A COMBINED INJECTOR AND FEL FACILITY AT MAX-LAB

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Abstract

A proposed concept for an injector system that will replace the ageing 100 MeV racetrack microtron at MAX-lab is presented. The injector will be able to inject both into the 550 MeV MAX-I [1] and the 1.5 GeV MAX-I [2] electron storage rings. The injector system will also be used to feed two free electron lasers (FEL), of which one is a single pass IR-FEL and the other is a ring-based UV-FEL. The injector will consist of a 50 MeV linac with a thermionic electron gun and two electron storage rings stacked on top of each other. The two electron storage rings will use identical magnets but their vacuum systems will differ. The lower ring, which is a 600 MeV booster, will be cycled at 10 Hz and it has a thin walled conduction limited vacuum system. The upper ring, which is a 600 MeV storage ring for the UV-FEL, will have thicker walls and also a better vacuum to reach sufficiently long beam lifetime.

1 INTRODUCTION

The present injection system for the MAX I ring consists of a 100 MeV racetrack microtron. Injection takes thus place at 100 MeV and the MAX I ring is after stacking ramped to 500 MeV. The beam life-time in MAX I is some 3-5 h, so a refill is needed each 4th hour. The MAX II ring is injected from the MAX I ring at 500 MeV. The beam lifetime in MAX II is considerably longer, so one injection per day suffices.

The main reason for beam downtime at MAX-lab is due to malfunctioning of the racetrack microtron, which is the oldest part of the system. The correction magnets are radiation-damaged and the vacuum system leaks from time to time. The microtron is kept alive but for how long is not known. Since both rings depend on this microtron a replacement of this item is most important. The cost of a 600 MeV booster synchrotron will not exceed the cost of replacing the 100 MeV microtron and will offer substantial advantages:

- The injection into the MAX II ring can then be de-coupled from the MAX I ring. It will thus be possible to inject directly into the MAX II ring and there is no need to use the MAX I ring as an injector for MAX II.
- The injection into the MAX I ring can take place at the full energy of MAX I. The injection into MAX I will then be simplified and the beam quality in MAX I in terms of stability and mean current can be increased.
- The energy range for nuclear physics in the MAX I ring can be increased.
- A 600 MeV storage ring, with the same lattice as the booster and placed on top of the booster will give the possibility to operate a ring-based UV FEL and this ring can then also be used as a light source for UV beam-lines.
- The pre-injector linac can be used as an electron source for IR FEL.

2 LINAC AND ELECTRON GUN

A thermionic 100 keV electron gun can provide several hundreds of mAs for the linac. A 500 MHz prebuncher will be used to provide the proper timestructure. An additional 3 GHz buncher will be used to further compress the electron beam. A 3 m long 3 GHz accelerator structure will provide 50 MeV. A 35 MW klystron will feed the linac with RF power. This klystron power will then be sufficient for 200 mA at 50 MeV.

The linac pulse length will differ for the the two different operation modes of the linac. When injecting into MAX I and MAX II the linac will fill the booster in one single turn and a pulse length of only 100 ns is required. For the operation of the IR FEL the pulses should be as long as possible, 10 μs or more. The pulse former net feeding the 3GHz klystron should hence be capable of delivering pulses exceeding 10 μs.

3 BOOSTER

A simple combined function four-period structure will be used. The quadrupoles are focusing in the horizontal direction. The dipole magnets have a gradient for vertical focusing. Sextupole components are included in the quadrupole and dipole magnets to provide a positive chromaticity. The lattice parameters are seen below in table 1. The magnet lattice is shown below in Fig 1 and the betatron functions are shown in Fig.2.

The linac beam is injected via a Lambertson injection septum placed close to the closed orbit and a fast kicker kicks the beam onto the closed orbit. This fast kicker is then switched off after one turn in the booster.

For the acceleration a 500 MHz system is used. The klystron power is quite modest, some 5 kW, so a TV tube in an in-house tube wagon is sufficient. A simple pillbox cavity (6 MΩ) will be installed.

Max energy	600 MeV
Injection energy	50 MeV
Circulating current	40 mA
Circumference	30 m
Straight section length	2.34 m
Mom comp factor	0.045
Nat hor emittance	31 nmrad
Quadrupoles	Lengths: 0.25, 0.4 m K:3.998 Bore radius: 2 cm
Dipoles	Length:1.3333 m n:1.8836 half-gap: 1 cm
Hor admittance	26 mm mrad
Vertical admittance	5 mm mrad
Momentum acceptance	1%
Rep rate	10 Hz

Table 1. Parameters of the 600 MeV booster .

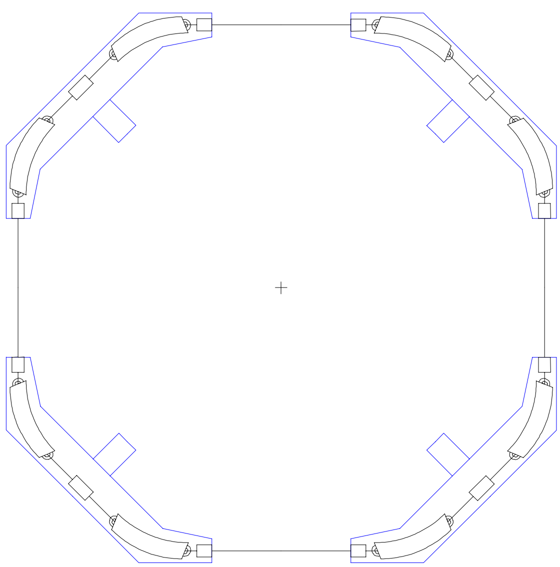

Fig.1. Magnetic lattice

All septa are of the pulsed Lambertson type. At injection into the storage ring above the booster, at extraction from the booster to MAX I and at injection into MAX II we have a parallel displacement of the electron beam. Two septa connected in series are then used for this purpose.

A similar extraction system to that used in MAX I will be used. It consists of two (or one) slow bumper magnets plus a fast extraction kicker. The kicker power supply can be switched to either of the two extraction kickers. The extraction kicker for MAX I injection can be reversed to kick into the septum magnet for injection into the upper storage ring.

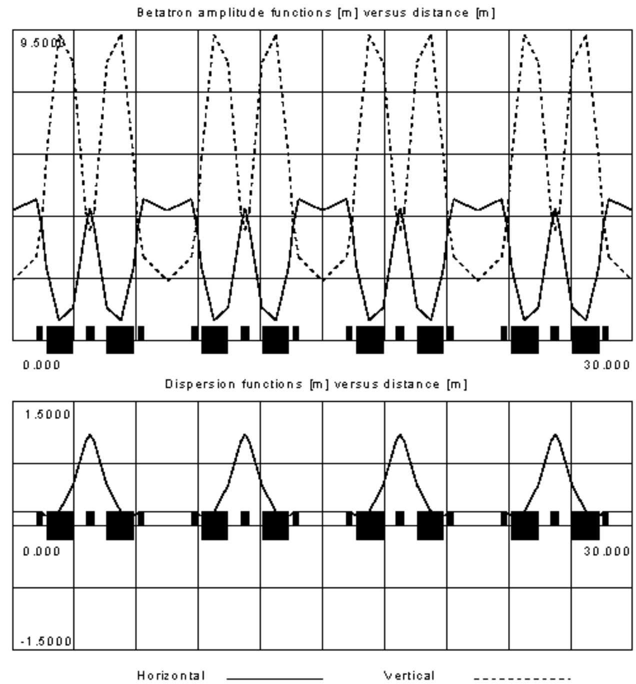

Fig.2. Betatron function

The vacuum system is conductance limited due to the small vacuum tube cross-section. A stainless steel system pumped by ion pumps will suffice to get the desired pressure.

All magnets within one cell will be placed on a common girder a la MAX II. Three legs will support the girder, one under each of the dipole magnets, which represent the main load. A third pillar is placed at the middle of the girder.

4 STORAGE RING

A storage ring will be placed on top of the booster. This storage ring has an identical lattice and is injected from the booster. The main lattice parameters are thus given in Table 1 above and parameters specific for the storage ring are given in Table 2. At the storage ring it will be possible to install a ring based FEL and also insertion devices and beamlines similar to the ones at MAX II, that no longer has vacant straight sections.

Vrf	0.21 MV
Half bucket height	1%
Natural energy spread	$0.4*10^{-3}$
Natural bunch length	0.75 cm
Touschek lifetime	0.27 Ah @ 10% coupling
Vac lifetime	8 h @ 1 nTorr CO
Beam size in SS	$0.35*0.07$ mm^2

Table 2. Parameters of the 600 MeV Storage ring

5 FEL

The proposed injector opens up the possibility to install two different FEL facilities at MAX-lab. One IR-FEL facility having the linac as an electron source and one UV-FEL facility having the 600 MeV storage ring as electron source. The parameters of the FEL facilities are given in Table 3.

	IR-FEL	UV- FEL
Undulator period	0.05 m / 0.10 m	0.04 m
Length	3 m	2 m
Type	planar	helical
K_{max}	3.0 / 2.75	3.0
Cavity length	7.2 m	7.2 / 15 m
e- energy	25-50 MeV	350-600 MeV
Wavelength	5-100 μm	≈150-500 nm
Power	> 100 MW (peak)	≈ 1 W (mean)

Table 3. Parameters of the FEL facilities.

5.1 IR-FEL

The IR-FEL system will use two undulators to cover a range from 5 μm up to 100 μm providing peak power in the 100 MW range and possibilities for sub ps pulses. The two undulators will be approximately 3m long and have 30 and 60 periods .The FEL will be fully synchronised to the storage rings at MAX-lab opening up the possibilities for pump-probe experiments.

The FEL can be placed in the basement directly below the LINAC and booster ring. This is the old "pump room" which is mainly unused today. The IR-beam from the FEL is easily transported over fairly long distances, in a nitrogen filled tube, which gives a large flexibility in the placement of the user laboratories.

9.1 UV-FEL

The storage ring on top of the proposed 600 MeV injector Booster for MAX-lab will be able to house a Storage Ring Free Electron Laser (SR-FEL) capable to lase down below 200 nm. Mean output powers around 1 W can be expected and a gain above 20%.

A 2 m helical undulator will be placed in one of the straight sections of the ring. Two optical cavities using multi-layer mirrors will form the 7.5 or 15 m long optical cavity. Special efforts will be made to control the deterioration of the mirrors due to strong radiation. The laser will have sufficient gain to overcome losses in the mirrors. The actual parameters can be tuned to make full use of the power in the electron beam, the undulator length and the mirror qualities.

The concept should follow in many of the steps the EU-collaboration: "Development of a combined Synchrotron radiation and VUV free-electron laser facility" which MAX-lab plays part of together with ELETTRA (Trieste), ENEA (Frascati), CEA (Paris), DELTA (Dortmund) and CLRC (Warrington)[3].

REFERENCES

[1] M. Eriksson, Nucl. Instr. And Meth. 196 (1982) 331.

[2] Å. Andersson, M. Eriksson, L.-J. Lindgren, P. Röjsel and S. Werin, Nucl. Instr. And Meth. A 343 (1994) 644.

[3] Development of a combined synchrotron radiation and VUV Free-Electron laser facility, EC contract ERB FMGE-CT98-0102