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STATUS AND PLANS FOR THE NEW CLS ELECTRON SOURCE LAB

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Abstract

The Canadian Light Source (CLS) has recently created a new Electron Source Lab (ESL) that can run independently from user operations. A section of the old Saskatchewan Accelerator Laboratory experimental nuclear physics tunnels has been rebuilt with new shielding and a separate entrance. The laboratory will be used to prepare an operational spare electron gun for the 250 MeV linac. In addition, there are plans to develop RF guns for a future branch line to inject into the linac and for possible short pulse production. This paper will give an overview of the ESL space and the first electron guns which plan to be installed.

INTRODUCTION

The CLS [1] has been in operation since 2005 and in 2018 suffered a major failure of the electron gun that brought down the facility for 7 months [2]. The gun dates from the 1970s and only a handful were built, hence very few spares are still available to repair it in case of another dramatic failure. To mitigate this risk, CLS has secured electron sources from other accelerator laboratories that can be used as replacements. The fastest way to come back into operation is to replace the present thermionic DC gun by another gun of the same energy. The DC voltage may require some tuning to match the beam dynamics at the exist of the gun to produce the appropriate bunches that can be transported and accelerated through the linac. Plans for such gun have been made with the help of a loan gun from MAX IV which is planned to be tested in the ESL. CLS has completed the construction of the ESL in a space in the basement which has separate and simultaneous access from the other linac tunnels, allowing for safe and flexible commissioning of electron sources and beams up to 100 MeV.

OVERVIEW OF ESL SPACE

The new bunker uses an existing location in the basement of the facility. The entire basement was used for nuclear research in the 1960s until the construction of the CLS ring. The area delimited in red, blue oval and black rectangle, see Fig. 1, were part of the Saskatchewan Accelerator Laboratory (SAL). Today the red part house the linac that feeds CLS; the blue oval has been decoupled from the linac tunnel for operation and for radiation protection and is home of the medical isotope production facility Canadian Isotope Innovation Corporation (CIIC) [3]. The area delimited in black is the location where the ESL will be installed (light blue area) including a reserved place where the local control room will be installed (dark blue area). The total area of the ESL is around 50 m^2.

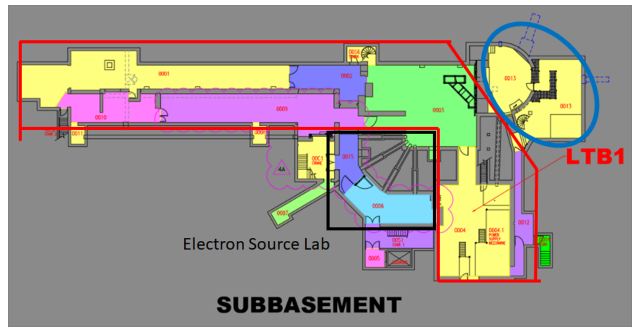

Figure 1: Location of the ESL in the CLS basement - next to the linac tunnel.

Like for the medical isotope production facility, new shielding, radiation protection system and interlocks have been installed to decouple the ESL operation from the linac operation. New operating license from the radiation regulator have been obtained that will allow the operation of ionizing radiation devices until 1 MeV. This phase has been achieved.

The second phase is to decouple the control room area from the experimental zone. Doors and radiation shielding are currently being installed. The experimental area can also be accessed via a side stairways with an elevator adjacent to it. The current door between the ESL and the stairways must be replaced by a lock with two doors, one is a fire resistant door the other is a radiation shielding door. Those doors are on order and the work regarding fire safety is ongoing including the needed paperwork as to certify that the construction comply to the construction code. It is expected that the infrastructure, water cooling, electricity, air conditioning, network, interlock system, fire safety system and city permit guaranteeing compliance to building code will be completed by end of March 2023.

Regarding radiation protection, the laboratory has been constructed and designed for operation up to 120 MeV electron beams by the CLS radiation protection authority. However, operation up to energy above 1 MeV will require new licensing from the Canadian radiation authority CNSC, which is also being taken care of at this moment.

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AVAILABLE ELECTRON GUNS AT CLS

DC Gun

The ESL as depicted in Fig. 2 depicts the plan for our first stage of operation. The first electron source to be installed and tested is a thermionic DC electron source provided by MAX IV in Sweden, operating up to 500 keV. A dedicated beamline will be installed to characterise the electron beam and measure the emittance, energy and energy spread, see Fig. 2.

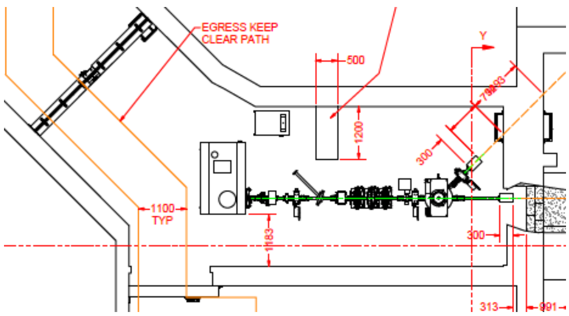

Figure 2: Zoom-in of the ESL depicting the placement of the gun and a potential diagnostic beamline.

The physical dimension of the interior of this DC gun has been mapped to make a precise 3D model of the complete cathode-anode assembly. Based on this 3D model electrostatic fields of the gun have been simulated in CST [4], see Fig. 3, and the propagation of the beam from the cathode, without any optics in the beamline are simulated using GPT [5], see Fig. 4. The main purpose is to gain a better understanding in the characteristics of the electron beam from the BaO cathode when heated up to approximately 1100 °C.

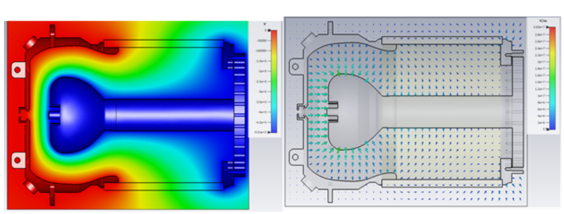

Figure 3: Left: equipotential lines, right: 3D EM field map of the DC gun - simulation made with CST.

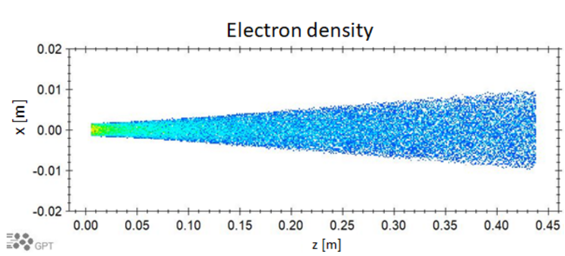

Figure 4: Electron density after propagation of a 100 mA emitter current after 500 kV acceleration up to 45 cm after the cathode and without any focusing or guiding optics.

The first results of a 100 mA divergent beam without any focusing optics provide a transverse normalised emittance in x- and y-direction of 0.4 μmrad. The 100 mA choice is the operational setting of the current linac electron source.

Once every components of the gun have been verified the gun will be installed for high voltage and electron production in the ESL lab. We expect the DC-gun to be operational in spring 2023, short after opening of the ESL.

RF Guns

After testing and qualifications of the 500 kV DC thermionic gun, the accelerator physics team plans to test two different type of RF guns.

The first is a thermionic RF electron source with a frequency of 2856 MHz that was designed by MAX IV for CLS based on their own 3 GHz designs [6–11]. Figure 5 shows the basic concept of the EM design which can achieve a beam energy of around 2 MeV. It is planned to use such a thermionic RF gun as a branch line into the CLS linac as a second operational gun.

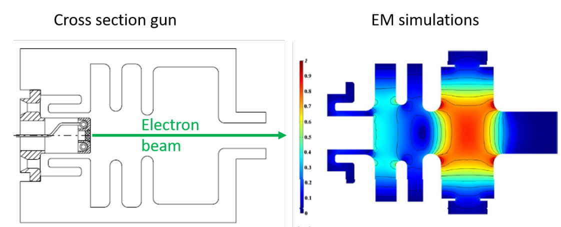

Figure 5: Thermoionic RF gun - cross section (left) and EM simulations (right).

Simulation of beam propagation for 100 mA of current from the cathode, using the same thermal emittance as for the DC thermionic gun, produces a beam with an normalised emittance of 0.8 μmrad in x- and y-direction and a kinetic energy of $E = 1.7 \pm 0.7$ MeV. CLS plans to test this gun in the winter of 2023.

Finally, the testing of a 1.5 cell RF photo gun [12] capable of producing a 4.4 MeV beam and a 2.6 cell RF photo gun [13, 14] providing a 7.4 MeV beam for single bunch operation is planned in 2024. Both guns are provided by the Eindhoven university of Technology in the Netherlands. A laser system still has to be evaluated, funded and bought. These guns, due to their short pulses, could be used as a source for ultra fast electron diffraction experiments or to produce hard X-rays through inverse Compton scattering.

Such guns and setup could enhance the CLS portfolio of techniques for investigation to the benefit of the user community.

CLS is preparing to procure a new linac and can potentially use the ESL for testing equipment before installation in the linac tunnel. The ESL will be prepared for the commissioning of the new linac e-gun so that it can be tested with beam prior to decommissioning of the existing gun and the installation of the new linac in 2024. All these capabilities of the ESL can be used for CLS own benefit but it will also

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be available for use in collaboration with other labs who in the future want to do experiments in the ESL.

CONCLUSION

The ESL construction is underway and will be ready by the end of the first quarter of 2023. The highest priority is to operate the spare linac DC electron gun by the end of spring 2023. Further possibilities for testing different guns and other usage for this bunker are being considered for 2024 as a mean to build new competencies as well as potentially provide new scientific possibilities. The ESL is planned to be used for commissioning of a new DC thermionic gun as part of a new linac that is in the process of being procured.

ACKNOWLEDGEMENTS

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REFERENCES

[1] J. Cutler, D. Chapman, and R. Lamb, "Brightest light in canada: The canadian light source," *Synchrotron Radiat. News*, vol. 31, pp. 26–31, 1 2018, doi:10.1080/08940886.2018.1409557

[2] StarPheonix, Saskatoon, *Foresight saves the day for canada's brightest light*, Accessed: 2022-06-06, 2018, https://thestarphoenix.com/news/local-news/canadas-brightest-light-to-shine-again-after-absolutely-lucky-repair

[3] *Canadian Isotope Innovations Corporation, Saskatoon*, http://isotopeinnovations.com/

[4] *CST Studio Suite: Electromagnetic field simulation software*, https://www.cst.com/

[5] *General Particle Tracer - Pulsar Physics BV, Netherlands*, http://www.pulsar.nl/gpt/

[6] B. Anderberg, Å. Andersson, M. Demirkan, M. Eriksson, and S. Werin, "A New 3 GHz RF-gun Structure for MAX-lab," in *Proc. EPAC'00*, Vienna, Austria, Jun. 2000, https://jacow.org/e00/papers/MOP1B05.pdf

[7] B. Anderberg, Å. Andersson, M. Demirkan, M. Eriksson, L. Malmgren, and S. Werin, "The design of a 3GHz thermionic RF-gun and energy filter for MAX-lab," *Nucl. Instrum. Methods Phys. Res., Sect. A*, vol. 491, pp. 307–313, 2002, doi:10.1016/S0168-9002(02)01174-9

[8] S. Werin, Å. Andersson, M. Bergqvist, M. Brandin, G. Georgsson, and L. Malmgren, "Experimental Experience with a Thermionic RF-gun," in *Proc. EPAC'04*, Lucerne, Switzerland, Jul. 2004, http://accelconf.web.cern.ch/e04/papers/THPKF058.pdf

[9] J. Andersson *et al.*, "Initial Commissioning Results of the MAX IV Injector," in *Proc. FEL'15*, Daejeon, Korea, Aug. 2015, pp. 448–451, doi:10.18429/JACoW-FEL2015-TUP036

[10] J. Andersson *et al.*, "The New MAX IV Gun Test Stand," in *Proc. IPAC'17*, Copenhagen, Denmark, May 2017, pp. 1537–1540, doi:10.18429/JACoW-IPAC2017-TUPAB095

[11] J. Andersson, D. Olsson, F. Curbis, L. Malmgren, and S. Werin, "New features of the MAX IV thermionic pre-injector," *Nucl. Instrum. Methods Phys. Res., Sect. A*, vol. 855, pp. 65–80, 2017, doi:10.1016/j.nima.2016.10.051

[12] W. Root, op 't, "Generation of high-field, single-cycle terahertz pulses using relativistic electron bunches," Ph.D. dissertation, Applied Physics, 2009, doi:10.6100/IR656376

[13] X. F. D. Stragier, O. J. Luiten, S. B. van der Geer, M. J. van der Wiel, and G. J. H. Brussaard, "Experimental validation of a radio frequency photogun as external electron injector for a laser wakefield accelerator," *J. Appl. Phys.*, vol. 110, no. 2, p. 024 910, 2011, doi:10.1063/1.3610509

[14] F. Kiewiet, "Generation of ultra-short, high brightness relativistic electron bunches," Ph.D. dissertation, Applied Physics, 2003, doi:10.6100/IR571240