CHARGE AND LASER BEAM ENERGY MONITOR FOR SPARC LINAC*

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Abstract

The experimental setup implemented in the SPARC linac control system used to monitor the laser beam energy and to measure the beam charge by means of a Faraday Cup will be illustrated and discussed. The experimental setup makes use of National Instruments 2 GS/s 8-Bit digitizer board. This tool has been shown to be useful in order to monitor the laser beam energy stability and to evaluate the quantum efficiency of the cathode.

INTRODUCTION

Within the goals of the SPARC high brightness photoinjector [1] the stability of the electron beam plays a crucial role. For this reason a new instrument of measure has been included in SPARC control system: the SPARC beam diagnostic system allows now monitoring continuously the laser energy delivered to the cathode and thus the quantum efficiency of the cathode itself. This new tool allowed us to keep under control the cathode performances in terms of its emission properties (QE mean value and uniformity of emission). The tool, now completely integrated inside the SPARC control system allows also to reconstruct the quantum efficiency map of the cathode surface.

EXPERIMENTAL SETUP

In the following paragraph the experimental setup for monitoring the laser energy and the beam charge and its implementation inside the SPARC control system [2] will be illustrated.

Laser Energy Monitor

The SPARC laser beam energy is measured by means of a fast photodiode (Thorlabs mod. DET210). The signal generated by the photodiode consists in a sharp current pulse with duration of approximately ten ns. The area of the photodiode signal results to be linearly dependent from the energy of the laser pulse. In order to deduce the energy carried out by laser beam, an accurate calibration is carried out by relating the area of the photodiode signal with respect to the laser energy measured by a commercial joulemeter (Molectron mod. J3-05).

A typical calibration curve is reported in Fig. 1. In this figure is evident that the photodiode response can be considered linear, and its slope represents the conversion factor that should be used to convert the area of the measured photodiode signal to the energy of the laser beam pulse.

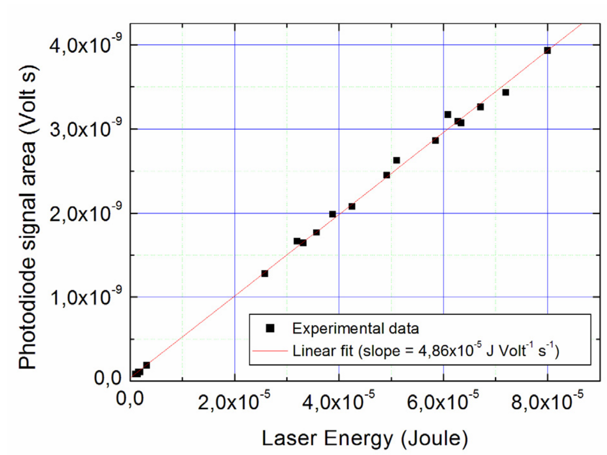

Figure 1: Typical calibration curve for the laser photodiode.

Due to the sensitivity of the photodiode with respect to the relative laser beam position with respect to the detector area the calibration factor is usually verified each time that the operators prepare the laser beam for the SPARC run. Moreover, a pointing procedure of the laser beam to the centre of the cathode is performed by means of a motorized mirror at the end of the optical transfer line. Thus the final path of the laser beam is frequently changed and this affects also the calibration constant. In order to avoid this problem we choose to sample the laser energy before the motorized mirror by means of a beam splitter as shown in Fig. 2 [3].

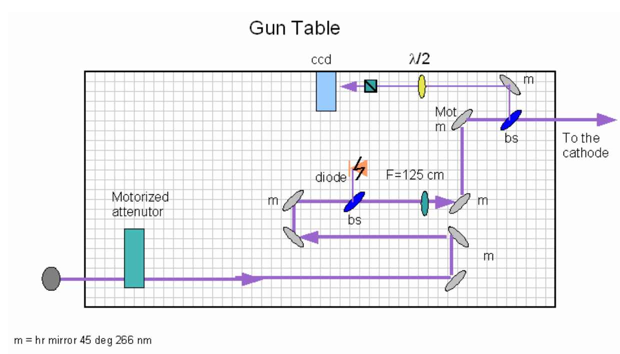

Figure 2: Layout of the final part of the laser beam transfer line. The position of the beam splitter and photodiode is also shown.

With this beam splitter and photodiode configuration, when the motors of the last mirror are used to move the laser spot over the cathode surface, the influence on the measurement of the laser energy pulse became negligible.

*Work supported by Italian National Institute of Nuclear Physics (INFN) and by Ministero Istruzione Università e Ricerca, Progetti Strategici, DD 1834, Dec. 4, 2002, within the SPARC project.
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Beam Charge Monitor

In order to measure the beam charge two different techniques are currently used in the SPARC photo-injector. The first one make use of a Faraday cup placed at 1.2 m downstream the cathode surface. The second one is based on Integrating Current Transformer (ICT) that take place at the beginning and at the end of the three accelerating structures that boost the energy of the electron beam up to 150 MeV. We will focus our description to the Faraday cup and on its use in measuring the emission uniformity of the cathode surface. We will describe the use of the ICT as monitor of the bunch charge during routine operation of the SPARC linac.

In Fig. 3 a picture of the SPARC Faraday cup is shown.

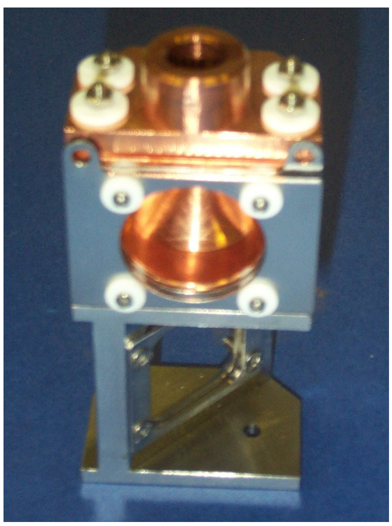

Figure 3: Faraday cup picture.

Signals Acquisition

The analogue signals obtained from the photodiode and from the Faraday cup are sent, one for each channel, through coaxial cables to a an high speed digitizer board (National Instruments NI PCI 5152 2 Gs/s Digitizer Oscilloscope).

The waveforms acquired from the digitizer can be directly manipulated by the local software that runs on the front-end CPU located in the SPARC bunker or can be transferred and analysed at the console level CPUs located in the control room by running dedicated software. The trigger of the digitizer board is achieved through a 10 Hz TTL signal of the SPARC timing system being so independent on the amplitude of the signals on the photodiode or Faraday cup dedicated channels.

ICT are connected using an electronic conditioning from Bergoz (BCM-IHR) that is read using the National Instrument board NI PCI 4070 DIMM.

At this moment the software for two control panels has been written with the aim to characterize the SPARC photocathode. The first one is used to keep constantly under control the laser energy sent to the cathode, the electron beam charge (by using ICT) and thus the quantum efficiency at the photo-injector working point. The second one is used to study the emission uniformity of the cathode by collecting the quantum efficiency map (by using the Faraday cup).

RESULTS

In the following paragraph some preliminary results obtained by integrating the laser energy monitor and the Faraday cup reading inside the SPARC control system will be illustrated.

QE Stability Results

Fig. 4 and 5 reports the result obtained over 24 hours of continuous QE measurement during a typical running shift of the SPARC photo-injector, including some shutdown periods.

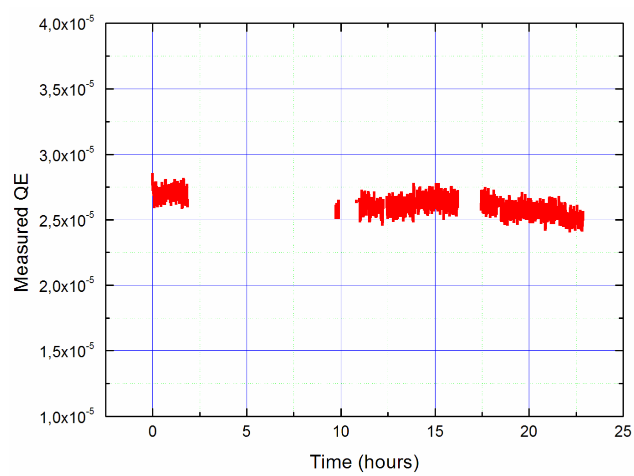

Figure 4: QE monitor results over approximately 24 hours.

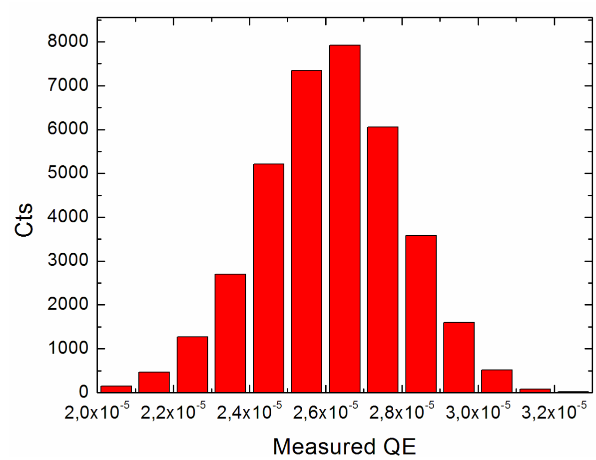

Figure 5: Histogram of the measured QE values during a typical shift.

Experimental data reported in Fig. 4 shows that some fluctuations can be detected in the efficiency of the cathode. We expect that the use of this new tool can be very useful to keep under control any variation of the quantum efficiency.

While in Fig. 4 a small decrease in the QE of the cathode has been revealed, the distribution of the same QE values reported in Fig. 5 shows that the standard mean value and standard deviation were respectively 2.5×10^{-5} and 1.8×10^{-6}.

We plan to use this QE monitor with the aim to build a slow feedback system dedicated to adjust the laser beam energy in order to prevent long term drifts of the electron bunch charge.

QE Uniformity

One of the key parameters of the SPARC photo-injector is the photocathode emission uniformity [1]. By using the Faraday cup and the photodiode, to measure respectively the electron bunch charge and the laser energy, the quantum efficiency can be deduced in a very small area (typically having 150 micron diameter). In order to deduce the QE map the laser beam spot size is tightly focused by means of a suitable fused silica lens and the quantum yield is determined from the slope of the emission curves (collected charge vs. laser energy) far from the space charge saturation regime. By moving the laser spot over the cathode surface the QE map of the cathode can be evaluated [4].

Figure 6 reports a picture of the front end software panel used to elaborate the waveforms acquired from NI 5152 board and related to the photodiode and Faraday cup readings

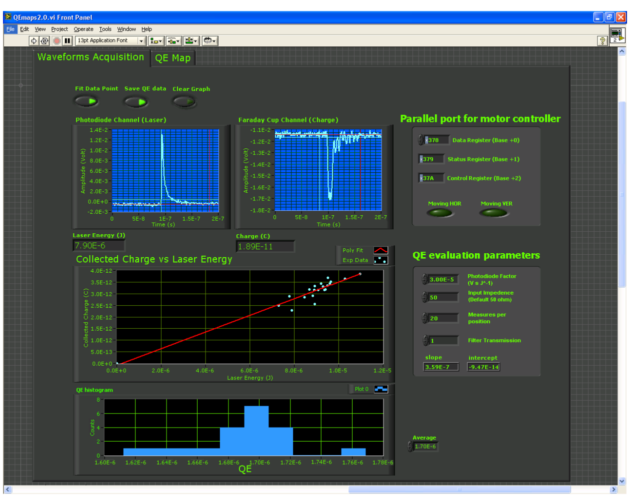

Figure 6: Picture of the front end software at console level used to acquire the emission curves of the photocathode.

Figure 7 reports the quantum efficiency map recorded after the laser cleaning process that was performed in order to restore the uniformity of emission together with a high value of quantum efficiency. Laser cleaning was performed by rastering the laser beam over an area of 3x3 mm^2 [4]. The acquired map shown in figure 6 clearly identify the squared area where the laser cleaning has been carried out giving also a measure of the emission uniformity achieved inside the irradiated area.

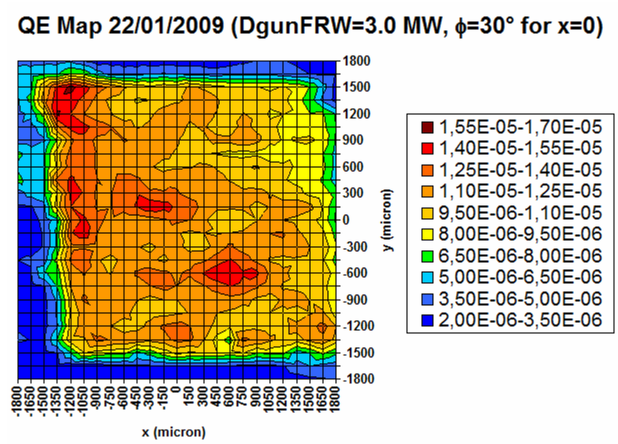

Figure 7: Quantum efficiency map of the SPARC photocathode obtained by data automatically collected through photo-injector control system.

CONCLUSIONS

In this work we have reported the implementation of the laser energy monitor and of the Faraday cup readings within the SPARC control system. The opportunity given by the insertion of this new devices are strongly related to the investigation of electron emission uniformity and to a future realization of a feedback system that will correct an eventual drift of the emission due to the degradation of the quantum efficiency properties of the photocathode.

REFERENCES

[1] SPARC Group, Conceptual Design Report, January 2004; http://www.lnf.infn.it/acceleratori/sparc/.

[2] G. Di Pirro et al, "SPARC contol system", Proceedings of ICALEPCS07, Knoxville, Tennessee, USA, TPPB25, p.215 (2007); http://www.jacow.org

[3] C. Vicario et al., "Drive laser system for SPARC photoinjector", Proceedings of PAC 2007 Albuquerque, New Mexico, USA, TUPMN040, p.1004 (2007); http://www.jacow.org

[4] L. Cultrera et al., J. Phys. D: Appl. Phys. 40 (2007) 5965