SUMMARY REPORT OF WORKING GROUP 4 ON e^+e^- SOURCES, LOW EMITTANCE PRODUCTION AND PRESERVATION

PART II: HIGH BRIGHTNESS GUNS

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It is worthwhile considering the possibility of operating the electron linac without a damping ring. To do so, the electron beam has to be generated within tight tolerances in terms of emittance, bunch length and peak current, and one must assume that the beam almost keeps its initial characteristics as it goes along the linac.

The SLAC-SLC gun is an example of a modern thermoionic, short-pulse, high-peak-current device. However, the normalized emittance is still two orders of magnitude greater than that required for a future linear collider ($\gamma\ \sigma_x\ \sigma_{x'}$ = 3 × 10^{-4} m.rad after the buncher). In the SLC the emittance is reduced to 3 × 10^{-5} m.rad by means of an electron damping ring

At the present time the device closest to fulfilling the future linear collider requirements (such as those of the Stanford Super Linear Collider now being designed) is the Los Alamos RF gun which uses a photocathode (Cs_3 Sb) triggered by a laser pulse and whose present performance is summarized in Table 1.

Table 1

Performance of the Los Alamos RF gun

Output energy	1 MeV
Peak current	100 A
Charge	8 nC
R.m.s. bunch length	80 ps
R.m.s. energy spread	± 3%
Normalized emittance ($\gamma\ \sigma_x \sigma_{x'}$)	3 × 10^{-6} m.rad

Notice that one could obtain a 1 nC charge within a 10 ps pulse length, while still keeping the current density constant. However, it is assumed that such a gun could fulfil the requirements of a multi hundred GeV linear collider if circular shaped beams were used. In the case of a ribbon beam, the current density would be 10 times higher and it is not obvious that the Cs_3 Sb photocathode could handle this higher figure.

As soon as it is possible to generate high currents from a photocathode illuminated by a laser pulse, it will be possible to eliminate high modulated voltages and bunching systems and just operate with a d.c. accelerating voltage. Such guns are presently being developed for high power RF sources such as the LASERTRON. For the high RF-frequency, high RF-peak-power LASERTRON, the beam requirements are almost the same as those for high brightness guns:

- High accelerating voltage
- High peak current
- Small emitting photocathode surface

Notice that one important advantage of d.c. guns is the small output energy spread, and which is independent of the pulse length, at least if space charge effects are controlled by very high accelerating gradients.

Short photo-emitted current pulses need:

- Corresponding picosecond lasers
- Instantaneous photo emission
- Good quantum efficiencies to remain below thermal effect thresholds.

This Workshop has shown that many laboratories are presently experimenting on high current photocathodes and that encouraging results have already been obtained. Essentially two families of photocathodes are being investigated:

a) Cesiated semiconductors

With this type of photocathode, peak currents above 200 A/cm^2 have been obtained in the picosecond regime. However, in the case of d.c. acceleration, emittances remain to be measured. The main problem comes from the cesium which leads to specific pollution and requires both a very good ultra-high vacuum environment and periodic reconditioning. In fact the photocathode lifetime gets worse as the extracted current and accelerating voltage increase. In this photocathode family one finds Cs_3 Sb (as used at Los Alamos) and As Ga (as used at SLAC and KEK)

b) Micro emitters

It has been already demonstrated that metallic micro emitters can produce 10 kA/cm^2 in the picosecond regime. Here too, emittances need to be measured and Table 2 gives two recent examples of their performance.

In the case of needles, the field emission process is used to lower the potential well and facilitate the electron extraction (photo field emission), so providing a very high quantum efficiency in comparison with the usual photo-emission from metals. Both metallic wires and needles appear to have long lifetime.

Table 2

Performance of micro emitters

	BNL	LAL
Material	Metallic wire	Single metallic needle
Surface density	10^4 A/cm^2	10^{10} A/cm^2
Emitting surface	10^{-4} cm^2	10^{-10} cm^2
Peak current	1 A	1 A
Quantum yield	< 10^{-4}	> 1

The requirement for very high peak currents with good quantum yield will dictate the use of arrays of needles and experiments have started to determine whether the current can increase directly with their number. According to Table 2 the gun requirements of 1 nC, 10 ps, 100 A peak currents can be fulfilled either with a 1 mm^2 metallic wire emitting surface (I ∝ emitting surface) or with an array of more than 100 needles (assuming the total emitted current does not increase exactly linearly with the number of needles).

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Discussion

U. Amaldi, CERN

1) The repetition frequency of the CLIC collisions is 30 times larger than for the SLAC collider. In designing the damping rings we always put as a condition a damping time of the order of 2-3 ms, equal to SLC and 10 times smaller than the one presented by Claudio Pellegrini. In this way we are thinking in terms of about 4 or 5 damping rings using the Chasman-Green lattice and about 100-150 m long each.

2) I want to correct the statement made by Joel le Duff. The longitudinal brilliance of the SLAC design is much larger than for CLIC because the bunch lengths are ~ 50 µm and 300 µm respectively.

N.K. Sherman, Ottawa

Laser brightness and pulse duration are not limitations nor is quantum efficiency, in low-emittance electron guns. This is because laser pulse durations are down to 8 Femto seconds now, and at longer durations are so bright that even with low quantum efficiency the electric field can be collapsed by space charge of emitted electrons. The limitation is really Gauss' law.

Reply

In the lasertron case we expect high power efficiency. This is the ratio between RF power and plug power. A powerful laser with poor efficiency might lower the total efficiency of the device. For a gun we should not worry too much about power efficiency, but much more about beam quality.

J. Seeman, SLAC

Is there any news on high intensity, low emittance positron sources other than damping rings?

Reply

We have not been considering particular methods of producing high brightness positron beams. I still believe that for the moment conventional methods of positron production are still right. The positrons need to be produced at quite high energy and then damped. However, one must try to find out in the case of high repetition rate if the target can handle the input electron energy.