ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPME025

DESIGN AND PERFORMANCE OF ULTIMATE VACUUM SYSTEM FOR THE AREAL TEST FACILITY

A.A Gevorgyan#, V.Sh. Avagyan, B.A. Grigoryan, T.H. Mkrtchyan, A.S. Simonyan, V.V. Vardanyan, CANDLE SRI, Yerevan, Armenia

Abstract

The basic aim of the AREAL (Advanced Research Electron Accelerator Laboratory) photocathode RF gun linear accelerator is the generation of 5-20 MeV energy, small emittance and ultrashort duration electron bunches for advanced research in the fields of accelerator and beam physics. Design specification of the AREAL test facility requires the residual pressure at the level of about 10nTorr with beam through entire vacuum chamber. We present the main peculiarities of the vacuum system, including the design and fabrication features of the dedicated components such as dipole magnet stainless steel vacuum chamber and the cubes for beam diagnostic stations. The philosophy and instrumentation of the vacuum system are discussed.

INTRODUCTION

The AREAL facility is designed for the low average current operation with the maximum chargeof about 200 pC per bunch. The facility performance implies both the single and multibunch operation modes with the electron bunch duration in the range of 0.5-2psec with further upgrade to tens of femtoseconds. To reach the design goals of the facility and its reliable operation, the Cu photocathode has been chosen. In comparison with the metal coated or semiconducter photocathodes, it has the long lifetime, the small response time and is easy in maintenance requiring the residual vacuum at the level of 1-10 nTorr [2].

The vacuum system for the AREAL test facility [1] is designed for maintenance of ultrahigh vacuum (UHV) at level of about 1nTorr. The construction of the AREAL facility implies two stages. The first stage aims at generation of low emittance ultrashort electron bunches of maximum 5 MeV energy based on RF photogun. The second stage aims to reach the energy of the electron beam up to 20 MeV using conventional S-Band accelerating sections.

The first phase of the AREAL facility has been completed recently. The results of the facility commissioning are presented in [3]. The schematic layout of the machine is presented in Fig.1. The main components of the gun section are the RF gun, gun mirror system, solenoid magnet, dipole magnets and diagnostic equipments (YAG screen stations, Faraday Cups, emittance measurement station (pepper-pot). The vacuum system is designed for providing the stable high vacuum along the entire facility. A number of new components for vacuum chambers has been designed and fabricated at the CANDLE in order to meet the design specifications.

gevorgyan@asls.candle.am

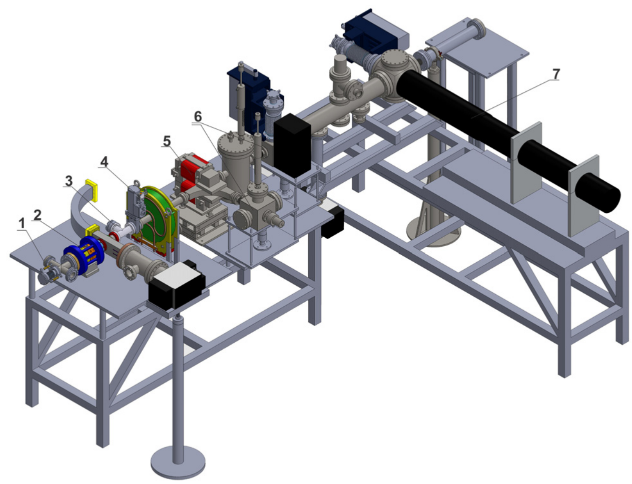


Figure 1: 3D layout of machine, 1-photocathode holder mechanism, 2-RF gun, 3-laser mirror system, 4-solenoid magnet, 5-dipole magnet, 6-vacuum cubes with optical boxes, 7-pepper-pot.

MAIN COMPONENTS OF VACUUM SYSTEM

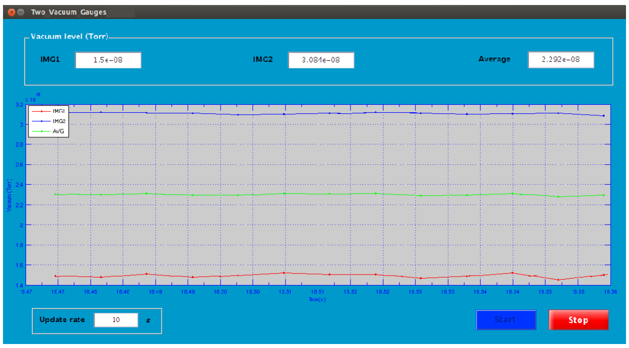
For obtaining an UHV it is necessary to use a right vacuum materials [4], thus most of all components, chambers, bellows, valves are fabricated from austenitic stainless steel of grades 304 LN and 316 LN. They have excellent mechanical and vacuum properties and satisfy the requirements such as very low magnetic permeability (<1.005), highly reliable welding joints and etc.

Some of the components are made from oxygen free copper aluminium and titanium, like RF gun, gun mirror folder, and YAG screen holders. As the main vacuum pumps the titanium sputter ion pumps (STARCELL) with 55 and 75 l/sec pumping speeds are used. Portable turbo molecular pumping station is used during roughing and baking. For vacuum level measurements two cold cathode and one hot cathode ion gauges (BA) are used. The interlocking and control of the gate valves and titanium sputter ion pumps are done through BA gauge. Fast actuating pneumatic gate valve is installed in the front plane of electron gun for prevention of vacuum drop in case of pump failure. All metal manually actuated right angle valve is used as main roughing port. All flanges are CF type, with copper sealing. The vacuum gauges, pumps, pneumatically actuated vacuum valves are

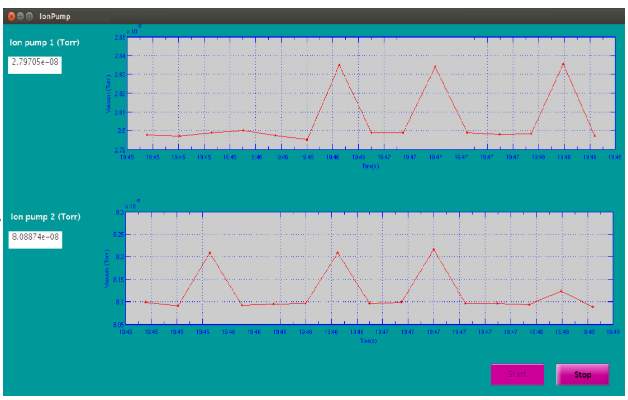
ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPME025

controlled and monitored from control room. The readings of pumps and gauges are archived in database.

The graphical user interface of pumps and gauges are shown in Fig.2. Fig. 2a shows the vacuum level at the gun backplane (red), pepper-pot (blue) and the their average (green) measured by two cold cathode gauges. The measurement corresponds to about 10 nTorr at the gun section and about 30 nTorr at the pepper-pot station. Fig 2b shows the vacuum level measurements by two corresponding titanium sputter pumps.



a)



b)

Figure 2: Graphical user interface for titanium ion pumps (a) and vacuum gauges (b).

DESIGN AND FABRICATION OF VACUUM COMPONENTS

During the AREAL construction, a number of vacuum system components has been designed and fabricated in-house. These components include: stainless steel dipole magnet vacuum chamber with 90^0 bending angle, vacuum boxes for YAG screen measurement stations, and gun photocathode holder mechanism with fine adjustment possibilities. After fabrication the chambers were tested at the vacuum laboratory for dimensional and leak tightness of the weld joints. The leak rate of welded vacuum chambers was less than 5 x 10^{-10} mbar l /sec.

UHV Chamber for Dipole Magnet

For fabrication of dipole vacuum stainless steel (SS) of grade 316LN is used. The dipole magnet vacuum chamber [5] has two halves: bottom is a box with 3 mm wall thickness and top is a sheet metal with 1.5 mm thickness. These two parts are connected together via manual tungsten inert gas (TIG) welding. Before welding of two parts the suitable clamps are used. Water-cooled jacket was installed in the bottom of chamber for heat removal.

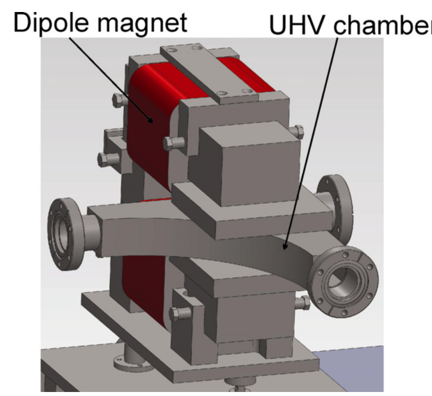


Figure 3: 3D view of UHV chamber with dipole magnet.

During the TIG welding the chamber has been filled by argon gas for preventing the oxidation of metal inside of vacuum chamber. The welding parameters are presented in Table1.

Table 1: TIG Welding Parameters

Welding Parameters	Values
Peak Current	60 Amps
Pulse Frequency	140 Hz
Type of arc	Hard arc
Shielding Gas	99.99 % Pure argon

Gun Photocathode Holder

The gun photocathode was initially installed without holder mechanism. For the resonant frequency adjustment the photocathode position was then adjusted manually. After closing back flange of the gun and pumping out this section the cathode position was shifted and the off-frequency was corrected using gun body temperature correction. The effective temperature for maximal RF power injection was slightly different from actual temperature.

A new cathode holder mechanism has been furthur developed to enable cotrollable adjustment and the gun operation on resonance with optimal body temperature. Taking into consideration the thermal conductivity, mechanical and vacuum properties of the material, the titanium rod is used as a holder of cathode.

The view of cathode holder mechanism with Rf gun is shown in Fig. 4.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPME025

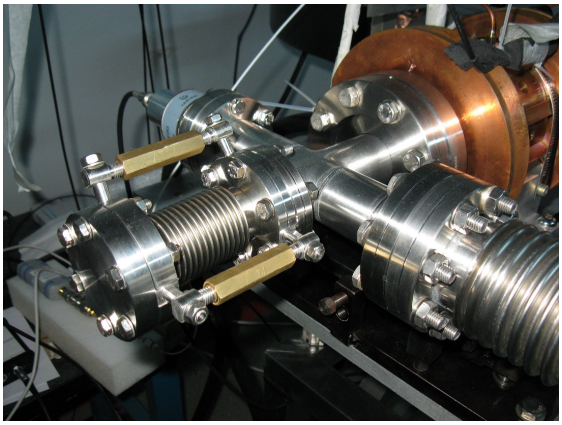


Figure 4: Cathode holder.

Vacuum Cube Chamber

Two stainless steel vacuum cubes with the holders for YAG screens are designed and fabricated. Cubes are made from stainless steel of grade 316 LN, annealed in vacuum furnace at 950 ^{0}C about 5 hours. Each 5 way cube have 2 ports for beam pipe connection, one for pneumatically actuated mover (YAG screen linear movement), vacuum windows for optical boxes, pumping ports for future pump installation. The stainless steel cube with optical box installed in the AREAL diagnostic station is shown in Fig.5.

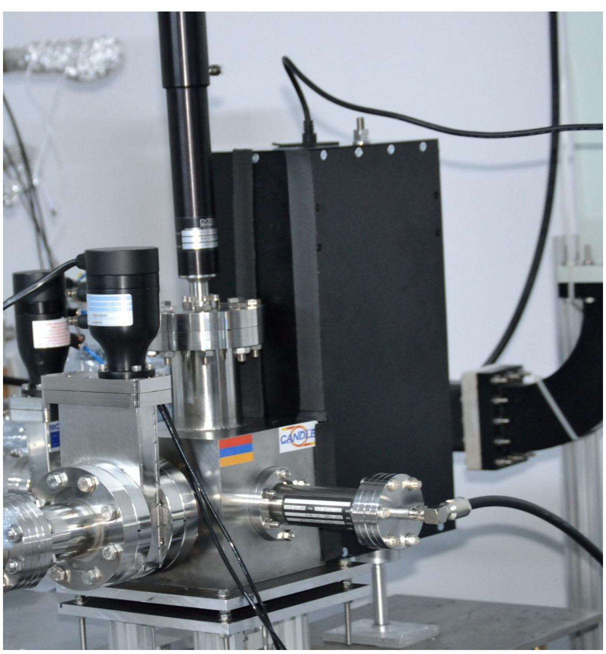


Figure 5: The stainless steel vacuum cube with optical box at the AREAL diagnostic station.

AREAL LINAC COMMISIONING

After final assembly and the test of accelerator various systems components, the commissioning of the AREAL test facility was held in May 2014. During this period dedicated measurements of various beam parameter namely bunch charge, beam energy and transverse profile are performed. The results of vacuum measurements during one commissioning shift (8 hours) are presented in Fig.6.

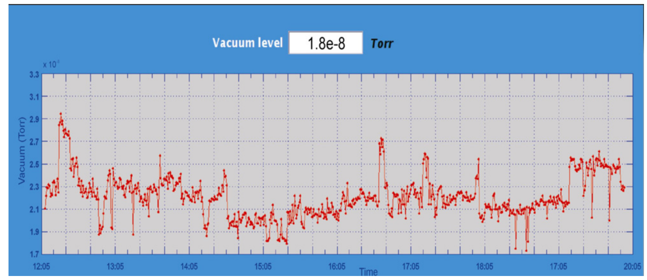


Figure 6: The results of mean vacuum level during one commissioning shift.

The similar behaviour of vacuum system was observed during the entire machine run, except gun and RF window conditioning period.

CONCLUSION

The vacuum system for the AREAL laser driven RF linear accelerator is designed and implemented. Number of new vacuum chamber components are designed and fabricated in the CANDLE institute. The new vacuum laboratory is established for the proper test of the vacuum system components before installation. The first vacuum measurements are performed during the facility commissioning, which show the reliable operation of the system for 10 nTorr of the residual vacuum. The further upgrade is foreseen to reach the 1nTorr vacuum at the gun section.

ACKNOWLEDGMENT

Authors express thanks to colleagues from the CANDLE RF and Diagnostic groups for cooperation, valuable discussion and comments.

REFERENCES

[1] B. Grigoryan et al, IPAC-11, San-Sebastian, Spain, TUPC031, 2011, 3 pp.
[2] T. Srinivasan-Rae, J. Fichcr, and T. Tsang, “Photocmission studies on metals using picosecond ultraviolet laser pulses,” J.Appl. Phys. 69, 3291 (1991).
[3] B. Grigoryan et al, IPAC14, these proceedings.
[4] W.H. Kohl, “Handbook of Materials and Techniques for Vacuum Devices”, AIP Press, New York, 623 p., 1995.
[5] A.A. Gevorgyan et al, PEAA, v.10, N4, pp. 747-750, 2013.