# ACCELERATOR R & D AT LAL-ORSAY*

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## ABSTRACT

An R & D programme was launched at LAL/Orsay at the end of 1985 as a contribution to the short term future. The programme mostly concentrates on conventional technologies for which improvements can still be made in terms of power efficiencies in the frame of very high energy linear colliders.

## 1. INTRODUCTION

LAL has recently been involved in the design and construction of LIL (LEP injector linacs). Consequently, new experience was gained in modern linac technologies which motivated the present research and development programme on future linear colliders.

This programme is based essentially on improvements and extensions of conventional technologies, and a start was made possible due to some major equipment being provided by SLAC and CERN. The main items of this R & D programme are:

- Beam dynamics simulation
- Generation of short-pulse, high-peak currents
- RF power source: LASERTRON
- High gradient warm structures

## 2. SIMULATION OF BEAM DYNAMICS IN THE LASERTRON [1-3]

A computer code, named RING, has been specially written to simulate the beam dynamics in the lasertron, but can also be used to design laser-triggered guns. The main features of this code are:

- Time is the independent variable
- Relativity is considered, but radiating fields are ignored
- Each bunch is split into disks (z coordinates) and each disk is made of rings (r coordinate). Both z and r are tracked for each particle and the velocity $v_\phi$ is obtained from Busch's theorem ($2^1/_2$ D code)
- Transient bunch behaviour is studied in the gun and drift regions
- Steady state is considered in the output cavity of the lasertron
- The code is relatively fast since high precision is obtained with only a few particles (for example 45 minutes c.p.u. for 100 electrons on a VAX II/785).

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More details on the physics of this code and examples of computer runs are given in a contribution from A. Dubrovin and J.P. Coulon to this Workshop. In particular the code has been used to design a prototype Lasertron at Orsay, with the characteristics and theoretical performance summarized in Table 1.

Table 1

Design parameters of the Orsay prototype Lasertron

| | |
|---|---|
| RF frequency | 6 GHZ |
| RF power | 20 MW |
| Efficiency | 75% |
| Beam power | 25 MW |
| Acc. voltage | 400 kV |
| Average current | 62 A |
| Charge/micro pulse | 10 nC |
| Cathode area | 1 $cm^2$ |
| Magnetic field | 2.8 kG |
| Optical frequency | UV |
| Micropulse length | 35 ps |
| Micropulse energy | 1 $\mu$J |

An interesting result from the simulation study is the optimum geometrical configuration of the gun region corresponding to a non-focusing geometry but giving a maximum uniformity of the accelerating field. The latter, for a short pulse, leads to a minimum distortion of the bunch with respect to the distance r to the axis, since all particles achieve almost the same velocity.

## 3. MICROPULSED PHOTOCATHODES STUDIES [4-6]

The Lasertron programme has led to specific experimental studies of high-current, pulsed photoemission, with the aim of achieving the best choice of photocathode. For instance, a good compromise between quantum efficiency and lifetime seems necessary. The first experimental apparatus consisted of:

- A picosecond Nd: YAG laser providing short bursts of a few 10 mJ in the IR, green and UV regions.
- A small ultra-high vacuum tank in which the distance between the cathode and anode could be adjusted and fitted with a 10 kV high voltage supply. The cathode support was especially designed to handle metallic needles and arrays of needles.

The first experimental results were obtained with single W needles and an array of $Nb_3$ Ti needles. These results are shown in Table 2, where $\Delta\tau$ is the micropulsed current width as measured with a 1 GHz bandwidth oscilloscope. Note that each laser macropulse (burst) is made of seven micropulses whose theoretical width is expected to be 35 ps. If the micropulse current shape follows the light pulse we should expect, in fact, much higher peak currents. In these experiments the high voltage is adjusted to be slightly below the field emission threshold. Hence the required laser pulse energy needed for electron extraction becomes smaller (photo-field emission).

Table 2

Experimental results from micro emitters

| Photocathode | I peak [A] | $\Delta\tau$ [ns] | Laser burst energy [μJ] |
|---|---|---|---|
| Single W needle | Green 2 | < 1 | 40 |
| | UV .8 | | 10 |
| $Nb_3$ Ti array)<br>(400 needles) | UV 10 | < 1 | 70 |

Since these first results were quite encouraging a more sophisticated ultra-high vacuum tank is being built to handle a much higher voltage (150 kV) such that photo-field emission can be tested in a more realistic HV environment. This tank (Fig. 1) should be ready before the end of 1987. In order to control the accelerating field at the needle, an intermediate anode is included in the gun region.

It is believed that just by changing the ceramic insulator, it should be possible to operate the same tank at up to 400 kV. In that case, with little modification, it will serve as a prototype Lasertron. In view of this future experiment the tank has been designed to allow easy access to the anode region. Finally, the experimental work is scheduled as follows:

a) High current photo-field emission tests. Extracted charges will be measured by using a wide band coaxial Faraday cup behind the anode.

b) Space charge effects. The micropulse current will be measured using a transient radiation monitor such that a picosecond streak camera can make the comparison with the incident laser pulse width.

c) RF efficiency. The previous monitors will be replaced with an extraction cavity. However, this experiment will only be possible after modification of the laser in order to get a long train of micro pulses with little amplitude modulation.

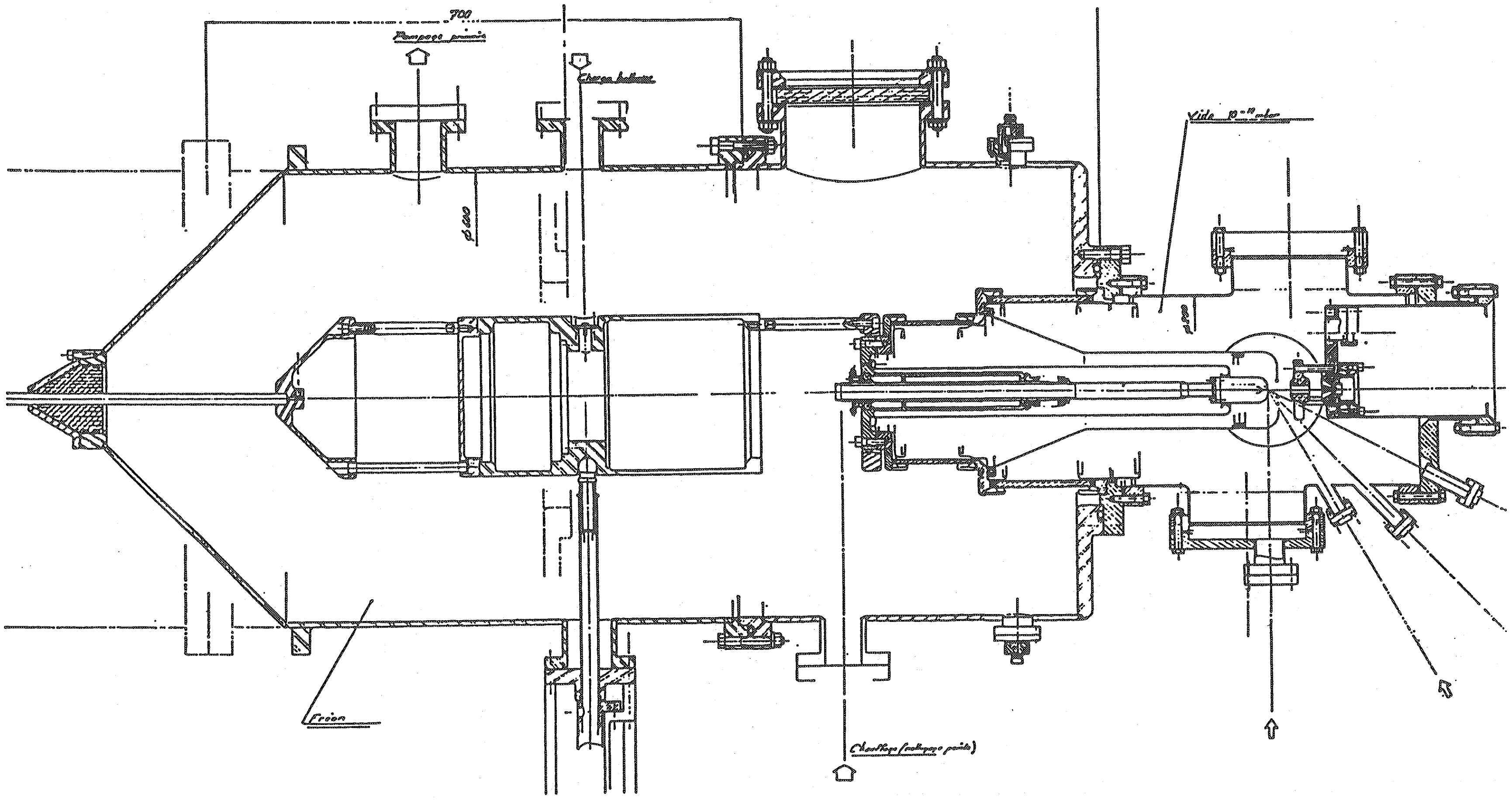

Fig. 1 High voltage, ultra-high vacuum tank for photocathode experiments

## 4. HIGH GRADIENT TEST FACILITY

A high gradient test facility has been mounted in one of the old experimental halls of the Orsay Linac. It uses a 38 MW pulsed klystron (4.5 $\mu$s) of the LIL type (3 GHz), and a SLAC-PEP type gun (1 A, 1 ns). It will also use storage cavities for RF pulse compression. The aim is to test short, warm, accelerating structures at high gradients (up to 100 MeV/m) with a beam passing through them. Equipment for beam analysis is included in the facility.

The short term schedule can be sumamrized as follows:

a) High gradient test of the LIL type structure. This structure was optimized to get the highest shunt impedance from an iris-loaded guide. The internal geometry is circular. A short structure (0.5 m long) corresponding to the last landing of the LIL quasi-constant gradient structure (iris diameter = 18 mm) has been built. The test will consist of determining the operational gradient limit of this type of structure.

b) Backward travelling wave structure. One can increase the shunt impedance by increasing the capacitance of the elementary accelerating cells. In an iris-loaded structure with electrical coupling from cell to cell this would lead to smaller group velocity hence to a longer filling time.

   A magnetic coupling (holes in the irises) would permit both the shunt impedance and the group velocity to be handled independently. In that case the phase and the group velocity have opposite directions (backward wave).

   Such a prototype structure, 1.2 m long, $4\pi/5$ mode, is being built now as a LAL-CGR MeV collaboration and will later be installed at the LAL test facility.

## CONCLUSION

The R & D programme related to future linear colliders is now well underway at LAL after almost 2 years of preparation. However, it is believed that some effort should be made in the future not to limit the experimental work to a single RF frequency (3 GHz) since the tendancy is to use higher frequencies. On the other hand, it is clear that ideas can go much faster than the setting up of an experimental test facility. Hence effort should be concentrated on such a facility being adaptable in order to allow closer collaboration with other laboratories.

## REFERENCES

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