A HIGH CHARGE PHOTOINJECTOR FOR THE PULSED RADIOLYSIS FACILITY - ELYSE*

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Abstract

The Physical Chemistry Department of the CNRS at the Université de Paris-Sud and the Laboratoire de l'Accélérateur Linéaire (LAL) will collaborate on a dedicated radiolysis user facility named ELYSE. The irradiation of users' samples will be performed using electron beams of energies varying from 4 to 9 MeV, produced from a laser triggered RF gun. The accelerator group at LAL, benefitting from the experience gained with their experimental RF gun (CANDELA), are responsible for the design and construction of the accelerator. The nominal beam requirements for ELYSE are 1 nC pulses of 5 ps width (FWHM). However there is a strong scientific interest in obtaining bunch charges of 10 nC for the same pulse width. The need to extract such high charges necessitates the use of Cs_2Te photocathodes with their high quantum efficiency. An essential user requirement is to keep the charge of the integrated dark current during the RF pulse width (3 microseconds) below 1% of the charge of the main beam. We will present the status of our studies aimed at construction of an RF gun and its associated transport optics capable of achieving these challenging goals.

1 INTRODUCTION

The ELYSE project is aimed at providing the French physical chemistry community with a facility for the study of fast chemical reaction dynamics. The increasing interest in such facilities has resulted in their study and construction elsewhere [1,2]. Irradiation of chemical samples will be possible with both electron beams (radiolysis) and laser beams (photolysis). A "probe" laser, synchronised with the excitation source, will then be used to examine the induced reactions. The Laboratoire de l'Accélérateur Linéaire has the responsibilty for the design and construction of the electron accelerator for the radiolysis experiments. Our design will benefit from the experience we have gained with our experimental RF gun project, CANDELA [3]. In this paper we will present the requirements of the accelerator and illustrate the status of our studies towards its design.

2 SPECIFICATION

The desired beam parameters for ELYSE are shown in table 1 below.

Table 1: Specification of the ELSYE Accelerator

Energy	4 - 9 MeV
Bunch charge	> 1 nC
Bunch duration	< 5 ps (FWHM)
Energy spread (RMS)	2.5%
Normalised RMS emittance	60 mm-mrad
Repetition rate	> 10 Hz
Beam diameter on target	2 - 20 mm

In addition to the above requirements there is a strong interest in pushing the bunch charge to 10 nC for the same bunch length and in having machine operation at frequencies up to 100 Hz. As the project requires a probe laser synchronised with the electron beam it seems natural to consider a laser triggered RF gun as the electron source. Following our previous experience with S-band structures we have opted for a 3 GHz RF gun. Good experimental conditions require the level of dark current charge incident on user samples to be less than 1% of the charge from the main electron pulse. As the RF pulse width will be typically 3 µs long it is clear that the dark current arriving in the experimental area must not exceed several µA and this condition is certainly one of the principal challenges of the machine.

3 THE ACCELERATOR

3.1 The Electron Gun

We aim to benefit as much as possible from existing RF gun experience and therefore we base our choice of gun on the one developed for the CLIC Test Facility (CTF) at CERN [3]. This 1-1/2 cell structure provides a beam of 4.5 MeV for a nominal electric field of 100 MV/m. As it is known that the dark current is a strongly increasing function of the cathode field (E_c) we aim to slightly modify the CERN geometry so as to permit operation at reduced fields. Calculations with the SUPERFISH code show that the introduction of a chamfer around the cathode plane can reduce E_c with respect to the maximum axial field by 17% [4]. With this modification we can envisage running the cathode at fields of typically 65 - 75 MV/m (79 - 91 MV/m peak axial field). In order to allow clean transmission of the beam for these reduced fields we open the iris diameter of the structure from 20 mm to 30 mm. PARMELA simulations indicate that such a gun should produce a beam of 3.6 MeV for E_c = 65 MV/m (4.2 MeV for E_c = 75 MV/m).

The additional energy needed to reach 9 MeV will be provided by a "booster" cavity which will be identical to the one employed on the CTF. This is a four-cell standing wave structure operated in π mode. As the 10 nC bunch leaving the gun will be strongly affected by space charge forces a solenoidal focusing coil, placed at the gun output will be used to focus the beam through the booster. Table 2 shows a summary of the beam parameters as calculated by PARMELA at the exit of the booster. A schematic drawing of the RF gun and the booster is shown in figure1.

Table 2 Beam parameters as calculated by PARMELA.

	9 MeV/1nC	9 MeV/10 nC	4 MeV/1 nC	4 MeV/10 nC
RMS Bunch length (ps)	1.1	2.4	1.2	2.8
RMS energy spread (%)	0.8	2.6	1.7	6.0
RMS Norm Emittance (mm-mrad)	14	67	15	70

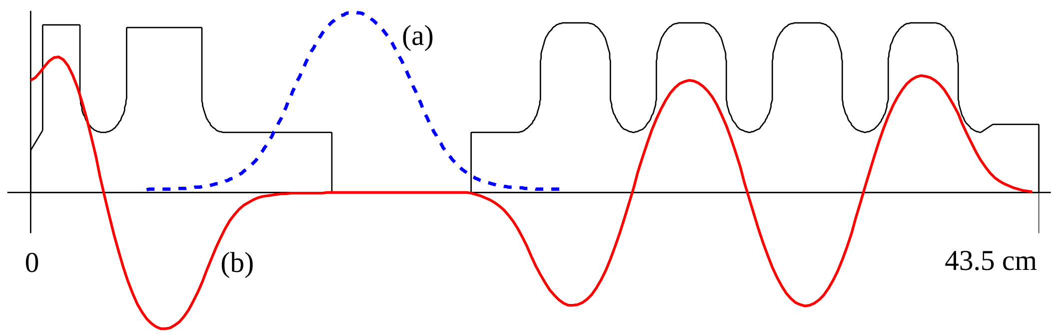

Fig. 1 Schematic of RF gun and booster showing (a) solenoidal magnetic field and (b) RF accelerating field.

The desire to have 10 nC bunch charges implies the use of Cs_2Te cathodes. Such cathodes have demonstrated quantum efficiencies in excess of 1% with life-times of several hundred hours [4]. We propose to use a 10 mm diameter cathode irradiated at near normal incidence by a 266 nm wavelength laser beam. A commercially available Titanium-Sapphire laser (800 nm) produces the UV light after frequency tripling. The UV pulses are typically of 1 ps RMS width and have an energy of 70 μJ.

3.2 The Transport Line

The beam from the booster can be delivered to any of three different experimental stations with the aid of two 30° bend dipole magnets (Fig.2). It is hoped that the dispersive nature of the dipoles will serve to reduce the level of dark current arriving at the targets of those users for whom this effect is particularly troublesome. Collimating slits between the two dipoles can be used to select a narrow energy band around the nominal beam energy. Until now we have checked the transport through the magnet elements with the TRANSPORT and TRACE-3D codes. Input to the codes was provided by outputs from PARMELA runs calculated from the cathode up to the exit of the booster cavity. PARMELA gives the distribution of the particles on the 2-D phase-space projections; x-x', y-y', and δϕ-δE/E, where these symbols have their usual meaning. However, as TRACE-3D has no notion of particle distribution we make the following approximation; the elliptical phase-spaces used to start the TRACE-3D runs are chosen such that the values of the beam parameters are equal to the RMS values calculated by PARMELA (for which the 2-D projections are not necessarily enclosed by an elliptical contour).

As the arc, composed of the two dipoles, has a non-zero momentum compaction we have the possibility of bunch compression due to energy-dependent path length effects. Initially we run TRANSPORT to find settings for quadrupoles Q4 and Q5 which yield $R_{51} = R_{52} = 0$, where R_{51} and R_{52} are the ϕ-x and ϕ-x' elements of the transport matrix (calculated from the entrance of the first dipole to the exit of the second). We then run TRACE-3D to add the effects of linear space-charge forces and finally optimise the settings of Q4 and Q5 to obtain a minimum in the bunch length at the exit of dipole 2. In the absence of space charge forces the final phase width of the beam, $\Delta\phi_f$, is given by,

$$\Delta\phi_f = R_{56}\delta p/p + \Delta\phi_i$$

where $\Delta\phi_i$ is the initial length and R_{56} is the ϕ-$\delta p/p$ element of the transport matrix. We have seen signs of such bunch compression from the TRACE-3D runs and experimental observations of this effect have been obtained recently using a two-dipole arc similar to the one which we propose [1].

Calculations indicate that compression is possible for all energies and charges of interest when the beam is transported to experimental area 3. In contrast we note that, for the case in which the space-charge is strongest (4 MeV, 10 nC), the bunch delivered to experimental area 1 is longer than the bunch which exits the booster. The PARMELA simulations indicate that the 4 MeV-10 nC beam exiting the booster has transverse phase space ellipses which are strongly distorted by non-linear space

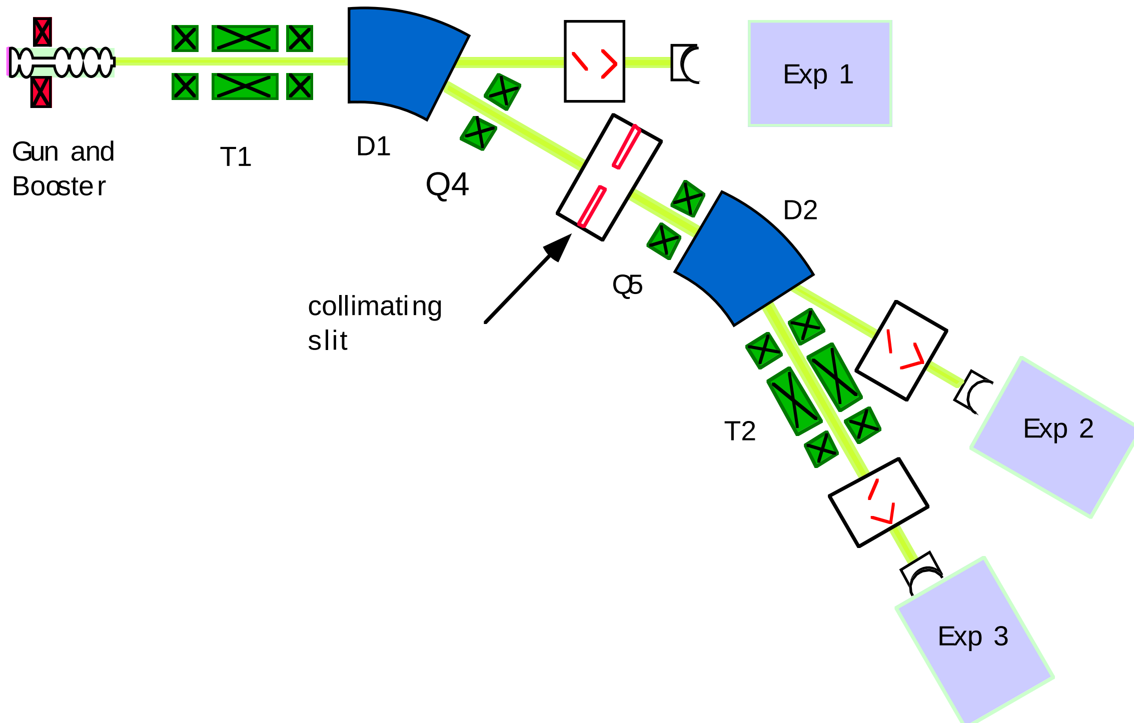

Fig.2 Schematic of the ELYSE accelerator showing the gun, booster, triplet magnets (T1, T2), dipoles (D1, D2), quadrupoles (Q4, Q5) and experimental areas (Exp 1, Exp 2, Exp 3).

charge effects. However, the input phase spaces for TRACE-3D simulations are ellipses with Twiss parameters which correspond to the RMS emittance, size and divergence of the PARMELA outputs. Therefore, the results of the TRACE-3D runs should be regarded with some caution. Now that we have some idea of the necessary quadrupole strengths required to confine the beam we intend to perform PARMELA simulations throughout the entire accelerator to verify the results of the TRACE-3D calculations.

ACKNOWLEDGEMENTS

We are indebted to R. Bossart and J.C. Godot of CERN for all the information they have provided us with concerning the CTF gun and booster cavity. The various simulation runs described above were performed by H. Monard and Y. Thiery with the aid of B. Mouton. The modifications to the CTF gun were suggested by J. Rodier. We thank P. Dufresne for the preparation of figure 2.

* Funding for ELYSE is provided by the CNRS, the MENRT, the Universite de Paris-Sud, the Conseil Regional Ile-de-France and the Conseil General de l'Essonne.

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