CANDELA Photoinjector Status Report*

J. Gao, B. Jacquemard, B. Mouton, M. Omeich, Y. Thiery, C. Travier
LAL, Laboratoire de l'Accélérateur Linéaire, Bât. 200,
A. Brun, P. Georges,
IOTA, Institut d'Optique Théorique et Appliquée, Bât. 501,
C. Bazin
LURE, Laboratoire d'Utilisation du Rayonnement Electromagnétique, Bât. 209,
UPS, Centre d'Orsay
F-91405 Orsay CEDEX

Abstract

Since the beginning of 1990, the "Laboratoire de l'Accélérateur Linéaire" (LAL) at Orsay, has started to develop a high-brightness photoinjector [1,2]. The project, now named CANDELA (CANon DEclenché par LAser), consists of a two cell 3 GHz microwave electron gun. The photocathode is illuminated by a Ti:Sapphire picosecond laser designed by the "Institut d'Optique Théorique et Appliquée" (IOTA) also located at Orsay.

The gun and laser designs are briefly described and the project status is reviewed.

1. INTRODUCTION

Future linear colliders and short wavelength Free Electron Lasers require very bright electron beams. The advent of microwave gun [3] and photoinjector [4] concepts shows the way towards the production of such bright beams. A large worldwide endeavour [5] has been undertaken to understand well the RF photoinjector physics and to bring its technology to a high level of performance and reliability.

As part of this general R&D effort, LAL and IOTA are constructing an experimental photoinjector named CANDELA. The purpose of this project is to widely study the RF gun physics by comparing experimental results and computer code simulations. It is a natural continuation of LAL's previous developments in the field of high gradient accelerating structures [6] and photocathodes [7] and of IOTA's expertise with short pulse lasers [8].

The gun is made of two independently powered 3 GHz RF cells. The first cell is designed to minimize the linear emittance growth. The second cell is used to reduce the energy spread. The details of the calculations that led to this design are given in reference [9].

At the beginning of the project, computer simulations were performed for a conservative 30 ps laser pulse [2]. Recently, we obtained the evidence that the real laser pulse is much shorter. New simulations are now being done. Since our project is devoted to RF gun studies, the working parameters will be widely varied. Therefore, in this paper, we will not give any nominal performance of the gun. We will simply describe the main components; gun cavities, laser and beam transport line.

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2. GUN CAVITIES

The cavities are made of oxygen free copper. In each cell, there is a loop to measure the RF field and a tuner to adjust the frequency. In the first cell, two ports are provided to allow off-axis laser illumination. While illuminating the cathode normally, these ports will be used to position the spot correctly.

The cathode is de-mountable in order to test several types. Since we want to have the possibility to heat the cathode, it should be thermally isolated from the cavity though in RF contact. To solve this problem, we used the SSRL design [10]. The cathode stem is held in the back, far from the hottest part. The RF contact is made via a toroidal thin tungsten-wire spring very near the cathode surface. To avoid heat propagation, the cavity wall in contact with the spring is made of stainless-steel. The loss of the quality factor due to the poor electrical conductivity of the stainless steel was considered to be acceptable (less than 20 %). The volume at the back of the spring is designed to make an RF trap thus allowing operation without the spring if necessary. However, this last solution is less attractive because there exists large electric fields in the trap that could lead to arcs. Figure 1 shows a view of the cathode region.

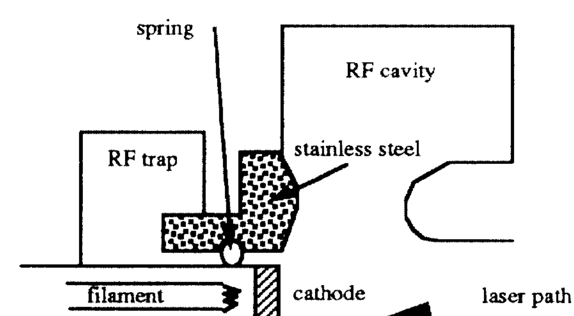

Figure 1: Cathode region

The first cathode to be tested will be a dispenser cathode [7]. It consists of tungsten impregnated with aluminate of Ba and Ca. This cathode does not have a very high quantum efficiency but has a long lifetime. Moreover, it can be reconditioned at high temperature after being exposed to air.

The gun cavities are powered and phased separately. The phase between the cavities is chosen to reduce the energy spread. By choosing the field ratio between the two cells, it is possible to improve the linearity of the energy-phase diagram, thus allowing further magnetic compression.

Started in February 1991, the design and construction of the cavities shown on figure 2 were completed one year later.

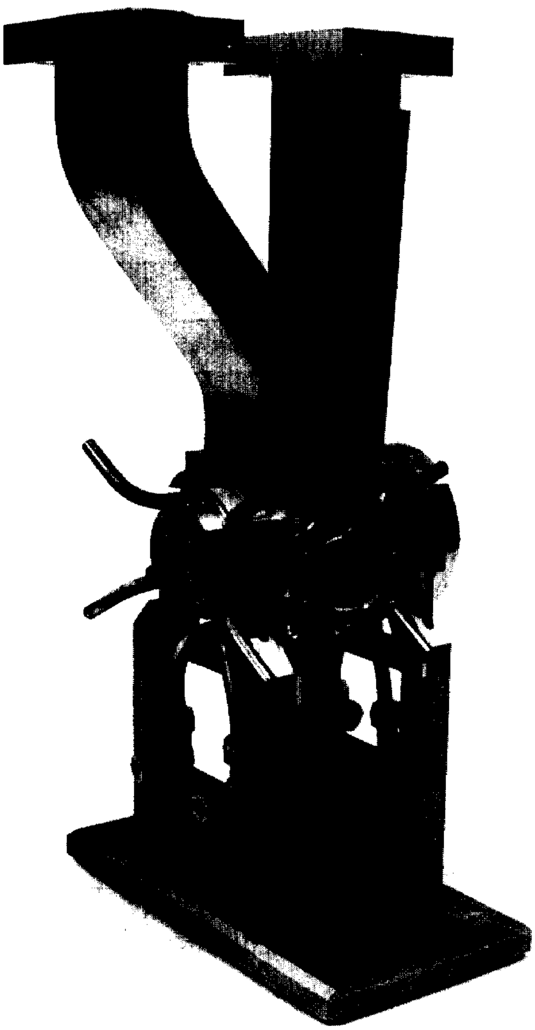

Figure 2: CANDELA RF gun cavities

3. LASER

The laser consists of an oscillator followed by an amplifier as shown in figure 3. It is based on recent developments around the Ti:Sapphire amplifier medium. The crystal combines the advantages of the dyes with a large fluorescence bandwidth (700 / 1000 nm) and those of the solid state medium with a saturation fluence of 1 J/cm^2. The laser is designed to produce short pulses on the order of 1 ps with an energy of 0.5 mJ in the blue region of the spectrum. The production of short pulses in Ti:Sapphire is based on the Kerr lens effect in the rod itself due to the high peak power in the cavity. In order to synchronize the pulses with the RF signal at 3 GHz, we add in the cavity an acousto-optic modulator. The oscillator produces pulses in the range of 1 ps to 100 fs at a 100 MHz repetition rate but with a very low energy of a few nanojoules. In order to increase the pulse energy we use a regenerative amplifier pumped by the second harmonic of a Q-switched Nd-Yag laser working at 10 Hz repetition rate. In order to avoid non linear effect in the components of the amplifier (such as self-focusing) we use the chirped pulse amplification technique. This technique consists of a strecher that temporaly broadens the pulse before the amplifier and a compressor after the amplification in order to return to the initial pulse duration. After the amplification, a non-linear crystal is used to generate the second harmonic beam at 400 nm. The energy of the blue pulse is expected to be in the order of 0.5 mJ. By changing the alignment of the compressor, we will be able to change the pulse duration in order to study the performance of the photoinjector as a function of the characteristics of the light pulses.

The laser is currently being tested.

4. BEAM LINE

In order to characterize the beam quality, it is necessary to measure the following parameters; charge, current, bunch length, energy, energy spread, transverse size, emittance. Since it is not possible to measure all these parameters at the same location, one has to build a beam line. In order to access the beam energy and energy spread, it is necessary to have at least one bending magnet. A second bending magnet is necessary to obtain an achromatic system. Since the beam divergence at the gun exit is very large, one needs a strong focusing system which consists of a solenoid and a quadrupole triplet. The beam line is shown in figure 4. It is similar to that of BNL [11] and CERN [12]. All the magnets which are now being measured have been designed to operate at a maximum energy of 20 MeV which will allow us further development of the experiment (new gun with more cells or addition of an accelerating section). Because of the reasonable size of this beam line, it will be installed on a 3 by 1.5 m marble table. The instrumentation system is not yet fully designed.

5. CONCLUSION

The CANDELA RF gun will soon be able to produce its first photo-electrons. It will then take some time to complete all the diagnostics and the control system which are compulsory for obtaining good experimental results. From the beginning of 1993, it will then be possible to do systematic experiments by varying all the parameters over a large range.

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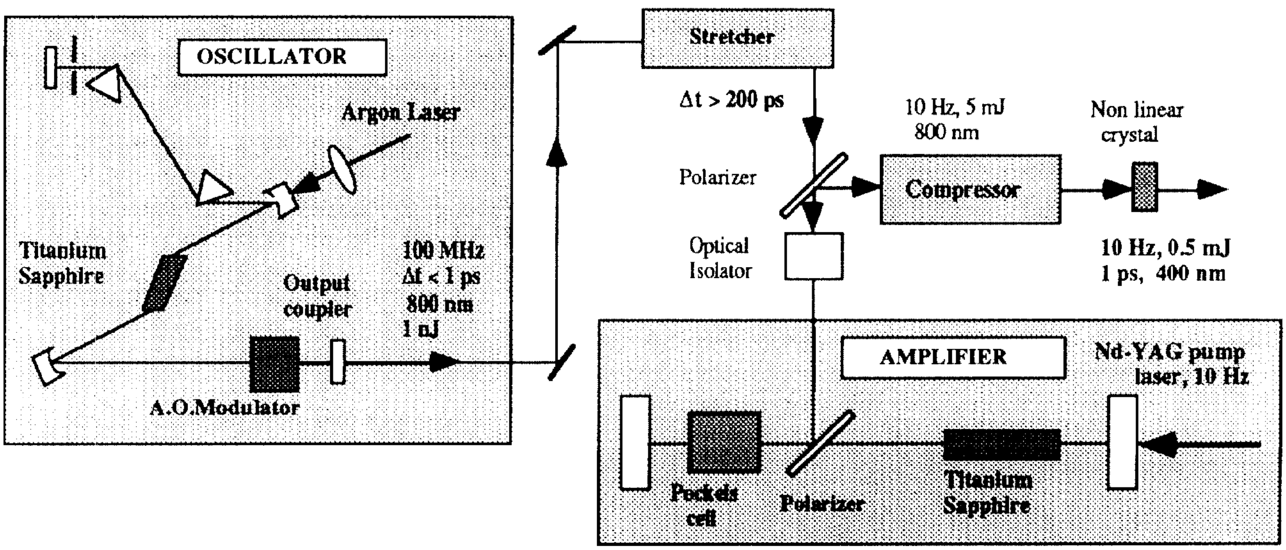

Figure 3: Laser layout

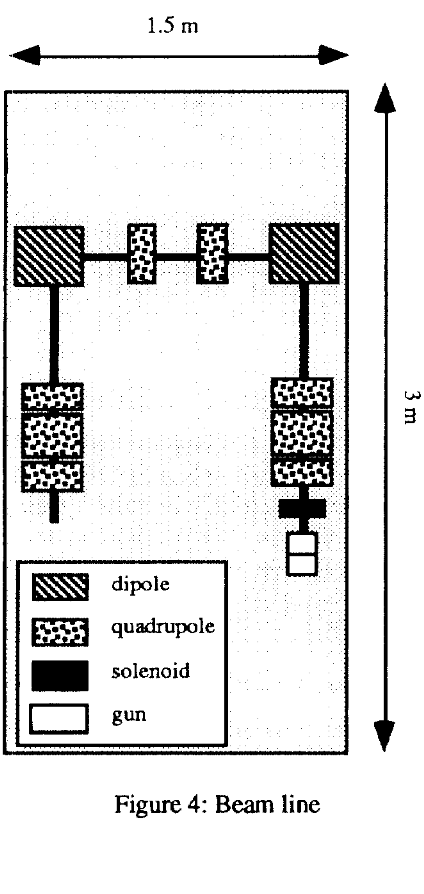

Figure 4: Beam line

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