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STATUS OF CARIE FACILITY DESIGN AND CONSTRUCTION*

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Abstract

Building new experimental facilities to house experiments is an expensive and time-consuming activity. Although usually less expensive, repurposing old experimental facilities to accommodate new ones has its own set of challenges with regard to obsolete equipment, adequacy of electrical power, radioactive shielding and cooling capacity. At Los Alamos National Laboratory (LANL), one such facility was previously used to provide a platform for Advanced Free Electron Laser (AFEL) experiments that were completed 20 years ago. This paper explores the techniques and process to repurpose an existing experimental facility to accommodate the Cathodes and RF Interactions in Extremes (CARIE) compact accelerator and the choices made to select and size equipment for success. Radio Frequency (RF) energy waveguide layout with vacuum calculation methods will be included as well as electrical power and radiation shielding requirements.

REPURPOSING OF SUITABLE FACILITY

At Los Alamos Neutron Science Center (LANSCE), experimental facilities are housed in buildings and rooms dispersed throughout the site. Experiments typically receive funding on a fiscal-year basis, with durations ranging from one to multiple years. A variety of internal funding sources are available such that experimenters often compete with one another to secure a budget. A proposal to build a compact electron accelerator in the C-Band (5.707–5.712 GHz) of Radio Frequency (RF) was submitted to the Laboratory Directed Research and Development (LDRD) funding source. This proposal was chosen based on previous research and development success with the C-band Engineering Research Facility in New Mexico (CERF-NM) [1] experiment and the potential for advancing the field in this unique regime.

When experiments are completed at LANSCE, there is often infrastructure and facilities left behind to be repurposed by successive endeavors. One such facility housed an AFEL (Fig. 1) in a concrete vault room enclosed in a laboratory building. This vault room was built for radiation protection using high-density concrete; 120 cm thick walls and a 30 cm thick steel roof. A 33-ton moveable shield door separates the vault from the control room. When closed during operation, the door protects personnel from neutron radiation, bremsstrahlung radiation and activated air. Mounted on four sets of Hilman rollers and guided by tracks on the floor, the door is opened and closed by a hydraulic piston. Adjacent to the vault is a separate room that housed a laser with penetrations into the vault to feed laser light into and out of the AFEL experiment. Other vault penetrations through the roof and walls provided both RF and instrumentation wiring accommodations for maximum versatility.

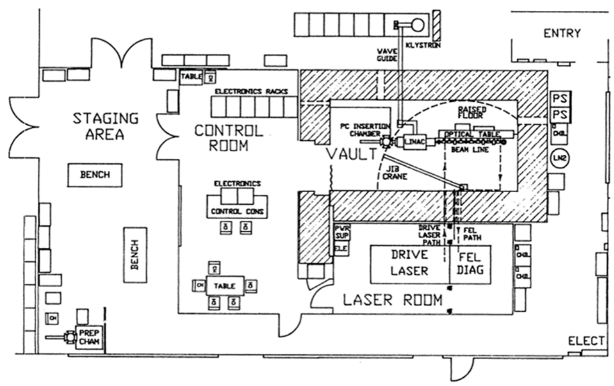

Figure 1: Top View of AFEL Experimental Facility.

A klystron with modulator provided RF energy to the AFEL and was situated in the aisle directly outside of the vault room. A waveguide, from the klystron through a penetration in the roof, was routed to the AFEL experiment in the vault. Electrical power for the klystron, modulator, laser and instrumentation was installed and still available to re-use. Water cooling for the klystron, modulator, waveguide and experiment was accomplished using a closed loop, deionized water system coupled with a small cooling tower through a plate and frame heat exchanger. Water pump, heat exchanger and resin beds were located outside of the building in an equipment shed. Copper distribution piping from the shed fed the deionized cooling water to the experiment and its associated peripheral equipment. Because the AFEL experiment was completed 20 years ago, this facility equipment required assessment to determine if it is adequate to be reliably repurposed.

Infrastructure funding was provided last year (FY22) by LANL to prepare the vault room for a new experiment. Since a scanning electron microscope (SEM), glovebox, tools and supplies were residing there, an effort to relocate and salvage these items commenced. After the room was vacated, an optical table became available from another area so it was relocated to the vault where it will become the base table for the compact accelerator.

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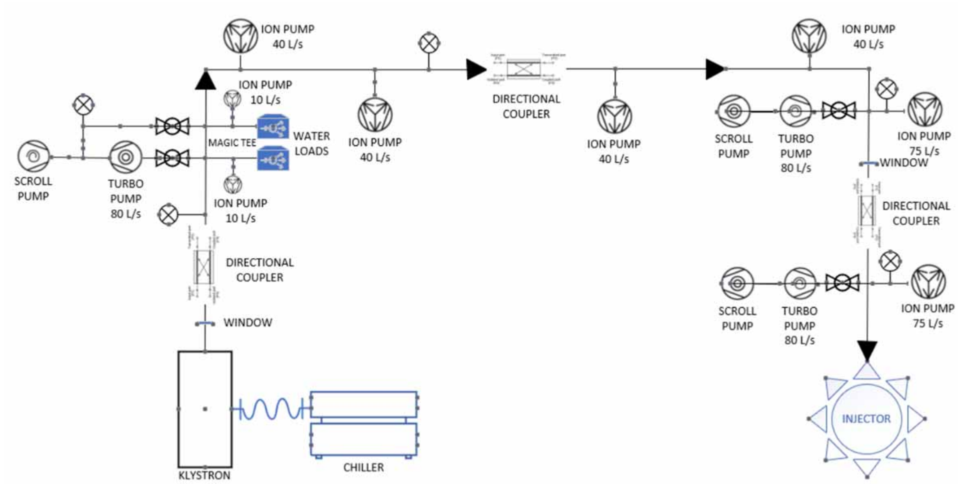

Figure 2: Process and Instrumentation Diagram (P&ID).

PRELIMINARY DESIGN

When fully implemented, CARIE will be a compact electron accelerator producing 7 MeV particle beam. The electrons are initiated using a laser excited photocathode in a resonant cavity. The resonant cavity also serves as the injector [2].

Figure 2 is the Process and Instrumentation Drawing (P&ID) conceived for CARIE. This diagram formed the basis of the design of the waveguide system delivering RF energy to the compact accelerator. RF windows separate both the klystron and injector from the waveguide vacuum system. The RF window that separates the waveguide from the injector cavity allows RF cavity changes in the injector without compromising the vacuum in the waveguide. RF energy from the klystron is output into a WR187 rectangular waveguide then split into two halves by a magic tee that protects the klystron from excess reflected power. Roughing, ion and turbo vacuum pumps were placed strategically along the system to achieve the required pressure in a prescribed period of time per the vacuum calculation detailed in the requirements section below.

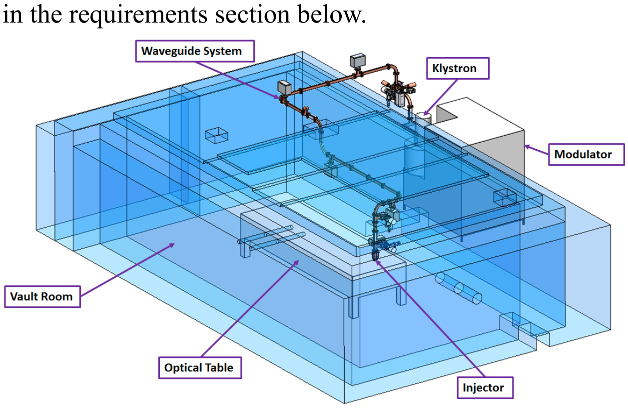

Figure 3: Model of CARIE Experimental Facility with Preliminary Design of RF and Waveguide Systems.

Figure 3 is the preliminary design model for CARIE derived from the P&ID and existing geometry of the vault room. The klystron, modulator and their associated chiller are positioned in the aisle outside of the vault with RF energy delivered to the CARIE experiment inside through the waveguide system. Based on the CERF-NM design [3], the waveguide system delivers 50 MW pulses with the pulse length between 300 ns and 1 microsecond, repetition rate up to 200 Hz, and is tuneable within the frequency band of 5.707 GHz to 5.717 GHz.

The waveguide continues through an existing penetration on the roof of the concrete and steel room to the injector cavity. The waveguide's diagnostics include both vacuum gauges and directional couplers that measure incident and reflected powers. The waveguide line and the cavity are vacuum pumped by scroll, turbo and ion pumps.

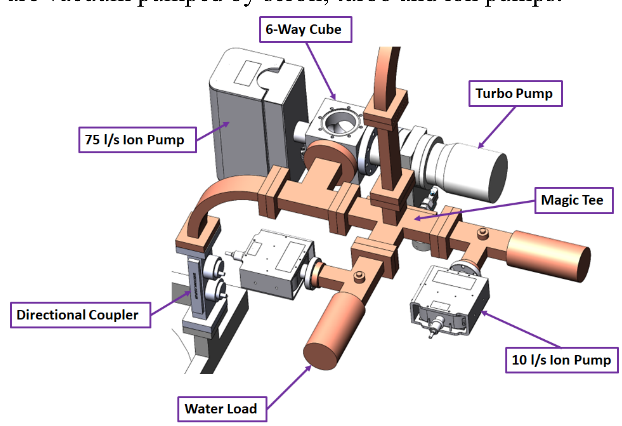

Figure 4: Waveguide System Design.

Figure 4 is an excerpt from the waveguide system model showing the output from the klystron into the first directional coupler, magic tee, water loads and associated vacuum pumps.

SYSTEMS REQUIREMENTS

Electrical outlets dedicated to the AFEL experiment were tested to be operational and will be repurposed for CARIE. The klystron/modulator is the main power consumer requiring 480V/3Phase/100 A. This power requirement was accommodated by replacing the outlet of an existing 480V circuit. In addition, each of the vacuum pumps,

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gauges, controllers, computer and display screens require electrical power per the control and instrumentation scheme shown in Fig. 5:

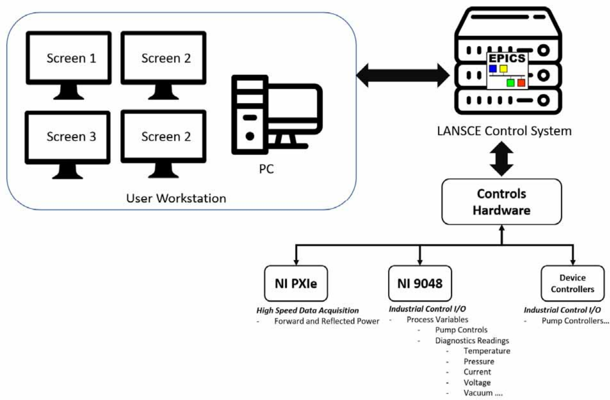

Figure 5: Control and Instrumentation Scheme.

Water cooling is necessary for the klystron, injector and future solenoid magnet. An air-cooled chiller was purchased to deliver the cooling water to the components and this chiller will reside in the aisle adjacent to the klystron/modulator. Deionized water is accomplished using a slip-stream branch to ion and oxygen resin beds. The flow capacity of the chiller is 35 gpm of which 27.5 gpm is required for the klystron/modulator.

Vacuum requirements were specified as maximum pressures in both the waveguide ($5X10^{-8}$ Torr) and injector ($5X10^{-9}$ Torr). To achieve the specification in the waveguide required that the ion pumps be equally spaced as in a lumped parameter system [4]. An analysis was performed to optimize the distance between these pumps. The ion pumps are directly connected to pumping ports that are strategically located in the waveguide assembly. This distributed pumping configuration requires each ion pump to evacuate gas from upstream (toward the Klystron) and downstream (toward the injector, Fig. 6).

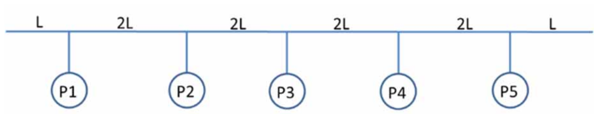

Figure 6: Distributed Gas Load Pumping Scheme.

The conceptual waveguide layout is approximately 9 meters long. An analysis was performed to determine base pressures for between 3 and 6 ion pumps, with selectable pumping speeds, spaced at approximately equal intervals in the waveguide. To determine L, the optimization determined the number of pumps and their spacing in the waveguide. The Excel spreadsheet analysis optimized base pressure achieved after 24 hours of pumping using standard outgassing rates for ultra-high-vacuum grade waveguide. Neglecting baking, this optimization concluded that four each, 40 l/s ion pumps distributed in the waveguide would achieve the base pressure specifications in a reasonable amount of time (Table 1).

Table 1: Vacuum Calculation Results

Number of Ion Pumps	**75 l/s P (10^{-8} Torr)**	**40 l/s P (10^{-8} Torr)**	**30 l/s P (10^{-8} Torr)**
3	5.03	5.35	5.58
4	3.02	3.25	3.43
5	2.05	2.24	2.38
6	1.50	1.66	1.78

The shield door was functionally tested and found to be operational. The plan is to replace the electronics and controls with modern components.

Radiation shielding requirements were simulated for a rectangular 30X60 cm beam dump in the middle of the experimental area. This beam dump was comprised of a stack consisting of 10 cm thick lead, 20 cm thick steel and 10 cm thick poly. The Monte Carlo simulation was accomplished using MCNPX code with 20 MeV electrons impinging on the inner layer of the beam dump. To keep all neutron and gamma-ray doses around the experimental area outside the vault below 5 mrem/h, the calculation showed that several shielding modifications/additions are required. Figure 7 shows the result of the simulation, a horizontal cross section of gamma at beam height. An additional simulation is being conducted using 10 MeV electrons to further optimize the shielding requirements.

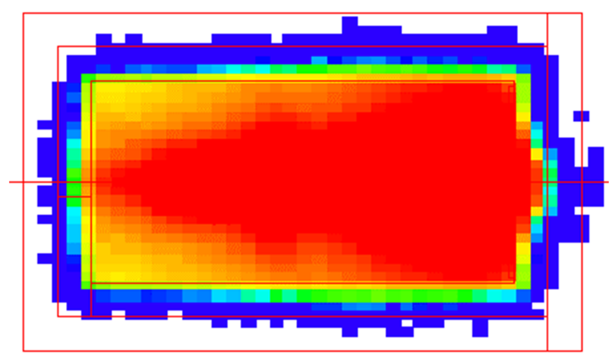

Figure 7: MNCP Horizontal Cross-Section of Gamma Rays at Beam Height.

REFERENCES

[1] E. I. Simakov *et al.*, "High Gradient High Efficiency C-Band Accelerator Structure Research at LANL", in *Proc. NAPAC'19*, Lansing, USA, Sep. 2019, pp. 882-884. doi:10.18429/JACoW-NAPAC2019-WEPLO20

[2] A. Alexander *et al.*, "Update on the status of the C-band high gradient program at LANL", presented at IPAC'23, Venice, Italy, May 2023, paper TUPL138, this conference.

[3] E. I. Simakov *et al.*, "Update on the Status of C-Band Research and Facilities at LANL", in *Proc. NAPAC'22*, Albuquerque, USA, Aug. 2022, pp. 855-858. doi:10.18429/JACoW-NAPAC2022-THYD3

[4] A. Roth, *Vacuum Technology (Third Edition)*, Amsterdam, Holland: Elsevier, 1990.

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