DESIGN CONSIDERATIONS FOR THE COHERENT RADIATOR, FEL, IN THE MAX IV PROPOSAL

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Abstract

The MAX IV proposal is a project for the next Swedish synchrotron radiation source. Currently a design study is produced with funding from the Swedish research council (VR). The first half of the project will be a double storage ring (at 3 and 1.5 GeV respectively) but the second half will be a coherent radiator, FEL, based on the 3 GeV linac injector.

INTRODUCTION

After spending effort on a number of different solutions (such as [1]) a basic design is now being elaborated. This consists of linac system providing a <1 nmRad sliced emittance, <1e-4 sliced energy spread, 2 KA peak current beam at 3 GeV which feeds three cascaded optical klystrons and a radiator undulator to produce radiation down to 1.5-3 nm at GW powers. The system will be seeded by a tunable laser system.

The linac system is foreseen to be normal conducting operating up to 100 Hz.

To assure synchronisation the gun laser and the seed laser share initial laser and amplifier.

BASIC LAYOUT INJECTOR AND LINAC SYSTEM

The basic layout now being sketched consists of a couple of building blocks which mainly show the ability of the system. This system will be adapted and optimised in the current environment as part of the continuing design work.

An injector system, which provides a suitable beam, has already been designed for the LCLS. As this is very much in line with the needs of the MAX IV injector we initially assume a similar system. [2] (table 1)

The linacs will be based on the same linac technology as already present in the new MAX-lab injector [3]. These are 5.2 m long normal conducting 3 GHz structures from ACCEL equipped with SLED cavities. They will be combined into 15 building blocks of one 35 MW klystron, one SLED system and two linac sections, thus providing 100 MeV per linac (20 MV/m). An additional 2 blocks will be used as back-up.

Two bunch compressors are foreseen to reach the necessary peak current. These will be placed at 150 and 500 MeV or slightly higher energy. The compression stages, strength and position, will be designed together with a wakefield and CSR analysis of the accelerator system.

NC v SC system

A normal conducting system is foreseen. A true CW system (SC-system) will be limited by the drive lasers for the PC-gun and the seeding to around 1 KHz. In this mode a linac such as the BESSY soft X-FEL will need a wall power in the order of 5 MW (3 KW @ 2K [4]). By going to semi CW operation the power will be reduced, and so the repetition rate. A NC system as the MAX IV system will be able to operate at 100 Hz needing a wall power of 1.5 MW. The gain by a factor of 10 in repetition rate is difficult to defend while regarding the increase in power demand and the complexity of a SC-system.

An increase of the repetition rate can be achieved by splitting the main laser pulse and generating several synchronised gun (and seed) pulses with 30 ns separation. These FEL pulses can also be chopped to different experimental stations.

Table 1. The parameters of the LCLS injector

Charge	1 nC
Bunch length	2.9 ps
Energy	150 MeV
Energy spread (integrated)	$1*10^{-3}$ RMS
Energy spread (slice)	$5*10^{-5}$ RMS
Emittance (slice)	<= 0.8 umRad

COHERENT RADIATION AND OPTICAL KLYSTRONS

The coherent radiation will be produced in a three stage optical klystron (figure 1). In each step the fifth harmonic will be extracted. The final stage will be an amplifier (“after burner”) to provide the necessary power.

By using an electron beam with a small sliced natural energy spread lower modulating electric fields are required. Each stage will be supplied by electric fields strengths in the GV/m range to achieve adequate bunching.

It is important to match the electron beam optics to the divergence of the radiation. A compact system is thus a necessity especially at the longer wavelengths (the 53 nm stage) as the divergence otherwise kills the field strengths in the following modulator. Long undulators will of the same reason not pay off.

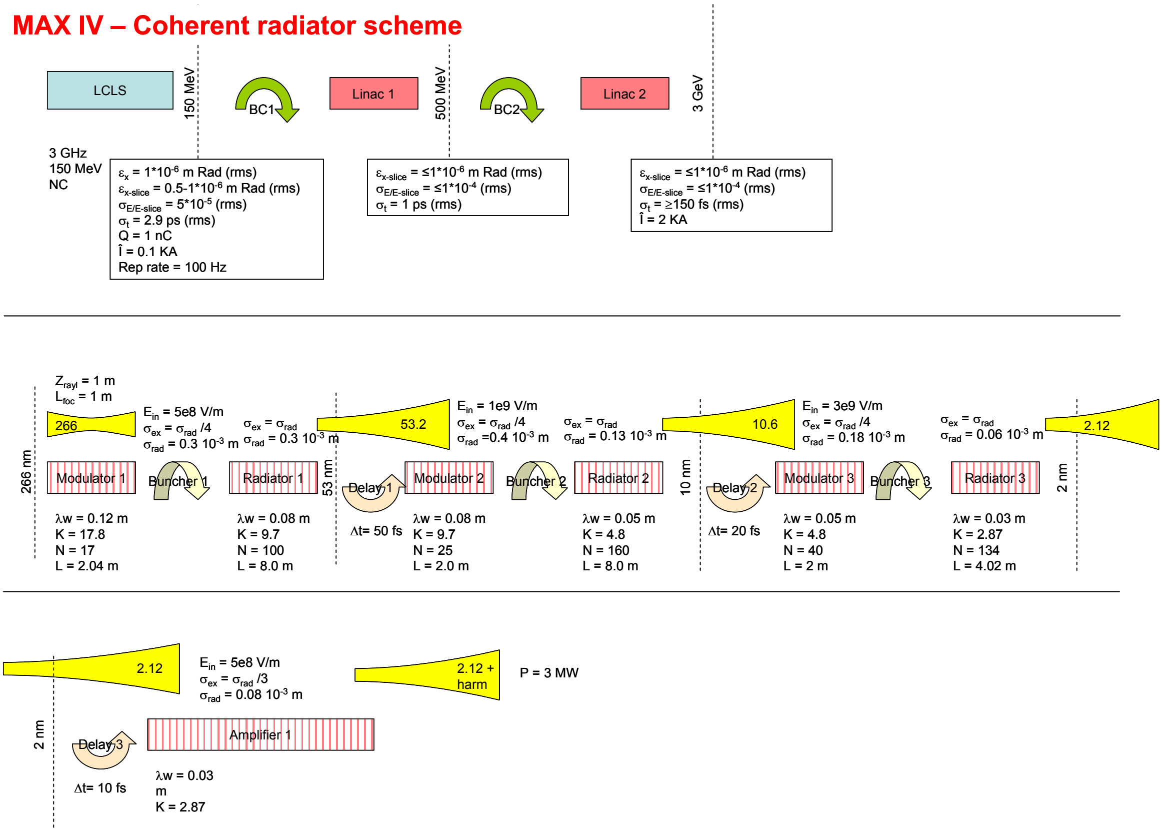


Figure 1. Schematics of the linacs and optical klystrons

The first HG stage can possibly use a bunch of lower energy generated in a second electron gun to allow for less powerful seed lasers, but the basic design only uses the fresh bunch technique.

GUN AND SEED LASER SYSTEM

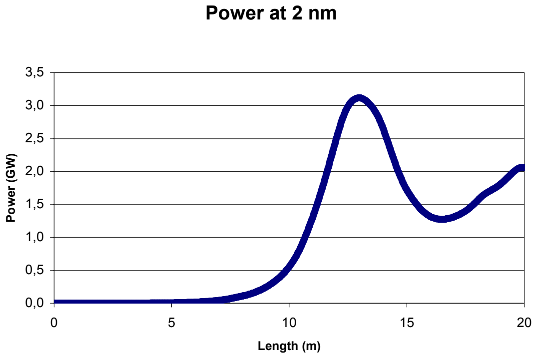
A main Ti:Sa oscillator, synchronised to the RF-clock, will provide the source both for the gun laser pulse and the seed pulse. The gun pulse will be treated in a ps-laser (10ps), made top-hat and amplified thus controlling the charge and spatial distribution of the electron pulse. Another branch will be the FEL seed pulse which will be directed to a Ti:Sa laser to provide the power for HHG in a gas cell where a harmonic of the around the 25th order will be generated. The tunability in the Ti:Sa laser is enough to cover the distance between the harmonics in the HHG process. Thus full tunability in the 30-50 nm range can be achieved. It might turn out to be advantageous to introduce an OPA before the HHG cell to provide easier tuning over a larger range.

PERFORMANCE, CALCULATIONS AND MODELS

The radiation propagation in the cascades has been calculated by using an analytical approach focusing on the retarded potentials of the fields. Thus the full information on source point, divergence and relevant field strengths is achieved. The preliminary results are shown in figure 1.
The amplifier in the system has been simulated in Genesis [5]. The necessary undulator length at 2 nm is around 13 m with powers around 3 GW. (figure 2.)

TEST FACILITY

A test facility is currently being planned at the MAX-laboratory together with BESSY to be utlised within the EUROFEL co-operation (figure 3). It will make use of the 500 MeV linac injector recently put into operation. A first stage of a harmonic generation cascade will be installed and the electron source will be upgraded to a photo cathode RF-gun. Already available in the lab are a Ti:SA laser, space for undulator installations and the electron transport line. The same laser oscillator will feed both the gun and be used as a seed pulse in a similar fashion as depicted for the MAX IV. Initially seed pulses at 260 nm



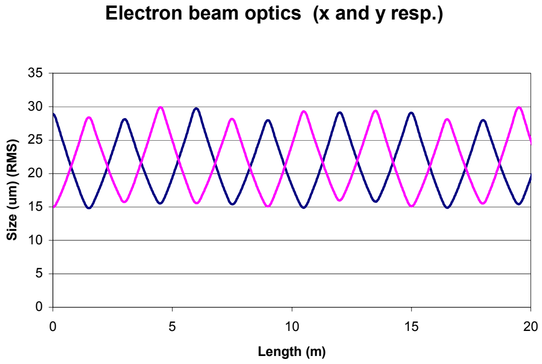


Figure 2. Amplification (top) and electron beam optics (below) in the amplifier.

will be utilised and coherent radiation at the third (90 nm) and fifth (53 nm) harmonic will be extracted.
In the test facility question like: benchmarking, electron beam control and transport, laser synchronisation, laser seeding, cascading etc. will be addressed.

SUMMARY

The design of the MAX IV coherent radiation source is taking form. The source will adopt the techniques of "second generation short wavelength FELs": Seeding, cascading and harmonic generation. A 3 GeV NC electron linac will provide a 100 Hz source which will generate tunable GW power pulses in the range of 2 nm. Basic simulations have been run using Parmela, Genesis and models using true field models.

REFERENCES

[1] M. Eriksson, L.-J. Lindgren, E. Wallen and S. Werin, A cascaded optical klystron on an energy recovery linac – race track microtron ,NIM A 507 (2003) 470
[2] LCLS design report (http://www-ssrl.slac.stanford.edu/lcls/cdr/)
[3] S. Werin et. al. Commissioning of the 500 MeV Injector for MAX-lab, EPAC04, Lucerne 2004
[4] BESSY soft X-FEL design report (http://www.bessy.de/publicRelations/publications/files/TDR_WEB.pdf)
[5] Genesis by Sven Reiche (http://corona.physics.ucla.edu/~reiche/)

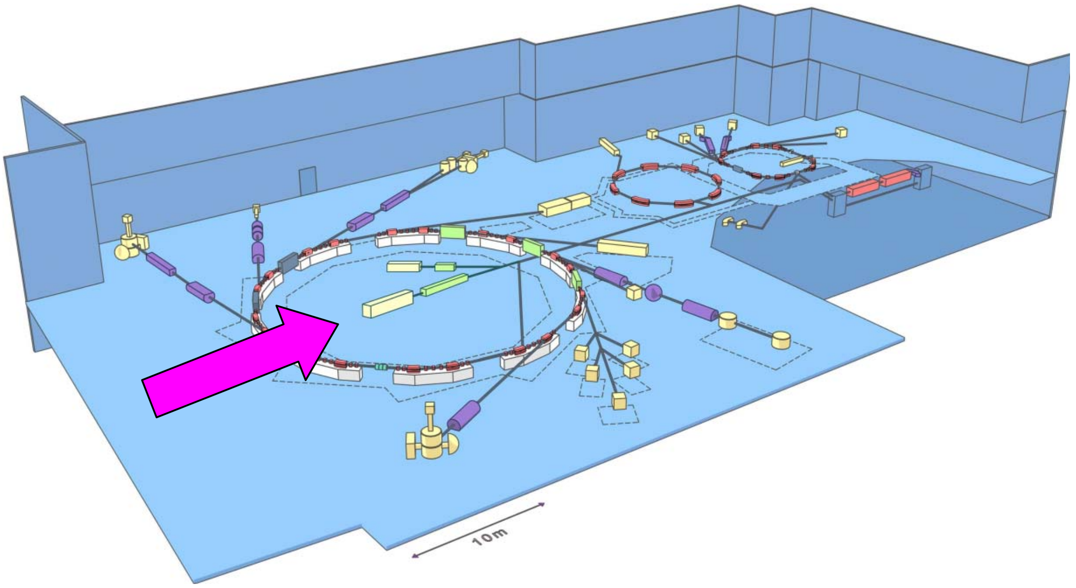


Figure 3. Placement of the test facility inside the MAX II storage ring.