DESIGN OF A NEW PREINJECTOR FOR THE MAX RECIRCULATOR TO BE USED IN EUROFEL*)

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Abstract

The MAX-lab recirculator injector will be equipped with a new preinjector system. The aim is to reduce the emittance, increase the charge and achieve a proper timing between accelerator and laser systems. All is aimed at the MAX-lab test facility for HG built in collaboration with BESSY in the EUROFEL program. The preinjector system consists of a photo cathode RF-gun with an emittance compensating solenoid. Special issues regard the injection of the new beam into the beam path of the MAX recirculator and the conservation of beam parameters.

INTRODUCTION

A test facility for FEL is currently being built at MAX-lab in a joint project with BESSY. The MAX-lab linac injector will be used for a seeded HGHG FEL in the 3rd harmonic at 88nm.

As a part of the project a new pre injector to reduce the beam emittance and to increase the bunch charge has been designed and is under construction. The design goal has been an accelerated charge of 0.5-1 nC with a normalised emittance of 3 mm mRad.

OVERVIEW OF DESIGN

The design is restricted by the existing injector which is a recirculated linac (fig 1) today operating with a thermionic RF gun [1]. The solution adopted in the new design is a 3 GHz RF gun with an emittance compensating solenoid. A 10 ps laser system synchronised to the linac RF (and the seed laser for the FEL) will generate the electrons. The bunch will be compressed in the passage of the recirculation system [2] from 10 ps to the fs range.

The main design constraint turned out to be to allow for the recirculated beam in the system. As the beam passes twice through the linacs it is not possible to place the electron gun on axis. Further the available space is tighly restricted both in the longitudinal direction and by the beam axis being very close to the ceiling.

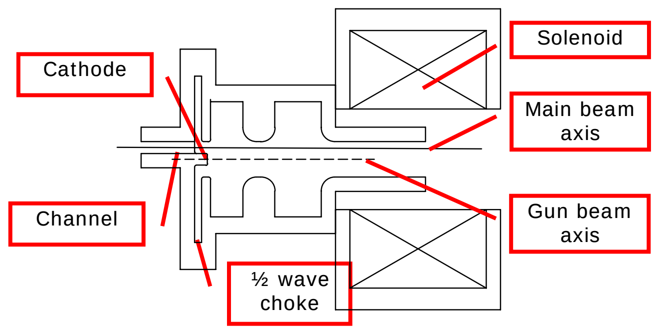

Figure 2: Drawing of the gun and compact solenoid assembly.

THE GUN GEOMETRY

The gun (fig 2) is based on the LCLS gun [3] adapted to European 3 GHz and changed to allow a beam channel close to the cathode. To minimize the influences by this additional channel close to the high field region a ½ wavelength choke has been introduced. This choke is circular symmetric.

The main 2D-design of the gun has been done in SUPERFISH [4] and limited resolution 3D-calculations have been performed in MULTIPHYSICS. Out of experience [1] SUPERFISH calculations are very accurate. As the final gun is not fully axial symmetric due

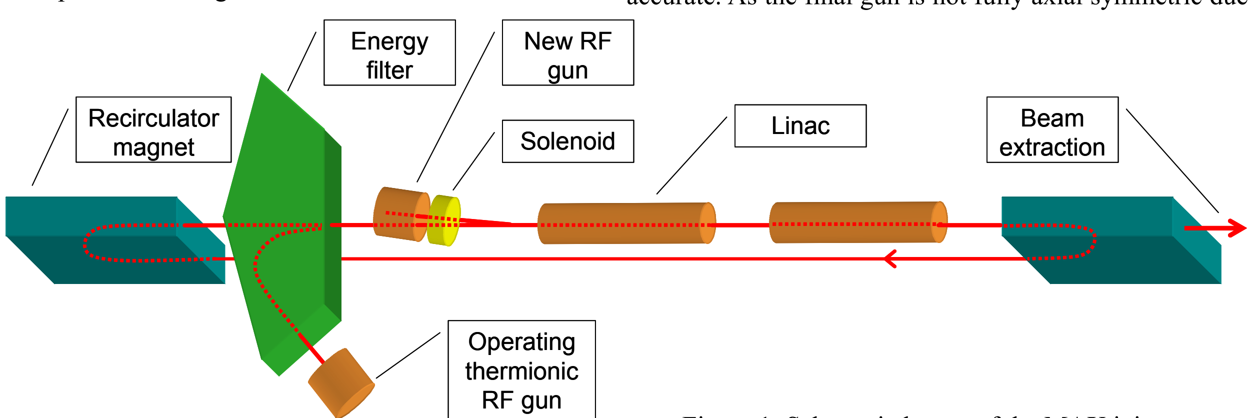

Figure 1: Schematic layout of the MAX injector.

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to the waveguide coupling hole, the pumping hole and the recrculated beam channel 3D calculations were necessary (fig 3a&b). These do not fully agree with the 2D calculations, mainly due to limited computer power, but are accurate enough to study non axial symmetry deviations.

Table 1: Gun specifications (SUPERFISH, without waveguides and beam channel)

Q value	13900
Shunt impedance =	44 MOhm/m
Energy	3.7 MeV (kinetic)
Power consumtption	3.9 MW
Max field strength on surface	121 MV/m

The recirculated beam channel does not influence the fields in the gun ½-cell significantly. The choke entrance close to the cathode surface gives an increased surface field strength though, and will most likely be the limiting factor for the excitation of the structure.

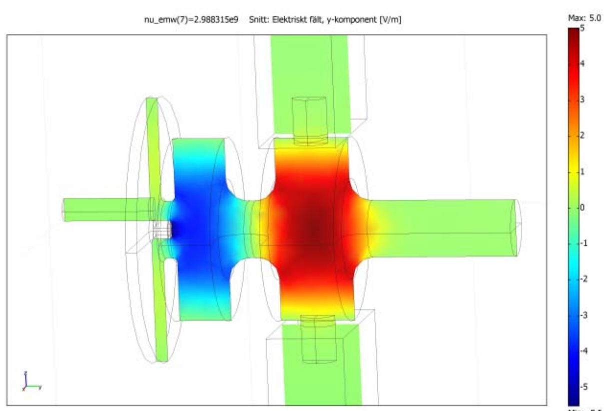

Figure 3a: Distribution of E-field component along the gun axis.

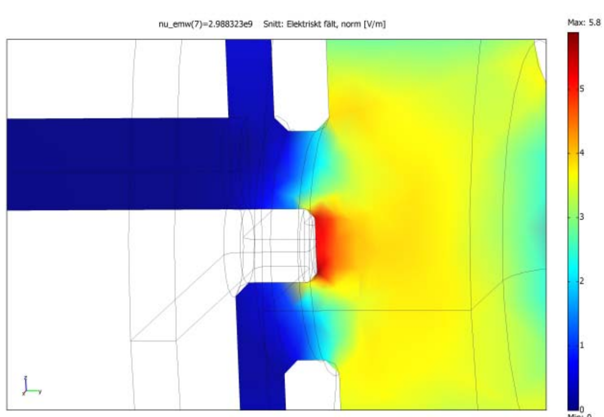

Figure 3b: Total field distribution at the cathode, choke entrance and additional beam channel.

The structure has a sensitivity for frequency which will be adjusted by a couple of thin wall positions which can be deformed and by a change in water temperature. This is not assumed to be a large problem. More problematic is the field balance between the ½-cell and the main cell. This balance can be changed by the deformable walls a/o changes in the depth of the choke (before brazing).

GUN OPTICS

The emittance compensation scheme adopted is similar to the LCLS [3]. Due to space limitations the solenoid compensation magnet will be very compact.

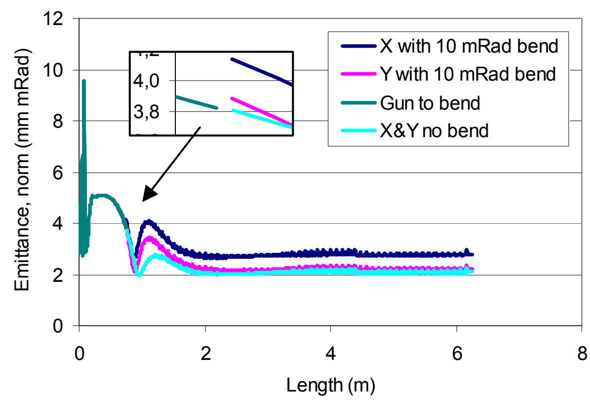

Figure 4: Emittance (normalised) (1 nC, 3.7 MeV, 10ps). Bending magnet (10mR) at 0.75 m and linac from 1m.

The beam from the electron gun is bent 10 mRad to get on the linac axis. This will increase the horizontal emittance slightly. Not only a direct increase in emittance is seen but the emittance compensation is also disturbed. Thus a final horizontal emittance increase of almost 50% is observed.

Simulation of the effect can not be done in ASTRA [5] is it does not treat bending elements. Thus the simulation is interrupted and swapped to *elegant* [6] and then moved back to ASTRA. By running *elegant* with only a drift section one can see that the program swap and lack of space charge effects in *elegant* are negligible at this location. Results of the tracking ar shown in fig 4 and 5.

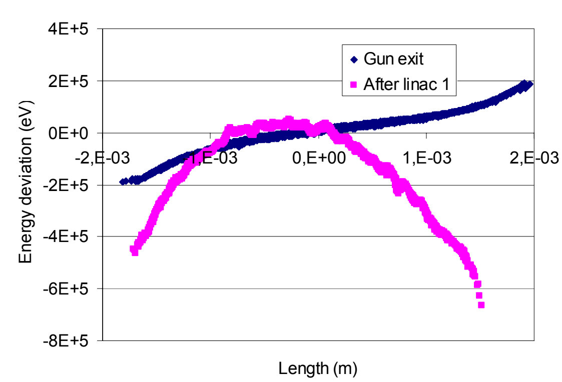

Figure 5: Energy distribution along the bunch (1 nC, 10ps) at the gun exit (4.2 MeV, total) and after linac 1 (108 MeV, total).

SOLENOID AND EMITTANCE COMPENSATION

To fit an emittance compensating solenoid (fig 2&6) onto the MAX injector a very compact magnet is necessary as the beam position is close to the ceiling. By allowing 70 mm flanges on the gun the solenoid aperture can be kept fairly small. The wiring of the solenoid needs to be water cooled.

No bucking coil to remove stray fields at the cathode surface are foreseen. The emittance increase due to such fields is negligible according to ASTRA simulations.

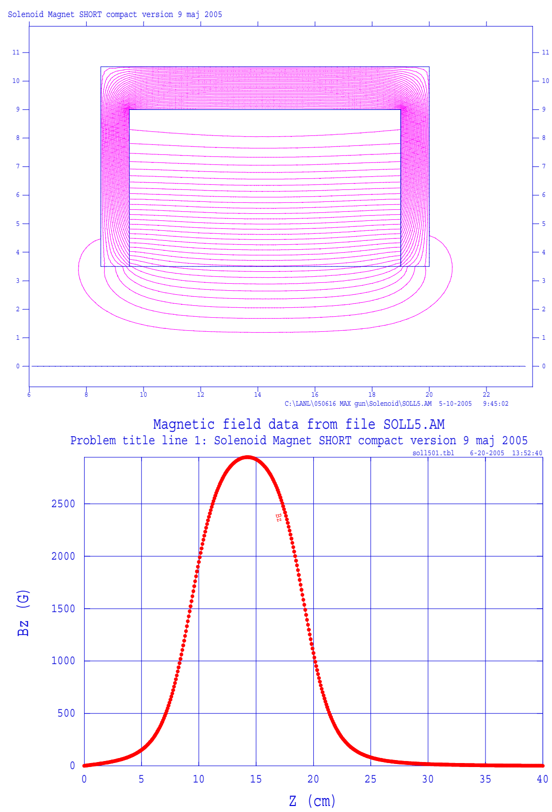

Figure 6: Solenoid geometry and field distribution.

LASER SYSTEM

A combined laser system for the gun and the seeding of the HG-FEL has recently been sent out with an invitation to tender. The solution is up to the supplier while the basic thought is a centrally located oscillator locked to the accelerator RF-system and an optical distribution to the amplifiers.

RF SYSTEM

To avoid having a separate klystron and modulator only for RF guns and to allow multiple guns on the MAX lab injector, the waveguide needs to be modified as following:

Through a 10 dB sidewall direct coupler, placed after the linac 1 SLED cavity, we will get the microwave power for the guns system.

To allow microwave power for two guns, we will use outputs of a waveguide Magic Tee and before this two phase shifters to adjust phases and amplitude.

The SLED pulse is rather short (~0.5 us) and thus the coupling of the gun will have to be >4, dependent of the final unloaded Q value.

SUMMARY

This gun design fulfils the goals on emittance and charge. The problems of space and recirculated beam are solvable, though an effect of the performance can be seen. The gun structure is sensitive especially in field balance between the two cells and only the final brazed gun will show if the desired values can be reached. Further rather high field levels will be present and also here only the final fully conditioned structure will show if these levels can be reached.

Today (June 2006) the gun structure is machined and under low power RF tests. The recirculator is being rebuilt to give space for the new gun and the waveguide system to allow additional structures receiving higher powers.

Further simulations of the bunch compression and FEL process have also been performed [7]. The optical klystron is designed and under production [8].

REFERENCES

[1] B. Anderberg, Å. Anderson, M. Demirkan, M. Eriksson, L. Malmgren and S. Werin, The design of a 3 GHz thermionic RF-gun and energy filter for MAX-lab, Nucl. Instr. And Meth. In Phys. Res. A 491 (2002) 307

[2] S.Werin et al., Commissioning of the 500 MeV Injector for MAX-lab, EPAC 2004

[3] R. Boyce, D.H. Dowell, J. Hodgson, J.F. Schmerge, N. Yu, Design Considerations for the LCLS RF Gun, LCLS TN 04-4 (2004)

[4] K. Halbach and R. F. Holsinger, "SUPERFISH - A Computer Program for Evaluation of RF Cavities with Cylindrical Symmetry", Particle Accelerators 7 (1976) 213-222 (http://laacg1.lanl.gov/laacg/services/download_sf.phtml)

[5] K. Flöttman "ASTRA User Manual", September 18, 2000, www.desy.de/~mpyflo

[6] M. Borland, "elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation" Advanced Photon Source LS-287, September 2000.

[7] S. Thorin et al., Simulations for the FEL test facility at MAX-lab within EUROFEL, These proceedings, EPAC 06, (2006)

[8] J. Bahrdt et al., Undulators for a seeded HGHG-FEL at MAX-lab, these proceedings, EPAC 06 (2006)