

# ERLP QUANTUM EFFICIENCY SCANNER

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## Abstract

The Energy Recovery Linac Prototype (ERLP) under construction at Daresbury Laboratory will utilise a photo injector as its electron source. In order to characterise the performance of the photo-cathode wafer, a low power laser is scanned across its surface and the resultant current measured to build up a map of the quantum efficiency (QE) of the wafer.

cathode for each mW of laser power incident at the cathode surface is the Quantum efficiency of the cathode.

## PHOTOCATHODE SCANNER

### Purpose of QE Scanner

The performance of GaAs photo cathode wafers have been shown to degrade over time and with usage. In order to operate the photo injector optimally, it is necessary to fully understand the condition of the photo cathode.

The purpose of the QE scanner is to build up a map of the quantum efficiency of the photo cathode wafer. This will allow the drive laser for ERLP to be steered to an area of the wafer with the highest QE.

The system will also enable operators to monitor the degradation of the wafer and plan for the re-processing of the wafer.

This system is based upon the QE scanner which has been successfully operated on the Jefferson Lab IR demonstration machine, and has proven to be an effective tool for monitoring the photo cathode condition [1].

### Objectives

The photo cathode wafer is a disc of GaAs, 25.4mm (1") in diameter. In order to produce a sufficiently detailed map of the QE of the cathode, the following objectives were set.

1. Scanning resolution = 0.2mm
2. Laser Wavelength  $\approx$  527nm

### Functional Description

#### Overview

The scanning system consists of a laser, which illuminates a pair of scanning mirrors. These mirrors rotate in order to scan the laser beam across the surface of the cathode in a raster pattern.

This beam travels through a window into a light box, within which mirrors are contained to direct the laser beam onto the cathode wafer.

The cathode is biased at a voltage of 66V; this voltage can be changed in order to avoid space charge limited emission. The current drawn from the cathode is measured at each point of the lasers raster scan using a Pico ammeter.

The QE at each point is calculated by software according to equation (1). [1]

$$QE(\%) = \frac{124I(\mu A)}{P(mW)\lambda(nm)} \quad (1)$$

## INTRODUCTION

### ERLP

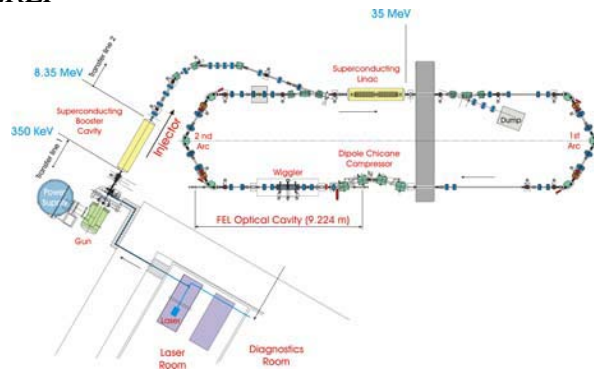


Figure 1: ERLP Schematic

The Energy Recovery Linac Prototype (ERLP), shown in figure 1, is a machine under development at Daresbury Laboratory.

A photo cathode gun is used to generate short bunches of electrons (Bunch charge up to 80pC, Bunch length =20ps) at 350keV. These bunches are passed through a booster Linac to raise their energy to 8.35MeV. The bunches are then injected into the main “ring”, where they are accelerated to 35MeV.

The bunch then travels around the beam transport system, through a FEL (to disrupt the beam) and is returned to the main Linac. However, this time it is 180° out of phase with the cavity RF field, and so is decelerated back to 8.35 MeV and steered into a beam dump.

The energy gained by the cavity from decelerating the first bunch is used to accelerate a second bunch, which contains a greater charge. Thus by recovering energy, a build up of bunch charge is achieved. This provides the beam quality expected of a Linac, and the efficiency of a synchrotron.

ERLP uses a Gallium Arsenide (GaAs) wafer as its electron source. This wafer is illuminated by a pulse (~4W) of 527nm laser light, and via the photoelectric effect, electrons are liberated from the cathode. A measure of how many electrons are liberated from a photo

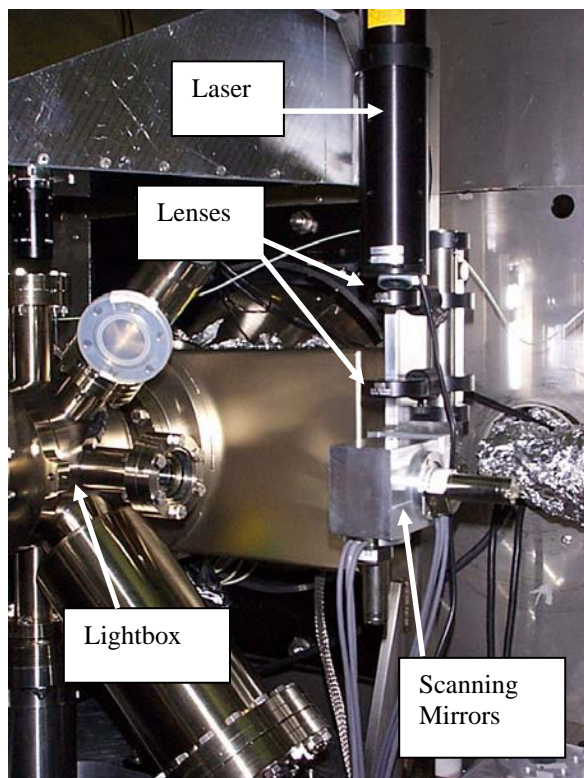


Figure 2: Photo cathode scanner

#### 1. Laser

The laser used is a JDS Uniphase Helium Neon laser. This has a wavelength of 543.5nm, which is close to the drive laser wavelength of 527nm.

This laser is highly collimated, highly stable and has an output power of 4mW which has been reduced to 1mW by fixing a neutral density filter to its output.

After the neutral density filter, two lenses are used to focus the beam to a spot size of 0.2mm at the cathode surface.

#### 2. Scanning mirrors

In order to scan the beam in a raster pattern, it is necessary to steer the beam in both X and Y planes. To achieve this, a pair of galvanometers are used. These devices convert an input voltage to an angular movement of the mirror.

The galvanometers used are model VM2000, being driven by temperature compensated MiniSAX driver circuits, manufactured by GSI Lumonics. This configuration offers extremely accurate pointing stability and repeatability.

#### 3. Measurement

Measurement of the cathode current is performed using a Keithley Instruments Pico ammeter / Voltage source. This can be programmed to provide a voltage between -500V to +500V, and can measure current with 10 fA resolution between 20fA and 20mA.

This device communicates to the control computer via GPIB bus, and can return data either digitally or via a faster analogue link.

#### 4. Computing / Software

The software for both the control of the mirrors and the acquisition of data is contained within one National Instruments Labview virtual instrument.

Control of the scanning mirrors is achieved using a National Instruments analogue I/O card. Voltages to control the mirrors are output directly by the controller computer.

There are three distinct menus within the control software. These are:

- Calibration

This allows the user to calibrate the movement of the galvanometers such that for a given point on the QE map, the exact coordinates of the point can be obtained, for use in steering the main laser. Figure 3 shows this menu.

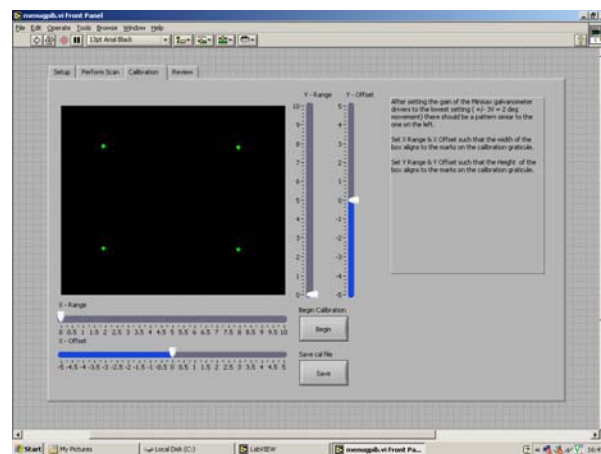


Figure 3: Calibration menu

- Scanning

The scanning menu allows the user to define the parameters of a scanning run, these are: The laser power, the cathode voltage, the number of lines used in the scan.

- Results review

This menu allows the user to review the results of a scan (and has the facility to review past scans). The data is shown in the form of a bitmap image with the colour of each pixel mapped to the QE at that point. By moving the mouse over a pixel, the software displays the coordinates of that point, and its precise QE.

#### Testing

In order to test the QE scanning system, a large photodiode was used in place of the cathode. This was biased at 1V, but with all other parameters identical to a real QE scan run.

In order to generate a range of simulated QE values across a scan, a printed mask was placed in front of the photodiode.

The image shown in figure 4 shows the results of one such scan. The visible area measures 10mm x 10mm and consists of 250x250 data points.

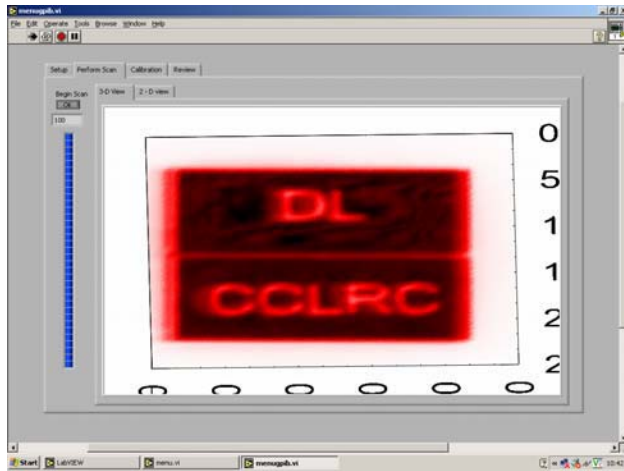


Figure 4: Image obtained during testing.

## CONCLUSION

The QE system has been installed on the ERLP system. It has been successfully tested by using a photodiode in place of the cathode, and is ready for operation.

The system will be put into full operation in July 2006 during ERLP gun commissioning.

### *Future work*

The system is currently controlled by a PC running Labview which is local to the photo cathode. The images from a QE scan are then transferred via the network to the ERLP control room.

A possible upgrade is to use NI Fieldpoint controllers to achieve remote operation. This will allow an operator to perform a QE scan without having to enter the accelerator hall.

## REFERENCES

- [1] J. Gubeli, "Jefferson Lab IR demo FEL photo cathode quantum efficiency scanner", Nuclear Instruments and methods in physics research, A 475 2001 554-558.