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BEAM DIAGNOSTICS AND CONTROL FOR AREAL RF PHOTOGUN LINAC

G. A. Amatuni#, B. Grigoryan, A. Lorsabyan, N. Martirosyan, V. Sahakyan, A. Sargsyan, A. Tsakanian, A. Vardanyan, G. Zanyan, CANDLE SRI, Yerevan, Armenia
K. Manukyan, Yerevan State University

Abstract

Advanced Research Electron Accelerator Laboratory (AREAL) based on photo cathode RF gun is being constructed at CANDLE. In current stage the gun section is under commissioning (phase 1). This paper presents the main characteristics of gun section beam diagnostics and the architecture of AREAL control system. The diagnostic system includes the measurements of beam charge, transverse profile, energy, energy spread and emittance. The results of the facility first phase commissioning are summarized from the beam diagnostic and control point of view.

INTRODUCTION

The main goal of the AREAL linear accelerator [1] is generation of 5-20 MeV energy, small emittance and ultrashort duration electron bunches for advanced research in the fields of accelerator and beam physics. For several experimental setup purposes the linac will operate in single and multi-bunch modes. The main design parameters of the electron beam are given in Table 1.

Table 1: Beam Parameters List

Main Parameters	Single bunch	Multi-bunch
Energy	5-20 MeV	5-20 MeV
Bunch charge	10-200 pC	5-10 pC
Transv. norm emit.	<0.3 mm.mrad	<0.3mm.mrad
Bunch length (rms)	<0.8mm	<0.8mm
Transv. Beam size (rms)	1mm	1mm

The beam diagnostic system for the AREAL linac can be divided into two sections: gun section diagnostics and linac diagnostics. In the current stage (phase 1) the gun section with corresponding diagnostic devices are put into operation. For phase 2 the full accelerator will be assembled [2].

The beam transport line between the electron gun and the first accelerating structure (energy < 5 MeV) has a length of almost 1.1 m, which is completely occupied by diagnostic devices. In this diagnostic line electron beam charge, transverse profile, emittance, energy and energy spread are planned to be measured. The schematic layout of the gun section with diagnostics is presented in Fig. 1.

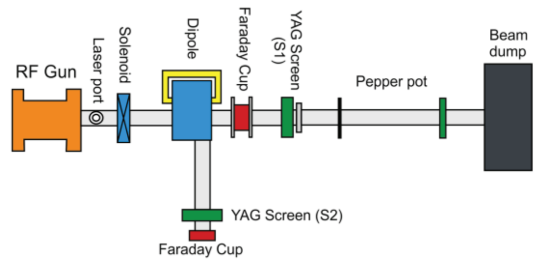

Figure 1: Layout of AREAL gun section with diagnostics.

ELECTRON BEAM DIAGNOSTICS

Beam Charge

The task for the beam current and charge measurement is to verify that the charge produced at the cathode is completely transported along the whole beam line to the beam dump. At phase 1 in the AREAL linac the charge of individual bunches is measured using two Faraday cups. One of them is located at the end of spectrometer arm and the second one, an insertable Faraday cup, is installed in the gun section (Fig.1, 2). Electrical connections are made to the base of the Faraday cups, terminating in a BNC connector. The output signal is integrated on the oscilloscope and divided by the termination to give a reading of the charge.

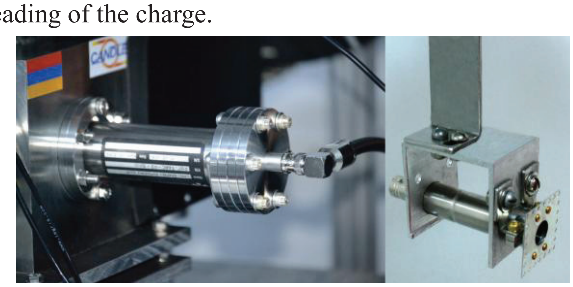

Figure 2: Faraday cups used in AREAL.

Specifications of Faraday cups are presented in Table 2.

Table 2: Specifications of the AREAL Linac Faraday Cups

	Standard	Insertable
Cup Diameter (mm)	15.1	9.5
Cup Length (mm)	75	69.5
Maximum Power (W)	10	4
Impedance	50 Ω	
Signal Output	BNC	

#gayane@asls.candle.am

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In Fig.3 the beam induced output signal from Faraday cup located in the gun section is shown. The observed maximum charge was ~180pC.

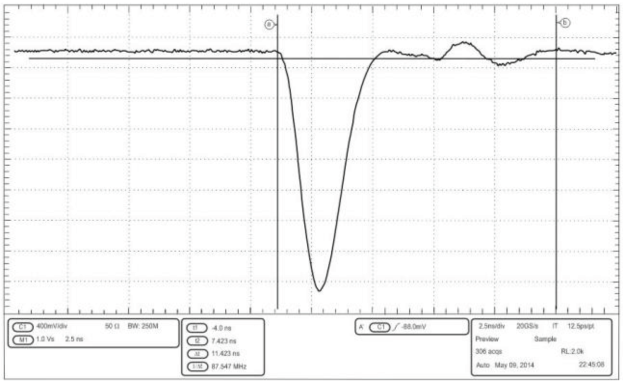

Figure 3: Faraday cup output.

Beam Transverse Profile

In the AREAL linac (for energies up to 20 MeV) only scintillating crystals are installed, because the other systems (such as OTR screen or the wire scanner) would not generate sufficient signal-to-noise ratio. Profile monitors (scintillation screens monitored by CCD cameras) are almost always the simplest beam profile measurement devices [3]. A full horizontal/vertical profile can be produced by a single beam pulse. The image is digitized, projected onto orthogonal axes, and fitted with an appropriate function. The calibration is obtained using reference marks etched directly on the screen.

Four optical screen monitors will allow the control, monitoring and optimization of the transverse beam profile in the AREAL linac. Two of them are placed in the low energy diagnostic line (Fig. 1) and the next two will be installed after the accelerating sections.

YAG: Ce scintillation screens of 25x25 mm^2 and 200 μm thick are used for the profile measurements. The screens are mounted to a holder and positioned in the beamline with a vacuum feed through by a pneumatic linear motion motors. The scintillators are mounted at the right angle to the beam. A mirror reflects the light out of the vacuum chamber (Fig. 4).

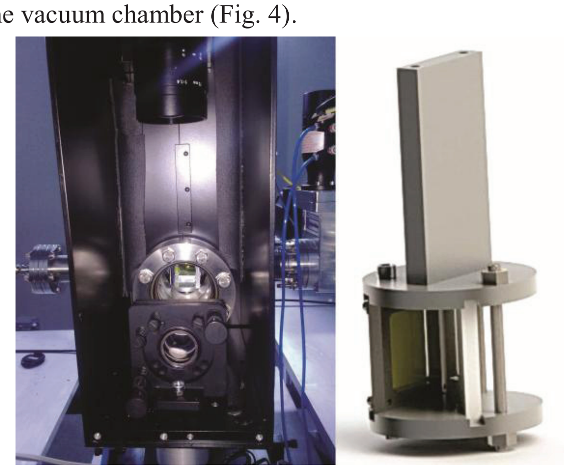

Figure 4: Optical black box and YAG:Ce holder.

Point Gray Flea2 08S2 (1032x776) and Flea2 20S4 (1624x1224) CCD cameras are used for electron beam transverse profile measurements. The CCD camera signal is transported from tunnel to control room PC via Repeater/HUB.

Fig.5 shows the electron beam transverse profile measured in the gun section. At the first operation of the AREAL linac the following transverse sizes have been registered: $\sigma_x = 0.3mm, \sigma_y = 0.4mm$.

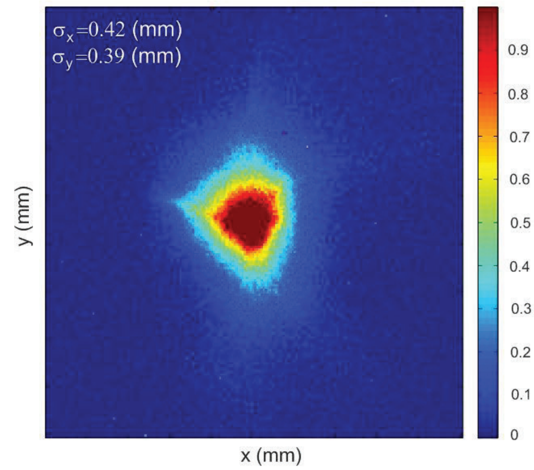

Figure 5: Electron beam transverse profile.

Beam Energy and Energy Spread

The first measurements of the beam energy and the energy spread have been performed using the dipole based spectrometer section with the YAG screen. Due to the limited space for diagnostics at gun section, 90° bending magnet is chosen (see Fig. 1). Absolute energy measurement is given by the geometry and calibration of the dipole and the subsequent drift length (about 20 cm). Fig.6 presents the beam profile at the YAG screen located after the bending magnet. The comparison with the spectrometer dispersive characteristics shows that the image corresponds to 3.7 MeV beam energy and about 2% rms energy spread.

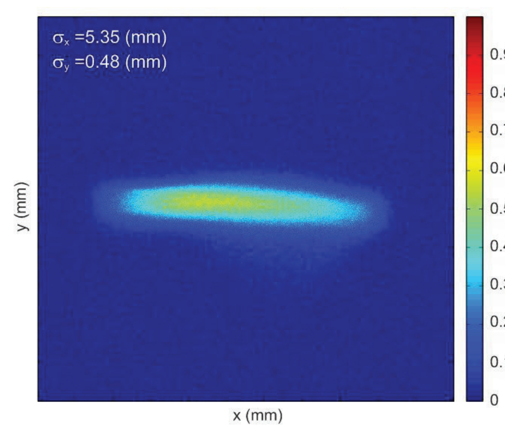

Figure 6: Electron beam transverse profile at the spectrometer YAG screens.

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Future Diagnostics Tasks

At the first operation of the AREAL linac the electron beam charge, energy, energy spread and transverse sizes have been measured. In the near future it is planned to measure the beam emittance. For the emittance measurement a pepperpot technique will be used [4]. Because of the space charge dominated, low energy beam dynamics this method is most convenient. The detailed information about the pepperpot station is presented in [2].

At the second stage, when the gun section commissioning is completed, the pepperpot will be moved to the high energy electron beam diagnostic line (after accelerating sections). In this section it is also planned to measure electron beam emittance using quadrupole scan technique.

At the same time when the whole linac is assembled it is also planned to measure electron beam longitudinal profile[5].

CONTROL SYSTEM

From the control system point of view the AREAL linac components are categorized as follows: vacuum system (ion pumps, vacuum gauges, gate valve and fast closing valve), RF system (LLRF), magnet system (solenoid and dipole magnets), cooling system, diagnostic system (CCD cameras, movers and Faraday cups), laser system and radiation safety.

The AREAL linac control system is based on "client-server" model and has two layers of hierarchy. The first layer is an interface computer to which the devices are connected via RS-232/485, USB and DAQ (Data acquisition), depending on a device type and specifications. The second layer is operator interface computers which are located in the control room. The connection between these two layers is performed via TCP/IP (Fig7.).

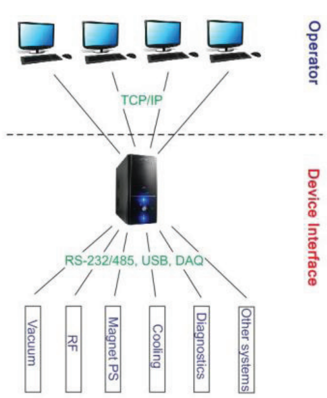

Figure 7: AREAL linac control system hierarchy.

During the first operation of the AREAL linac the following control and monitoring tasks have been performed:

- Readings of vacuum gauges and ion pumps have been monitored.
- The LLRF control is performed via LIBERA which is a digital low level RF stabilization system. EPICS and all required IOCs are already installed on LIBERA. Channel accesses between IOCs and operator interface computers are developed.
- All magnets are controlled remotely. The electronics for power supplies was designed and assembled at CANDLE SRI. The control of the power supplies includes the following functions, namely current set, power on/off, status monitoring (remote/local, over current, etc.) and degaussing for bending magnet.
- The remote connection between diagnostics equipment and operator interface computers has been provided. CCD camera signal analysing software was developed, which allows users to capture beam image and get the required information (transverse rms size, position). The remote control of movers and shutters was performed. Homemade controllers were used for this task.
- The remote connection for cooling system control was established. The main goal of the cooling system control is to monitor and control temperature of the gun, klystron and solenoid magnet.
- In the current stage the laser system is controlled locally via software provided by the laser manufacturer. One of the nearest tasks of control group is the integration of laser control to the global control of the linac.

For the completeness of the AREAL linac control system the following tasks must be accomplished: parameter and measurement database development and timing system integration to the global control system.

SUMMARY

This paper presents the current status of the AREAL linac operation and first measurement results. The diagnostic system for phase 1 is described in details and further plans are listed. The control system hierarchy is presented with detailed description for all main subsystems.

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