ADAPTION OF AN RF-GUN FROM THERMIONIC TO PHOTO CATHODE

Sverker Werin, Magnus Berglund, Mathias Brandin and Tue N Hansen,
MAX-lab, Box 118, S-221 00 Lund, Sweden

Abstract

The thermionic RF-gun operating at the injector at MAX-lab is being adapted to a photo cathode. A 5 ns laser system will produce pulses suitable for the new 100 MHz RF system of the storage rings and allow for a reduced emittance and beam loading.

INTRODUCTION

The current electron source for the injector at MAX-lab is a thermionic RF-gun. This gun produces a 100 ns long pulse with a significant beamloading. The current RF-system of the MAX II storage ring operates at 500 MHz, but is beeing replaced by a 100 MHz system, which also will be the frequency of the new MAX III storage ring. To increase the efficiency and control of the injection we intend to go to “one bucket” injection. In a 100 MHz system the need thus is only “a few” ns pulse. Another important point is to build experience with photo cathode installations and lasers.

To allow for “few bucket” operation and emittance reduction the gun will be adapted for operation with a ns laser system. The system is a 3rd harmonic injection seeded Nd:YAG laser. The thermionic BaO cathode already in use will be used at a temperature just below thermal emission where a quantum efficiency of around $5*10^{-5}$ is expected.

OVERVIEW

The first step of the injector system at MAX-lab has been in operation since a year at 110 MeV. Currently the full system is under commissioning for 500 MeV. The gun in the first step is almost identical to the second gun used in the full system. The layout was already from the beginning prepared for a future photo cathode and the drive laser beam (see fig. 1)

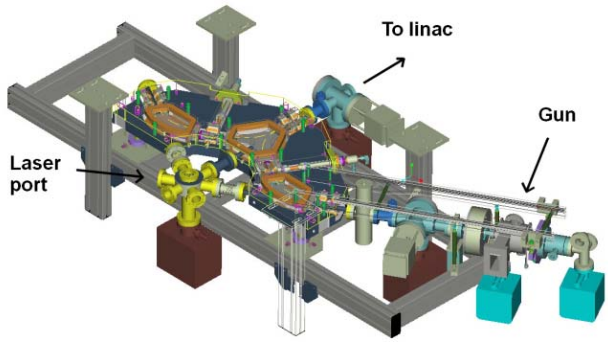

Figure 1. The RF-gun and energy filter with port for laser beam.

The RF-gun [1] gives around 2 MeV of acceleration in a ½+½+1 cell structure powered from a 5 MW 3 GHz klystron. At present the gun is operated with a BaO cathode at around 900 °C producing an injection current of around 100 mA after the first linac.

Cathode choice

The cathode will not be replaced when run as a photo cathode. The reason is that the BaO material is a good enough electron emitter at just below thermal emission (~700 C) to fulfil the injection requirements. The main problem will instead lie in a fairly high dark current. We don’t foresee this to be of significance in this application. Another aspect is that for routine daily injections a laser system might show up not to be 100% reliable. In such cases the temperature of the cathode can easily be increased and the whole set-up be operated as a thermionic system again with loss of the “one bunch” injection.

The quantum efficiency of the system is expected to be around $5*10^{-5}$ at 355 nm. [2-4]. By using 266 nm instead, the quantum efficiency would rise by roughly a factor of 4, but the number of laser photons drops by roughly the same number which makes the two wavelengths comparable. A laser operating at 355 nm is believed to be more stable than at 266 nm, which finalised the choice.

LASER SYSTEM

The laser system is a commercial Nd:YAG system from New Wave (Tempest IS-10) (table 1).

Table 1. Laser performance (design)

Wavelength	355 nm
Pulse length	<5 ns
Rep rate	10 Hz
Energy/ pulse	40 mJ (@355 nm)
Jitter	<0.5 ns

Despite the bunch length being a few ns the gun produces its “useful” electrons in a 10-20 ps window during each 3 GHz cycle. Thus it is important to have a uniform pulse on a 10 ps scale. This is ensured by injection seeding of the laser.

The laser will be placed outside of the linac cave, available even at operation. (fig 2). A safety issue here is that the electron beam at the gun is at 190 cm height, which is not a good choice for transporting a laser beam.

The beam is transported in air, reflecting off mirrors.

A down focusing telescope employing two lenses (f= -300mm , f=+500mm) can be used to image the laser beam on the cathode. Alternatively more simply the laser crystal rod end can be imaged onto the photocathode using a plano-conex lens (f=+1500mm). A remotely controlled stepper motor driven mirror directs the beam into the gun and can be used to correct for e.g. drift in the laser beam pointing. The telescope is shown in Figure 3 with the focused energy distribution as simulated by OSLO [5] displayed in Figure 4. The minimum laser spot diameter is seen to be ~0.1mm FWHM.

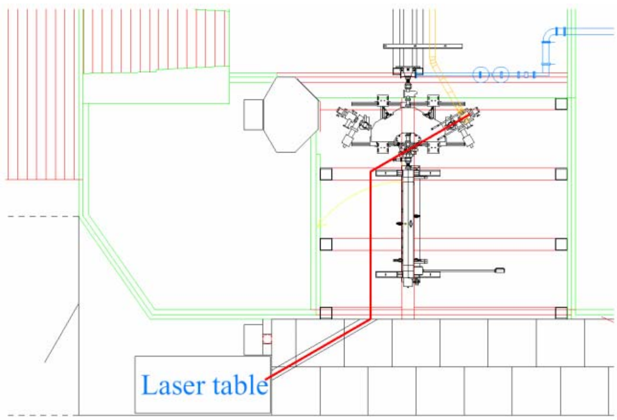

Figure 2. Laser lab location.

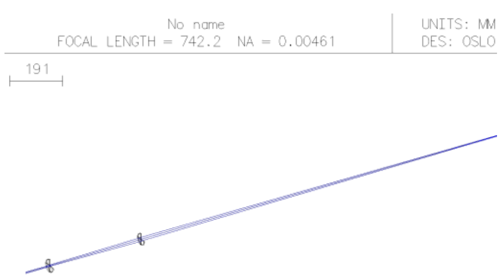

Figure 3. The optics of the telescope.

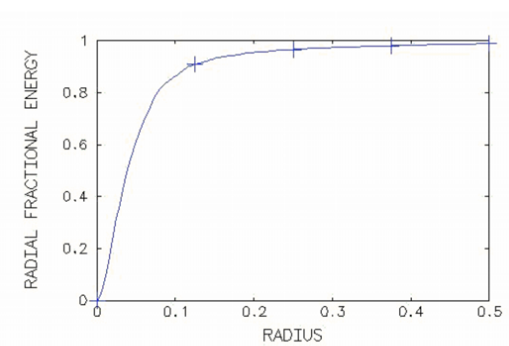

Figure 4. Focusing properties of the laser beam on the cathode surface.

EXPECTED PERFORMANCE

Today the extracted pulse length from the gun is on the order of 100 ns but electrons are active causing beam loading over a longer time. By using a 5 ns pulse from the laser the beam loading in the gun should be reduced by 95% and in principle not important. It will be possible to extract more current from the gun with the laser emission. The limit will now be almost entirely defined by space charge effects.

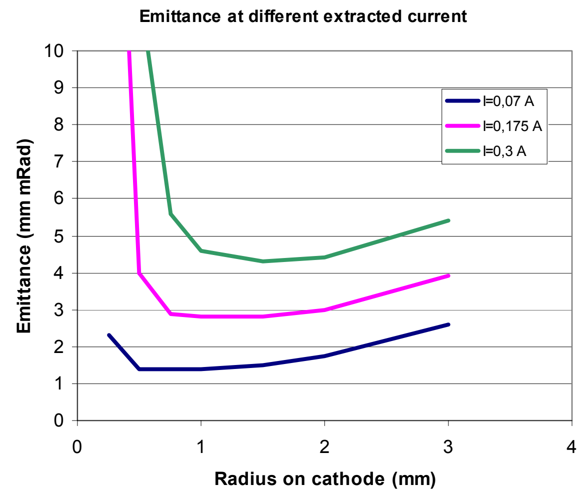

Figure 5. Emittance as a function of radius of the laser spot on the cathode for different extracted currents.

The gun will not be able to produce a large current at acceptable emittances and this is due to two main factors:

1. The accelerating fields in the gun are not very high close to the cathode, and thus the acceleration over the first cm so low that space charge effects will be severe.
2. By operating with long macro pulses (>> RF-period) which is the case both in thermionic and ns-laser pulse mode it is not possible to choose the optimum RF-phase in the gun. The pulse will thus be heavily compressed longitudinally in the gun producing strong space charge effects.

The emittance of the gun will be reduced both by the reduction of the beam loading but also by the smaller emitting area of the cathode. Depenging of extracted current the emittance will be reduced a factor of 2 (fig 5) with a minimum radius on the cathode of 0.5 mm which is easily achievable with the laser system.

Table 2. Expected maximum cathode performance

#photons	2.1e14 ph/15 ps window
#electrons	1.1e10 electrons (@QE 5e-5)
Q	1.7 nC

SUMMARY

The thermionic RF-gun at MAX-lab will be adapted to operate as a photo RF-gun by using the existing BaO cathode just below the thermal emission limit. A 5 ns laser system at 355 nm will be able to produce a more than suffient number of photons in a pulse which almost remove all concerns on beam loading in the accelerator system.

By this change not only easier operation of the machines will be the result but also the option on bunch-by-bunch injections into the storage rings (which are being refitted with 100 MHz RF systems) and we will build more knowledge on operating laser guns in routine operation.

REFERENCES

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