the device driver level, which uses the standard interfaces, such as CAMAC and GPIB, and can be backup by other modules, (b) local unit computer level, which consists of the same units and it can be configured to share the task in the multiple computers, and (c) network level – if it is necessary, the network can be also doubled using an optical link of GPIB or serial communication at the expense of the data transfer speed.

The user interface is a severe problem when we employ the personal computer as a console and use graphics extensively, because display has lower resolution and the cpu ability is smaller compared with the workstations. To resolve the overload problem, the tasks to control devices directly are distributed over the network nodes (local units) and the console works only for organizing the messages among them.

The main console unit has an associated computer to display the auxiliary panels for supporting the control. It computes the beam characteristics using simulation codes, if required, and helps the operator to manage the knowledgebase on the machine operation. This causes to integrate the device control and simulation calculation in the FEL oscillation experiments.

The response speed is also a critical issue when the beam quality is fluctuated in a short time span. In the first phase of the project, the accelerator is operated in pulsed mode with 1 ms macro pulse width and 10 Hz repetition, so it is preferable to remedy the malfunctions found at the prior macro pulse in the 0.1 s pause. Basically, the feed back loops are inside of the device controllers, and it is designed that the CAMAC/GPIB data acquisition speed and the network speed are not critical.

III. Software Architecture

The system software consists of a multitask real–time kernel, drivers for the network, CAMAC and GPIB interfaces, and a graphical user interface. It has two modes of operations: simulation and on–line modes. In the development stage, the former mode is used to abstract the details and evaluate the system performance. In the actual operation, it is turned to the latter mode.

The flexibility and the reliability are enhanced by employing the object–oriented approach for software development. The software for FEL system control is configured in a hierarchy of three levels: *(1) process level, (2) hardware system level,* and *(3) hardware device level,* as shown in fig. 3.

As an instance, it is assumed that the task of process level control to transport in a portion of beam line is issued by an operator and it is requested to stabilize the condition of the electron beam (e.g. the position and the size). The process class has a sub class of hardware system level, one of whose instances is a double bend achromat in the current beam line. The hardware system

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comprises of the several sub classes of the hardware devices and one of the instances is a specific dipole magnet.

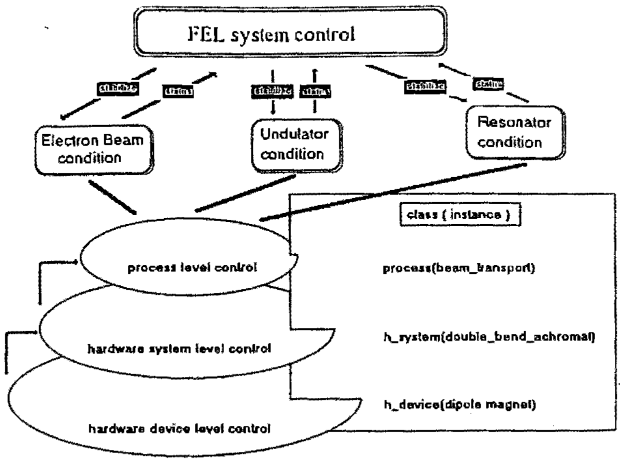

Figure 3. Software hierarchy of FEL system control.

To satisfy the request, the database of the magnet is searched and the corresponding control variable is found, then it is adjusted according to the rules sensitive to the objectives (beam position and size). There are many variables related to the hardware system so that they synchronize and communicate to each other. The final results are reported to the console as the status. And if required, the precise information about the history of the processing is recorded and reported the reasoning.

In the system database, or knowledge base after learning the rational rules of the operations, the classes of objects are represented by frames. Figure 4 shows an example of such a representation. It is described by the Prolog style. The "is_a" predicate represents an inheritance between classes, and "create"/"destruct" makes/deletes an instance. As the option, the multiple inheritance is attractive for categorizing the control items with the different aspects, such as the control method, speed, quality and quantity. The independent database is used when the informations are known to be orthogonal and the speed of the search is important.

As an example, the frame for bending magnet in a beam line is shown in figure 4. There are static and dynamic slots. And the dynamic slots are either the measured values or the derived values. The derived values can be controlled by a specified rule or formula. The slot can be created or deleted by using "assert" or "retract" predicates.

The integrity of the control and the simulation codes[4] can be attained by "beamtrace" or "matching" predicates, which produces an estimated beam condition or the optimized parameters during the control. These functions are combined to "stabilize" some characteristics. And "status" and "history" are reported as the resultants.

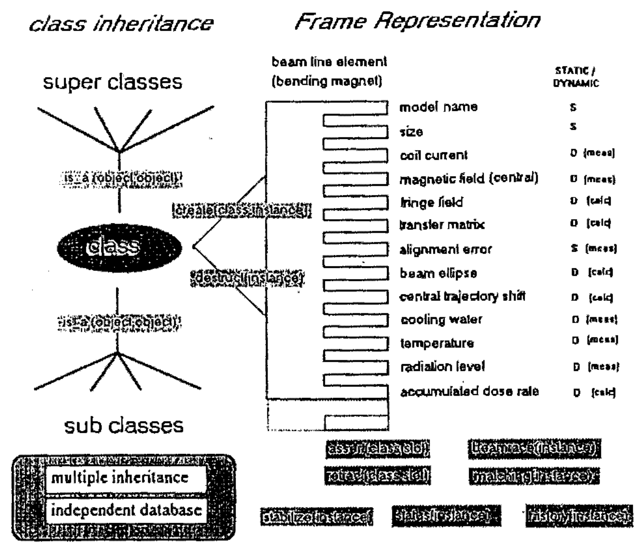

Figure 4. Representation of the system database in FEL system control.

The user interface for operator console is designed based on the graphics representation. Figure 5 shows an example of the panel for control. It contains all parameters of the electron gun, two buttons, three slide bars and four meters. The parameters can be controlled by using a mouse.

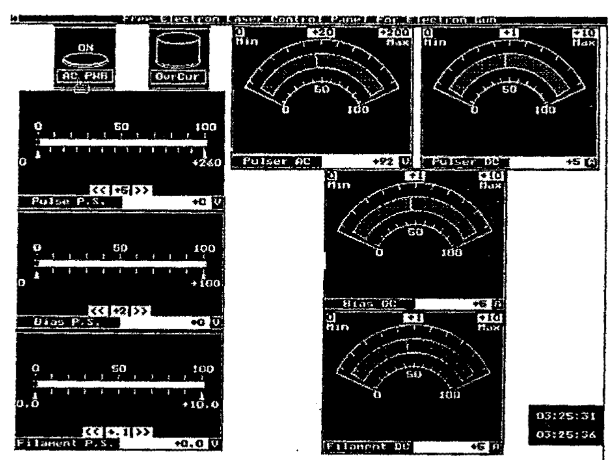

Figure 5. An example of the control panel.

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IV. Conclusion

The most important feature of the JAERI FEL control system is flexibility for evolving in the future. So the hardware is selected in the frame of the standard interfaces, CAMAC, GPIB and Ethernet, and the software is organized using the object–oriented approach. The control process is combined with the simulation code to support the operator to know the theoretical background of the current status and acquire the experiences on the operation procedure. The construction is not yet completed, but the control system may be used by hiding the unimplemented hardware with the simulated (virtual) devices.

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