CANDELA Photo-injector: the Drive Laser*

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Abstract

In view of the future linear colliders, a bright photo-injector named CANDELA is being constructed at LAL Orsay. To illuminate the photo-cathode, a femtosecond Ti:sapphire laser has been developed. It consists of an oscillator that delivers a continuous train of femtosecond pulses at a repetition rate of 100 MHz. This train is then amplified in a regenerative amplifier pumped by a second harmonic Q-switched Nd:YAG laser. The status of the overall RF gun experiment is also mentioned.

I. INTRODUCTION

Since the beginning of 1990, the "Laboratoire de l'Accélérateur Linéaire" (LAL) at Orsay, has started to develop a high-brightness photo-injector [1,2]. The project, named CANDELA ("CANon DEclenché par LAser"), consists of a two cavity 3 GHz microwave electron gun. These cavities are independently powered: the first one is designed to minimize the linear emittance growth and the second one is used to reduce the energy spread. The details of the calculations that led to this design are given in reference [3].

The photocathode is illuminated by a Ti:Sapphire picosecond laser designed by the "Institut d'Optique Théorique et Appliquée" (IOTA) and presented in this paper.

II. LASER DESCRIPTION

The laser system, we have developed is based on the Titanium Sapphire crystal which has been proved to be the best material to produce very short and high energy pulses in the near infrared [4-6]. This 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 consists of an oscillator followed by an amplifier as shown in the Figure 1.

The femtosecond oscillator is a self mode locked Ti:Sapphire laser based on that originally produced by Spence et al. [4] and producing 100 fs at 780 nm. In the linear cavity the two curvature mirrors are used off axis in order to compensate the astigmatism introduced by the Brewster angle cut crystal. The pump beam is focused on the crystal with a curvature mirror through a dichroïc mirror.

The two prisms arrangement is used to compensate the positive Group Velocity Dispersion (GVD) in the rod and to obtain very short pulses. The mode locking is produced by non linear effect (Kerr effect) in the crystal itself. This effect introduces a positive lens in the cavity that changes the cavity beam waist in the mode locked regime compared with the cw regime. By properly aligning the laser, we are able to have a large beam in cw regime that decreases in size when the laser operates in femtosecond regime. By using an aperture (slit) in the cavity, we introduce losses that are more important in the cw regime. To start the laser in pulsed regime, we mount the high reflective plane mirror on a piezoelectric transducer to create a modulation in the laser signal that initiates the non linear regime and so the mode locking.

The transducer is also used to synchronize the optical pulses with the RF wave in the cavity. The phase locking of the laser is achieved by mixing the output of a monitor photodiode with a reference signal to derive a phase-error signal. Amplification, integration, and level comparison of this signal allow a suitable error signal to be supplied to the piezoelectric transducer controlled cavity mirror. The output of the laser is so maintained in phase with the reference signal that also drives the RF cavities. We have experimentally recorded an rms jitter of 2 ps between the optical pulses and the reference signal.

The oscillator produces pulses in the range of 100 fs to 1 ps at a 100 MHz repetition rate but with an energy of a few nanojoules. In order to increase the pulse energy, we have to amplify the pulses to the millijoules level. This amplification is obtained in a regenerative amplifier pumped by the second harmonic of a Q-switched Nd-Yag laser working at 10 Hz repetition rate.

The amplifier consists of two high reflective mirrors, a Ti:Sapphire crystal, a broadband polarizer and a Pockels cell. A Faraday isolator is used to discriminate the input and the output of the amplifier. The pulse trapping and dumping is accomplished as follows : initially the pockels cell is oriented to give a quarter wave of static birefringence in order to prevent any lasing effect in the cavity. One pulse of the oscillator is then trapped in the amplifier by applying a quarter wave voltage step on the Pockels cell. The pulse then travels into the amplifier, its energy increases until it reaches the saturation. At this level, the pulse is ejected from the cavity by applying a second quarter wave voltage step on the

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Pockels cell. The energy of the output pulse is typically 6 mJ. However, in order to avoid non linear effects in the components of the amplifier (such as self focusing) we have to decrease the peak power of the amplifier pulses by using the well-known Chirped Pulse Amplification (CPA) technique.

This technique consists of a stretcher that temporally broadens the pulse before the amplifier and a compressor after the amplification in order to return to the initial pulse duration. The stretcher consists of a single grating (2000 grooves/mm used at Littrow angle) and a lens that introduces a positive GVD. The stretching factor is of the order of 1000 to 5000. At a few hundred of ps, the peak power is decreased by the same amount and the pulses can be amplified safely. The compressor is based on a two parallel gratings arrangement (same as in the stretcher also at Littrow angle) giving the opposite (negative) GVD. The overall transmission of the compressor is more than 50 % and so the compressed pulse energy is typically 3 mJ. Furthermore by slightly disaligning the compressor we are able to vary the pulse duration of the amplified pulses and so it will be possible to study the performance of the photo-injector as a function of the temporal characteristics of the light pulses.

By using non linear effect (second and third order harmonic generation) in BBO crystals, we will produce ultrashort pulses in the UV and so take advantage of the better quantum efficiency of the photocathode at this wavelength. With 3 mJ in the near infrared (780 nm) we expect to obtain 0.3 mJ at 260 nm.

The laser was assembled in August 1992, and has been working since then.

III. CANDELA STATUS REPORT

Some problems with the RF power source (modulator, klystron, RF network components) did not allow to start the gun conditioning in the fall of 1992 as scheduled. These problems are now solved and the gun will be conditioned starting in May 1993 with the first photo-electrons scheduled for the summer 1993.

The gun was baked for 20 days at 150°C. After that the vacuum measured just at the gun exit in the beam pipe was 3.10^{-10} Torr. This indicates that the vacuum inside the cavities is probably very near 10^{-10} Torr.

A U-shape beam transport line is being assembled. It will support several diagnostics used to characterize the beam properties. These diagnostics will include Wall Current Monitors for charge and position measurements, slit and Faraday cup for energy, and OTR monitors for transverse profile measurements. For these last measurements, we are also trying to develop a gaz ionization monitor which has the advantage to be non-destructive for the beam and the laser.

IV. ACKNOWLEDGEMENTS

All the people that participated in the construction of CANDELA RF gun are acknowledged.

V. REFERENCES

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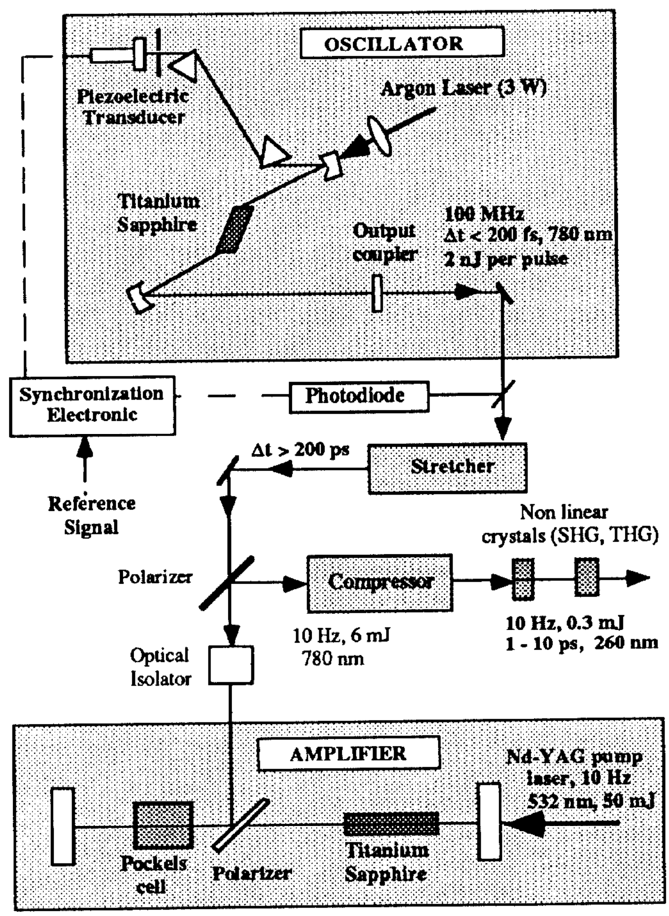

Figure 1: Schematic of the Ti:Sapphire laser system