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THE STATUS OF THE DARESBURY ENERGY RECOVERY PROTOTYPE PROJECT

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Abstract

The major component of the UK’s R&D programme towards an advanced energy recovery linac-based light source facility is a 35 MeV technology demonstrator called the Energy Recovery Linac Prototype (ERLP). This is based on a combination of a DC photocathode electron gun, a superconducting linac operated in energy recovery mode and an IR FEL. The current status of this project is presented, including the construction and commissioning progress and plans for the future exploitation of this scientific and technical R&D facility.

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The major component of the UK's R&D programme towards an advanced energy recovery linac-based light source facility is a 35 MeV technology demonstrator called the Energy Recovery Linac Prototype (ERLP). This is based on a combination of a DC photocathode electron gun, a superconducting linac operated in energy recovery mode and an IR FEL. The current status of this project is presented, including the construction and commissioning progress and plans for the future exploitation of this scientific and technical R&D facility.

INTRODUCTION

A description of ERLP, its role as a technology demonstrator and a tool for developing the skills of the staff designing the Fourth Generation Light Source (4GLS) at Daresbury Laboratory have most recently been recorded in [1]. The layout of the ERLP is illustrated in Fig. 1. The 4GLS is a novel, next-generation proposal for a light source based on a superconducting energy recovery linac with both high-average current photon sources (undulators and bending magnets) and high-peak current free-electron lasers [2]. The key feature of the 4GLS proposal is the prospect of opening up new fields of research arising from unique combinations of sources with femtosecond pulse structure.

The purpose of the ERLP project is to:

(i) Build an energy recovery linac-based electron accelerator based on a combination of a photoinjector with superconducting accelerating structures to a specification that allows some of the key technical challenges of 4GLS to be addressed;

(ii) Have active international collaborations in place for those challenges that are best addressed in this way;

(iii) Report on the results of addressing the challenges and the impact of these studies on the design of 4GLS;

(iv) Develop expertise levels to such an extent that the design of the 4GLS facility can be completed.

GUN

The DC gun is a copy of the one employed at the Thomas Jefferson National Accelerator Laboratory (TJNAL) on the IR-FEL project [3], employing a GaAs cathode and coupled with a 81 MHz CW mode-locked drive laser, frequency doubled to 532 nm. The commissioning of the laser system and its diagnostics has been completed in readiness for gun commissioning.

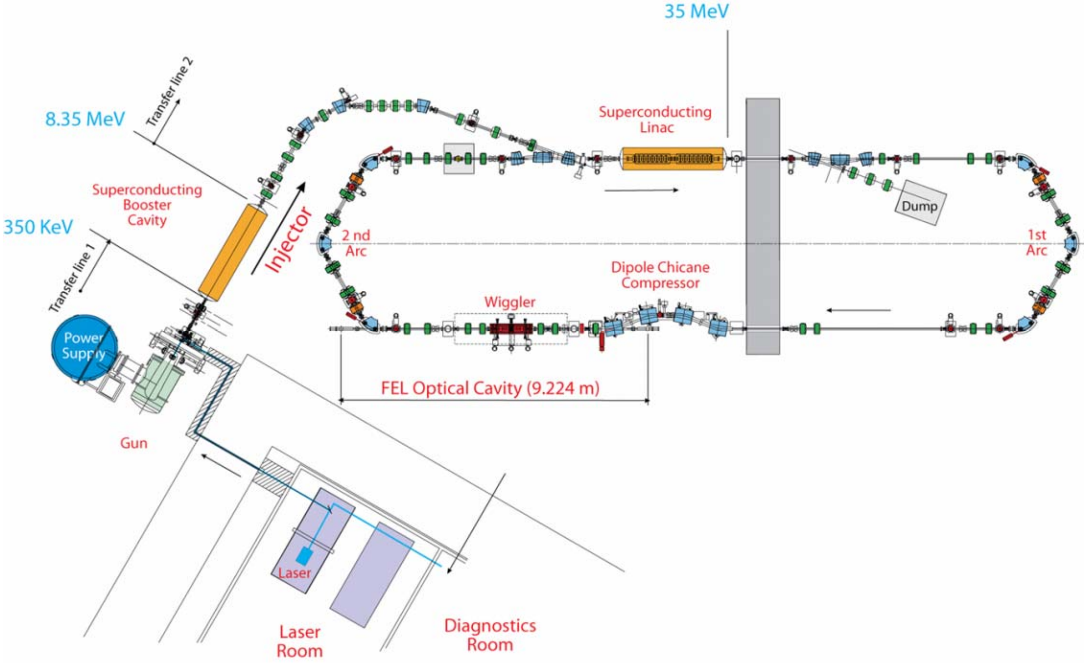

Figure 1: ERLP layout.

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Procurement of the large ceramic required to support the cathode ball at 350 kV proved to be the most difficult issue that the project has had to deal with up to this point. A novel single-piece design was chosen, utilising a ceramic with a bulk resistivity (the original TJNAL used a coated two-piece design). Problems with the processing of this component, mainly due to its size, significantly delayed its delivery. However, a fully-compliant part has been at the laboratory now for several months and has been installed in the completed gun. Fig. 2 shows the ceramic supporting the highly-polished cathode ball.

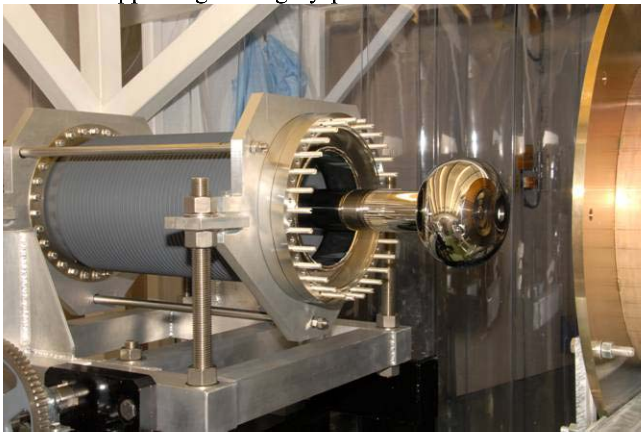

Figure 2: ERLP gun ceramic and cathode ball.

In order to achieve reasonable cathode lifetime it is necessary to operate the gun under XHV conditions. Unfortunately, during the cooldown period following the bakeout of the gun, a small leak was detected in a weld which has required the gun to be partially disassembled while this repaired. It is now expected that the gun will be ready to produce electrons in July.

SUPERCONDUCTING LINAC MODULES

Of the two superconducting linac modules on order from Accel, the first was delivered in April with the second one scheduled to arrive in July. These consist of two 9-cell TESLA structures in a cryostat designed by FZ Rossendorf. These are the first superconducting module assemblies to be sourced entirely from industry. Fig. 3 shows the first module being moved into the accelerator hall at Daresbury Laboratory.

These modules cannot be moved to their final position until completion of the gun diagnostic phase, which utilises a dedicated diagnostic beamline.

GUN DIAGNOSTIC BEAMLINE

In order to characterise the gun as fully as possible before injection of electrons into the superconducting linac modules and to verify the results of simulation work, a dedicated gun diagnostic beamline has been designed, manufactured and installed [4]. This will be ready for the date when the first electrons are expected from the gun in August. Fig. 4 shows the gun diagnostic beamline prior to installation.

Figure 3: The first superconducting linac module arriving in the accelerator hall.

An important element of the diagnostic beamline that is shared with the completed machine is the buncher. The electron bunches produced by the GaAs cathode will have quite a long tail due to the nature of the electron emission process. The purpose of the buncher is to reduce the longitudinal emittance before the bunch enters the booster. In the short term the buncher will be powered by one of the IOT devices under development as the RF power source for the superconducting linac modules. This will be replaced before final machine commissioning with a solid-state amplifier.

Figure 4: Gun diagnostic beamline prior to installation

CRYOGENIC SYSTEM

The system, including the compressor, the 4 K cold box, the 2 K pumping system, the liquid nitrogen bulk storage tank, the interconnecting ambient pipe work, the cryogenic helium transfer lines, the control system and the cabling and utilities is now mainly in place. Some of these components can be seen in Fig. 5. Commissioning of the 4 K cryogenic system has now been completed, to be followed by the 2 K part later this year.

Figure 5: 4 K and 2 K vessels and cold box in place.

MODULES

All of the ERLP beam transport system has been assembled as individual modules on single girders. This work has been undertaken in a new facility at Daresbury Laboratory, prior to moving the modules to their final location in the accelerator hall in the Tower building. The facility consists of an clean room, insertion device construction room, magnet test room and large capacity assembly hall for the range of collaborative projects involving technical build and measurement work. Fig. 6 shows the support girder systems, magnets, diagnostic devices and vacuum chambers being assembled.

Figure 6: Modular girder assembly.

Building on Daresbury Laboratory's excellent track record of producing and operating UHV vacuum systems, new procedures have been added to ensure that the very high particulate standards required for the ERLP are achieved. All of the vacuum chambers are being subjected to a particle cleansing process in the clean room until the stringent ISO 5 standard has been achieved.

It is expected that the remainder of the modules will be moved into the accelerator hall over the summer.

EXPLOITATION

Following the successful commissioning of the ERLP, a number experimental programmes are envisaged. These include:

(i) Development of diagnostic equipment and techniques;

(ii) Development of DC photocathode guns and associated technology;

(iii) Studies of superconducting accelerator operation (including cyosystems);

(iv) Electron beam, laser and synchrotron radiation synchronisation studies;

(v) A Compton back-scattering source for time resolved X-ray diffraction studies aimed at probing the mechanisms of shock compression of matter on sub-picosecond timescales;

(vi) An experimental programme utilising ultrahigh intensity broadband terahertz radiation for the study of biological systems;

(vii) To test an undulator module for a proposed positron source for the ILC;

(viii) As an injector for an experimental FFAG accelerator called EMMA.

CONCLUSION

A number of setbacks that have delayed the ERLP project have now been overcome and the ERLP team are looking forward to first electrons from the gun this summer. The experience gained from this project will be invaluable preparation for the even more challenging 4GLS design, procurement, construction and operation phases.

REFERENCES

[1] M.W. Poole and E.A. Seddon, “4GLS and the Energy Recovery Linac Prototype Project at Daresbury Laboratory”, PAC’05, Knoxville, USA, May 2005, p. 431.

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[4] D. J. Holder et al, "ERLP Gun Commissioning Beamline Design", LINAC’04, Lübeck, August 2004, p. 93.