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LINAC-200: A NEW ELECTRON TEST BEAM FACILITY AT JINR

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Abstract

Commissioning of a new electron test beam facility Linac-200 comes to the end at JINR (Dubna, Russia). The core of the facility is a refurbished MEA accelerator from NIKHEF. The key accelerator subsystems including controls, vacuum, precise temperature regulation were redesigned or deeply upgraded. The facility provides electron beams with energy up to 200 MeV while the beam current varying smoothly from 40 mA down to almost zero (single electrons in a bunch). The main goal of the facility is providing test beams for particle detector R&D, studies of novel approaches to the beam diagnostics, and education and training of graduate and postgraduate students. The current status and operation parameters of the facility will be reported.

INTRODUCTION, MACHINE PARAMETERS

Due to the increasing demand for test electron beams in JINR a new test beam facility is being constructed. It is based on the MEA linear electron accelerator which was transferred to JINR from NIKHEF in the end of 90s [1].

Main accelerator structure unit is a *station*. The injector station A00 includes the electron gun, chopper, prebuncher and buncher. First accelerator station A01 includes one accelerating section and a klystron, which also feeds the RF equipment of the A00 station. All the rest stations include two accelerating sections and a klystron each.

Current setup (Fig. 1) consists of 5 stations, A00–A04, and allows generation of the 200 MeV electron beam. In the future it is planned to install 9 additional stations A05–A13, with a resulting energy of 800 MeV (for more details see *RF & acceleration* subsection below).

For now the electron beam is available for users in two places: after stations A01 and A04 (see Table 1). At the end of the first stage of the facility construction two more beam extraction point will be added: after stations A02 (expected energy of 60 MeV) and A03 (130 MeV). During the second stage (800-MeV accelerator) yet more extraction points will be added. Current plan is A06 (350 MeV) and A08 (500 MeV) but other options are also available—in principle it is possible to extract the beam after any station). The facility has two control rooms: for operators and for users.

Several points should be noted concerning Table 1:

- Current values provided are the maximum ones. If necessary, current can be changed from the specified value down to almost zero (by means of gun extractor and focusing electrodes voltage adjustment, and beam collimation). Maximum current can be obtained at energy ranges of 10–25 MeV at A01 and 80–180 MeV at A04.
- Energy is changed by means of the RF power (i. e. klystron anode voltage) adjustment.
- Optimal pulse duration is 2 μs. Gun can produce pulses with the duration of up to 50 μs, but the duration of the accelerated pulse is limited to 3.5 μs by the RF pulse length. It's also possible to generate pulses with the duration below the specified range (i. e. 50 ns), but at the cost of the pulse quality (the lesser is the duration, the more non-rectangular is the pulse).
- Despite beam is not yet available for users after stations A02 and A03, the pulse current there was measured: maximum values were 60 mA after A02, and 50 mA after A03. Energy was not measured, but is estimated as 60–70 MeV for A02, and 120–130 MeV for A03.
- Maximum reached pulse current at maximum obtainable energy, 200 MeV, is 10 mA so far.
- Specified frequency range is for full accelerator. At 20 MeV (stations A00 and A01) the machine can operate at 50 Hz.

Table 1: Parameters of the Linac-200 Electron Beam Available for Users

Parameter	Station A01	Station A04
Electron energy, MeV	5–25	40–200
Pulse duration, μs	0.1–3.5	0.1–3.5
Max. pulse current, mA	60	40
Pulse repetition rate, Hz	1–25	1–25

ACCELERATOR SYSTEMS OVERVIEW

Electron Gun

The beam is generated by the 400-kV DC triode-type electron gun with a thermionic cathode [2]. The gun control system was completely redesigned at the end of 2000s [3]: new in-gun microcontroller and operator PC were installed, new software was developed for both of them.

RF & Acceleration

Beam is accelerated by the iris-loaded travelling wave structures. RF power is provided by the 20-MW Thomson TH 2129 klystrons. Each klystron feeds two accelerating sections. The exception is the first one, which feeds one accelerating section and bunching devices. Due to the modulator limitations only half of the klystrons peak power is used (i.e. each accelerating section receives 5 MW of RF power). Extra klystron power available can be used in future

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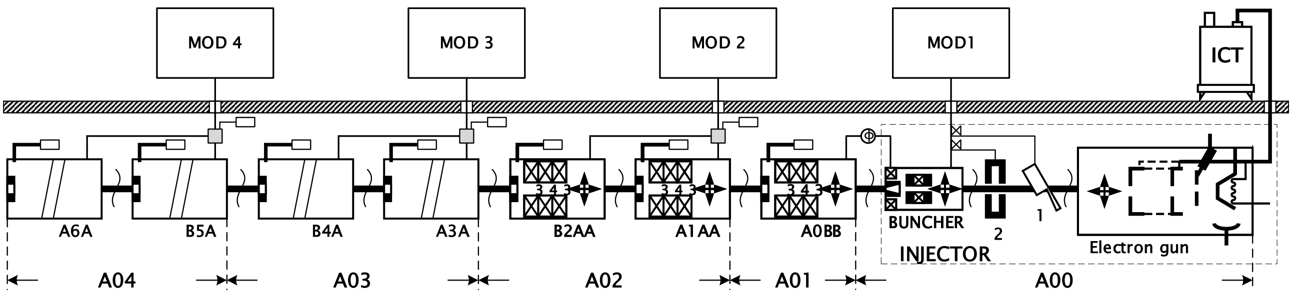

Figure 1: Linac-200 accelerator layout.

to increase peak accelerator energy from 800 MeV to about 2 GeV. Key acceleration & RF parameters for both 200 and 800 MeV configurations are given in Table 2.

Table 2: Linac-200 / 800 Key RF & Acceleration Parameters

Electron energy, MeV		200	800
Number of short (3.7 m) sections		3	3
Number of long (7.3 m) sections		4	22
RF frequency, MHz		2856	
Wave type		TW	
Field mode		2π/3	
Filling time, μs		1.3	
v_g/c range		0.0093–0.0389	
Shunt impedance, MΩ/m		56.5–48	
Iris aperture:	diameter, mm	32–17	
	thickness, mm	5.84	
Number of klystrons		4	13
RF power:	peak, MW	10	
	mean, kw	20	

The solid state modulator consists of the special multi-core pulse adding transformer and 40 PFN (Pulse Forming Network) units. Each of these units is a printed circuit board with a 2 kV line-type (50 μs) modulator. Two units feed a primary of the pulse adding transformer [4]. Such a layout allows generation of pulses which amplitude can be changed by changing the number of active PFN units. This number is controlled by the special Weltek controllers. These controllers also provide information on the modulator status to the control and interlock systems [5].

Magnets

Linac-200 magnet system consists of three subsystems:

- Focusing. At the low energy part (stations A00–A02) the beam is focused by solenoids, at the rest part—by quadrupole dublets.
- Steering. Pairs of steerer magnets (horizontal & vertical) are located at the gun output, before chopper, before buncher, inside each of the sections with solenoidal focusing (including buncher) and at the drift space at the end of each station where quadrupole focusing is used (i.e. a pair of steerers per every two long sections).
- Bending. To extract the beam from the accelerator to provide it to users, pairs of bending magnets are used (one magnet to extract a beam from accelerator, another one—to return it to the direction parallel to the accelerator).

More information about Linac-200 / 800 magnets and their parameters can be found in [6].

Vacuum

The beam vacuum chamber, as almost all accelerator equipment, is divided to stations. Corresponding chamber sections are separated from each other by gate valves. Typical vacuum layout of one station is shown at Fig. 2.

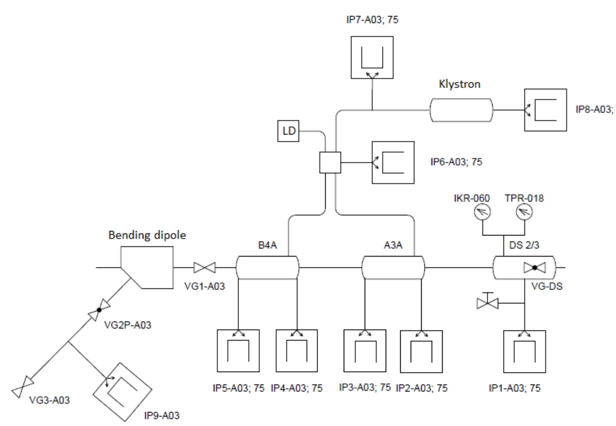

Figure 2: Vacuum system layout of one linac station.

The vacuum chamber is evacuated by the ion pumps. Old Varian pumps from MEA are gradually replaced by new Agilent ones. No stationary foreline is present; initial pumping is performed by the mobile pumping stations (scroll pump + turbo pump).

Pressure in the chamber is measured by pairs of Pfeiffer Pirani and Penning gauges, and by monitoring of ion pumps' current.

Beam Diagnostics

The following tools are used for diagnostics:

- Faraday cups to measure beam current during the commissioning.
- Current transformers for current measurement in the operation mode. Typical signals can be seen at Fig. 3.

- Beam viewers with scintillator screens and video cameras.
- Compton radiation monitors to detect major beam trajectory errors.
- Traveling wave monitors allow to define both beam current and position.

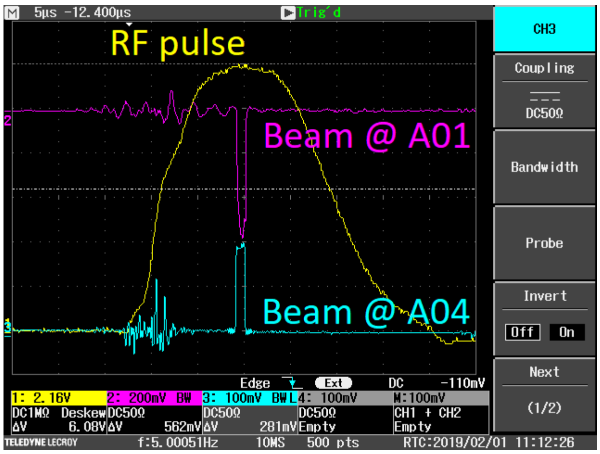

Figure 3: Beam current signal from the current transformer after A01 (magenta) and A04 (cyan) stations, and RF pulse (yellow).

Controls

Almost all MEA equipment is in good condition and has reasonable operating resource. However, control systems hard- and software, as it is the most rapidly developing sphere, were mostly out-of-date already at the moment of accelerator transfer from NIKHEF to JINR. Therefore, two major accelerator control system upgrades took place. The first one was continuous, when necessary control subsystems were developed when they were needed. The second one started in 2018 when development of the Tango-based global control system began [6].

To date, Tango device servers and clients for the electron gun, RF system, and power supplies of steering and quadrupole magnets were developed. Preliminary tests were done, final tests, as the new synchronization system tests, will be done after building renovation finish.

CONCLUSION & OUTLOOK

New Linac-200 electron test beam facility at the Joint Institute for Nuclear Research (Dubna, Russia) is nearing completition. Two beam extraction points (5–25 and 40–200 MeV) are available. The beam current can be smoothly varied from 40 mA (60 mA at 25 MeV) to almost zero (single electrons in a bunch). The test beam facility is open for accelerator and detector R&D, sample irradiation for applied research and other studies.

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