ACCELERATOR-BASED EDUCATION ACTIVITIES AT JINR

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Abstract

Professional practice is essential to train an engineer. However, many activities are impossible to run at high school, especially if they require sophisticated equipment such as accelerators. A series of practical engineering courses is being set up at the Joint Institute for Nuclear Research to overcome these difficulties while educating students from the JINR Member States. A dedicated 'training' beamline of the Linac-200 electron accelerator is being constructed to practice the beam management and diagnostics, including the operation of standard beamline elements such as a bending dipole, quadrupoles, a sextupole and steerers. Various types of particle detectors can be used in the beam area as well in order to study the passage of electrons and photons through matter and to learn about the detector operation and properties. The practice at the beam will be accompanied by a series of hands-on trainings on radiation protection, vacuum and RF technology, electronics and metrology.

INTRODUCTION

Almost every physicist-experimentalist, and, particularly, engineer working with physical equipment, needs a basic understanding of its operating principles. For a person working at accelerator it is necessary to know basics of electronics, vacuum and RF technology, automation etc. Important are such topics as general, electrical and radiation safety. All these fields require the hands-on training alongside the theoretical learning.

One of the important activities of the University Center of the Joint Institute for Nuclear Research is the Engineering and Physics Training. Currently it has two main directions, first of which is a number of hands-on courses on analog and digital electronics, RF and vacuum technology, automation and basics of nuclear physics. The second part of the training should be conducted at the dedicated training beamline of the Linac-200 electron accelerator, which is under construction now.

DEDICATED HANDS-ON COURSES

Dedicated courses are located in the same building as the Linac-200 accelerator and are aimed at preparing students for work on a real particle accelerator. Most courses are designed in that way that students can either accomplish several lab works from the beginning of the course and gain some basic knowledge or pass the full course and gain the advanced knowledge.

The Lab Work on Electronics is aimed at hands-on acquaintance with the main radio-electronic components. Unlike the other lab works described below, this Lab Work includes minimum of equipment: an oscilloscope, a multimeter, and a soldering iron as the main tool. Students do not work with specially designed training models, but with real radio components: resistors, capacitors, diodes, transistors, self-made coils, etc. The Lab Work begins with an introduction to the main elements — resistance / capacitance / inductance. Afterwards, filters, semiconductors (diodes, transistors), logic operations and TTL logic, timers and transformers are studied. The course ends with assembling a fully-featured power supply unit with a step-down transformer, rectifier, and L-filter. The total time of the practice is about 10 days.

The Lab Work on RF Technology is aimed at studying the behavior of the RF range EM waves in the rectangular waveguide with different loads and irregularities. Students get hands-on experience with such RF elements as matched load, inductive and capacitative diaphragm, reactive dowel, and see how each of these elements influences the wave propagation in the waveguide.

The Lab Work on Vacuum Technology (Fig. 1) consists of 5 laboratory works. Three of them are dedicated to hands-on activities on the vacuum volume: assembly and evacuation, leak detection, and work with the inlet valve. The remaining two laboratory works are dedicated to the inner arrangement of a pump – assembly and disassembly of a backing and diffusion pumps. This and the previous courses last 2 days each.

Figure 1: The Lab Work on Vacuum Technology.

Automation Lab Work is the extension of the Vacuum one and is devoted to the remote control and monitoring of the physical facilities. The goal of the work is to design and assemble the automated control system for the above-mentioned vacuum bench including some simple interlocks, i.e. by pressure in the vacuum volume and pneumatic line (manual gate and valves from the Vacuum lab are changed to pneumatic ones). Students by themselves collect the in-

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Figure 2: Overview of the dedicated hands-on courses room.

formation about the control object (pumps, gate, valves etc.). On the basis received in the Vacuum lab students design vacuum equipment operation logic for different modes (start, stop, emergency), specify control equipment requirements (necessary amount of inputs and outputs of PLC, amount and type of relays, terminals, lamps etc.), design block and electric diagrams. Finally students assemble the control system according to the designed schemes, program the controller and do the commissioning. Siemens Simatic S7-1200 and OWEN 110 PLCs are available, as well as a number of the peripherals.

The Lab Work on Nuclear Physics is aimed at studying of the interaction of the ionizing radiation with matter. Lab Work equipment includes a set of low intensity ionizing radiation sources (α: Pu-239, Ra-226; β: Sr-90 and γ: Cs-137, Co-60, Na-22, Am-241), three detector units (solid state and two scintillation ones — with organic and non-organic scintillators), a set of different absorbers and a PC with the software for data acquisition and processing.

The general view of the room for the dedicated hands-on courses is shown at Fig. 2).

LINAC-200 TRAINING BEAMLINE

Linac-200 is the linear electron accelerator which is based at the MEA accelerator transferred to JINR by NIKHEF in 1999 [1]. The first stage of the accelerator should provide the 200 MeV electron beam for such purposes as accelerators, particle detectors and FEL R&D. The accelerator structure includes 4 accelerating stations, each feeded by a klystron. At the end of the each station (corresponding beam energies of 22, 50, 130 and 200 MeV) a dipole magnet will be installed to send the beam in the corresponding user section. In addition, at the end of the first station the dedicated training beamline (Fig. 3) is being constructed.

The training beamline is assembled mostly from MEA components and includes a bending dipole, some sextupoles and steerer magnets and a number of diagnostic devices: Faraday cup, integrating current transformer (ICT) and a scintillating screen with a CCD camera. In future it is planned to develop and add some elements absent at MEA or handed over to other facilities, i.e. quadrupole magnets and some special equipment for education (for example, a set of different thickness plates from various materials to study electron propagation through matter).

Depending on students' specialization, they will have a possibility to design the training beamline configuration needed for the certain task, assemble the beamline from scratch, pump it out and work with the real accelerator without any risk of harming its operation in general. Initial pumping out is performed using the exhaust cart including the fore-vacuum and turbomolecular pumps, then the ion pump is being started if needed. Easy to mount KF flanges are used by default but the high-vacuum option with CF flanges is also provided.

Fairly large number of available equipment provides a wide variety of hands-on activities for students of different qualification. For example, students with basic or no knowledge of the beam dynamics can just watch at the scintillating screen how is the electron beam influenced by different magnet types. However, students with advanced knowledge can make a simulation, develop on its base necessary magnet setup (types, location, current etc.), assemble this setup by themselves and see the real result of their calculations.

For students specialized in control and automation this training section provides a plenty of opportunities: monitoring and control of a considerable amount of wide range analog and digital values presented by real equipment, interlock system development, etc. The Linac-200 control system will be based at TANGO Controls toolkit [2], but generally the subsystem for the training beamline can be realized in any other SCADA system as appropriate.

Future particle physicists can work not only at the 22 MeV training beamline, but also at other user sections, studying beam diagnostics, detectors radiation hardness, response to

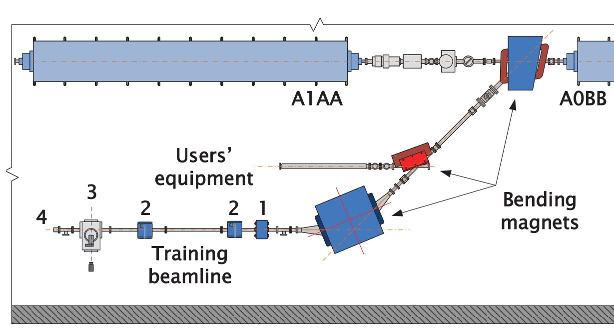

Figure 3: Linac-200 training beamline current setup scheme (1 — sextupole, 2 — steerers, 3 — video imaging box, 4 — Faraday cup).

high energy electrons etc. Furthermore, works in such fields as material science or FEL sources could be realized.

Currently, 2 accelerating stations are in the stage on operational testing, and one user section is installed (at 22 MeV). Pulse current of 15 mA was obtained for 22 MeV beam, 1 mA for 50 MeV (in the main accelerator beamline). The training beamline construction also comes to its end (Fig. 4), first electron beam was obtained at the dipole exit, but with low current yet (0,4 mA, Fig. 5). The primary limiting factor is the fact that while the Linac-200 accelerator is in the stage of operational testing it is prohibited to conduct any educational activities there. The official launch of the accelerator is expected in 2018.

Figure 4: Current setup of the 22 MeV part of Linac-200. From left to right: main accelerator beamline, user beamline, training beamline.

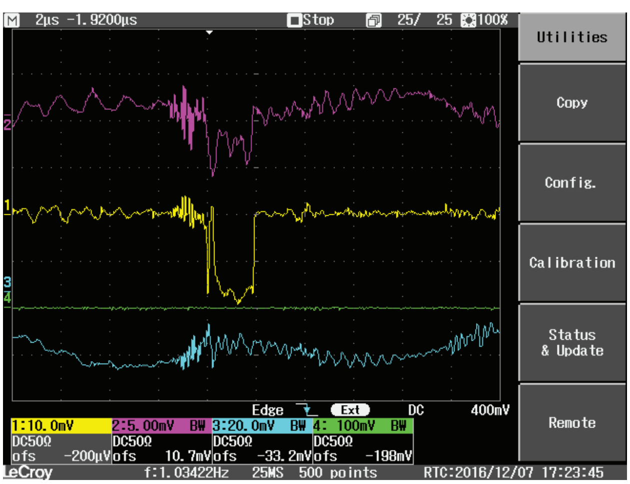

Figure 5: Signal from Faraday cup (channel 1) installed at the training beamline dipole exit. Corresponding current is approximately 20 mV / 50 Ohm = 400 µA.

FUTURE PLANS

A number of either new dedicated courses or extension of existing is planned.

The Magnets Lab Work should give the basic knowledge about the magnet design and power supply, magnetic induction measurement, hysteresis and so on. As the combination with the Automation Lab Work, the one on magnetic field map measurement device construction can be done — Hall sensor, two precision actuators for its movement, and a PLC for control and data acquisition.

The Automation Lab Work development can be infinite: different PLC's, different software (EPICS [3], TANGO, LabVIEW [4], ...), different hardware (VME, µTCA [5], ...), different devices to control and so on and so forth.

The Lab Work on dosimetry is planned as an extension of the Nuclear Physics lab. It will be possible to get acquainted with different dosimeters and radiometers, study such topics as radiation protection, radiation fields measurement and search of the radiating source, neutron radiation measurement and protection.

The Lab Work on the various detector characterization is also foreseen. It includes measurements of spatial energy and timing resolution of pixel Medipix detectors, Micromegas chambers and many other detectors used at physics facilities of JINR.

CONCLUSION

A set of hands-on courses on various engineering fields was developed in the University Center of the Joint Institute for Nuclear Research. Electronics, RF and vacuum technology, automation and nuclear physics are covered. Construction of the students training beamline of Linac-200 electron accelerator is in its final stage. First beam with 400 µA pulse current was obtained. Further infrastructure development includes extension of the current courses and new fields, such as magnets, dosimetry, particle detectors. Existing infrastructure can be used by educational and research organizations for creation of their specific hands-on courses.

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