DESIGN OF THE MAX IV RING INJECTOR AND SPF/FEL DRIVER

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Abstract

The MAX IV linac will be used both for injection and top up into two storage rings, and as a high brightness injector for a Short Pulse Facility (SPF) and an FEL (in phase 2) [1]. Compression is done in two double achromats with positive R56. The natural second order momentum compaction, T566, from the achromats is used together with weak sextupoles to linearise longitudinal phase space, leaving no need for a linearising harmonic cavity. The design of the linac focuses on flexibility, simplicity and stability, while keeping the costs low. The accelerator structures have been ordered, as well as modulator/klystrons. The linac will be the first accelerator to be assembled and commissioned in the MAX IV project, starting mid 2012.

MAX IV

The MAX IV project [2] at MAX-lab has been funded, and construction has started to build two storage rings, a full energy linac and a Short Pulse Facility (SPF). The rings will be operated at 1.5 and 3 GeV. The SPF will be a single pass spontaneous linac lightsource, producing sub-ps x-ray pulses. The injector will be flexible enough to drive both injection and top-up for the storage rings, and produce high brightness pulses for the SPF. The SPF has relaxed demands on emittance (< 10 mm mrad) and demands a bunch length below 100 fs FWHM. Simulation results presented later in this paper show that such pulses are easily obtained with the MAX IV injector. In phase two of the MAX IV project, the injector should also be able to produce low emittance pulses to drive an FEL. Such results have also been produced in simulations.

THE MAX IV INJECTOR

Layout and Optics

The lattice in the main linac is made with few magnets for simplicity and reduction of vibration sensitivity. Matching is done before each bunch compressor, and the beam is focused with one triplet before each injection extraction point. This means that only 6 quads are used through the whole main linac, about 200 m. This restrictive use of quads leads to a simple, stable and cost effective lattice, that is easy to operate and tune, but it can be quite sensitive to miss alignment and transverse wakefields. This will be investigated further.

The beam is kicked out for injection into the rings at 1.5 and 3 GeV. Bunch compression is done in double achromats at 260 MeV and at full energy, 3 GeV. A schematic view of the layout can be seen in Figure 1 and the optics is shown in Figure 2. BC2 is not only used for bunch compression, but also works as a beam distributor for a few beamlines. This is done by letting all electrons pass through the first achromat, and then chose where, in a long transport, to extract the bunch in the second, compressing achromat. This scheme can be seen in Figure 3. In our current plans, only the SPF beamline will be equipped with the second achromat.

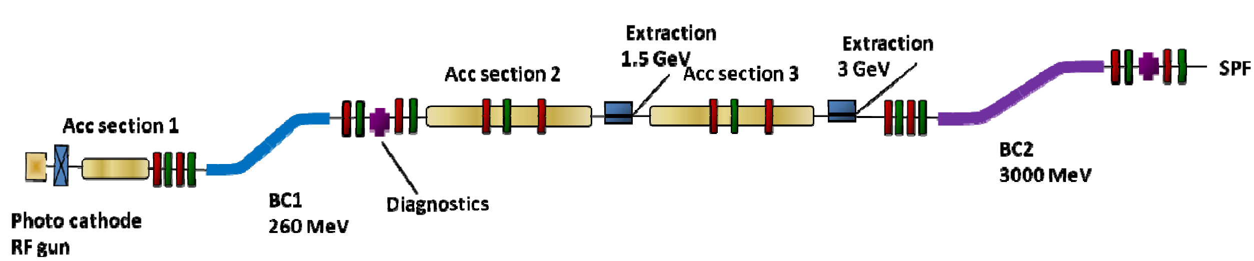

Figure 1: Schematic overall layout of the MAX IV Injector.

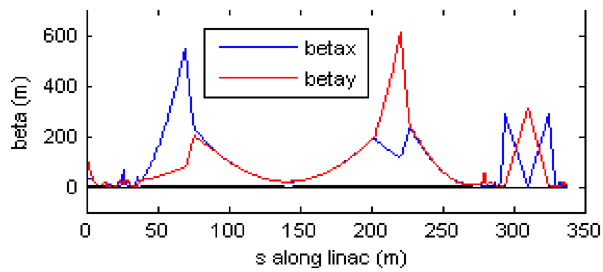

Figure 2: Optics functions in the MAX IV linac

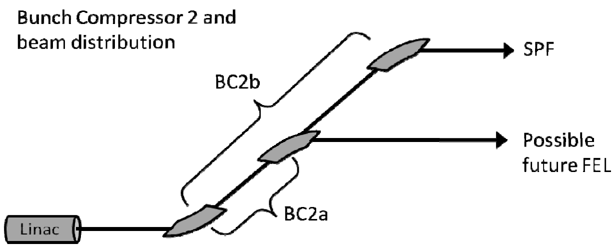

Figure 3: The second bunch compressor also works an a beam distributor for different beamlines.

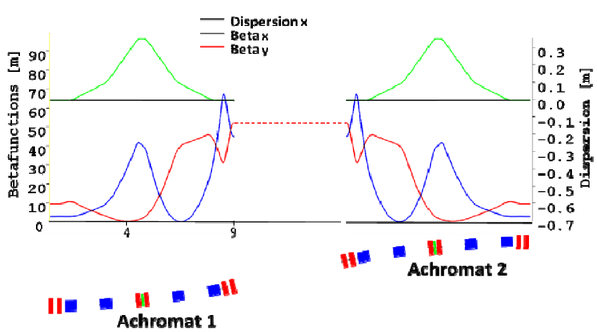

Figure 4: Layoutand optics of BC2

Compression and Linearisation

The magnetic double achromats used as bunch compressors in the MAX IV injector has a positive R56 unlike the commonly used magnetic chicane which has a negative R56. The electrons are therefore accelerated on the falling slope of the RF voltage. Both types of bunch compressors naturally have a positive T566. The MAX IV linac uses this natural non linearity together with a weak sextupole [3] in the centre of the achromat to linearise longitudinal phase space. We can thus choose the optical parameters in the achromat to get optimal linearisation without needing a harmonic linac for this purpose. The linearising bunch compressors are described in more detail in [4]. The magnetic layout and optics of the second bunch compressor can be seen in Figure 4. In Figure 5 simulation results for a fully compressed bunch, optimised for the SPF is shown.

Operation

The MAX IV linac will be used for both top up and injection into two storage rings, as well as a high brightness source for a short pulse facility. Preparations are also being made for a possible future FEL, where only a few upgrades and a potential extension of the accelerator are needed to meet the demanding specifications for an FEL driver [5].

In SPF operation mode the linac will deliver 100 pC pulses at 100 Hz. The electrons are then accelerated off crest for bunch compression and short pulses are delivered at 3 GeV to the SPF beamline.

For injection and top up into the storage rings, the injector will produce triple pulses, i.e. three 100 pC micro pulses in consecutive RF buckets. The triple pulses will be extracted to each ring at 10 Hz for injection and top up. In between each top up period the beam will be delivered to the SPF. Electron parameters for the different operation modes can be seen in Table 1.

The MAX IV control system will be based on TANGO [6], which will also be used for the storage rings. MATLAB and ELEGANT [7] will be integrated into the control system: the former to allow a familiar scripting environment for operators and physicists, and the latter to make a physics simulation code available on-line for the injector. Additional physics codes for specific applications will be added only if ELEGANT does not fulfil the associated criteria.

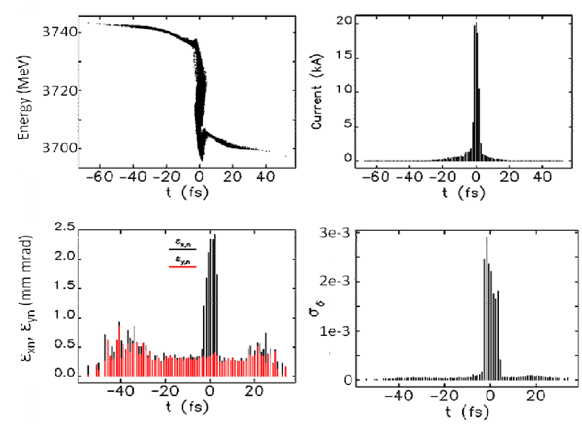

Figure 5: Simulation results for the high peak current optimisation for the SPF.

Table 1 Linac parameters

	1.5/3 GeV inj	SPF mode
Operating energy	1.5/3.0 GeV	3.0
Max energy	3.7 GeV	3.6 GeV
Charge/bunch	0.1 nC	0.1 nC
Bunches/RF pulse	3	1
Rep rate	10 Hz	100 Hz
Micro bunch length (FWHM)	5 ps	30-100 fs
Macro bunch length	660 ps (3 RF buckets)	30-100 fs
Peak current	20 A	3-15 kA
Norm. emittance	< 1 μmrad	< 10 μmrad

Electron Gun

The same photo cathode RF electron gun will be used to drive both ring injection and SPF. It is a 1.6 cell photo cathode gun capable of producing an emittance of 0.4 mm mrad at a charge of 100 pC. The gun will be operated together with a kHz Ti:sapphire laser at 263 nm. The same laser will be used for timing and synchronisation of the whole accelerator.

Accelerator and RF Units

The acceleration is done in 39 warm S-band linac sections together with 15 RF units, each consisting of a 35 MW klystron and a solid state modulator. The Klystrons are operated at the lower power of 25 MW which reduces the operational cost and gives a total redundancy in energy of 0.6 GeV. The RF power will be doubled with a SLED. The repetition rate of the injector is 100 Hz, but top up and injection to the rings will be at 10 Hz. Figure 6 shows a schematic view of the accelerator and RF units.

The main drive line is divided into three sections, where the first one controls the linac units up to BC1, the second one up to 1.5 GeV extraction and the last one up to full energy. The RF phase and power in the linac can be individually tuned for these three sections. The MDL is situated inside the linac tunnel and is attached to the linac in such a way that it will follow the length variations of the linac and keep the phases stable.

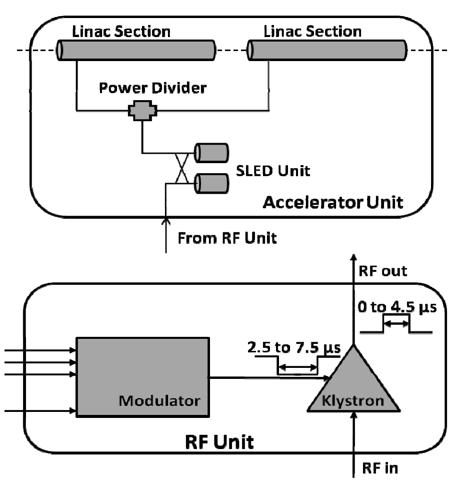

Figure 6: Schematic view of the accelerator and RF units.

Magnets

Basic specifications for the magnet design are the effective lengths, focusing strengths, etc, defined by the lattice design, and the necessary beam stay clear as deduced from the lattice design. Another condition is that we want to have as few types as possible, installing the same types at different locations operating at different excitation levels where possible. The detailed magnetic design has been made using the FEMM [8] and Opera3D [9] codes, with the aim of getting correct effective lengths and minimizing higher order multipoles. We consider mechanical tolerances on the order of +/-0.01mm to be the best practically attainable on individual yoke parts. We are therefore specifying tolerances on the order of +/-0.02-0.03mm for the common pole profile in the assembled state. 2D simulations indicate that this would correspond to error multipoles on the order of 1E-3 of the main component at r=10mm. What impact this have on the performance of the linac will be investigated further.

Status

The RF and accelerator units have been ordered from Scandinova and Research Instruments respectively. The gun laser system is also ordered and will be delivered by KM labs in October this year.

Test stands for both gun and diagnostics, and cooling system are being set up at MAX-lab and should be running before the summer.

Delivery of the first accelerator structure is scheduled for the beginning of 2012. Access to the linac tunnel and installation of accelerator and RF units will start mid 2012.

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