THE NEW MAX IV GUN TEST STAND

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Abstract

The gun test stand from MAX-Lab has been upgraded and moved to a new facility at the MAX IV Laboratory. The new test stand will reuse parts of the equipment from the old test stand but a number of improvements to the setup are be made. In this paper we report on the design of the new gun test stand, research plans in the near future as well as planned and possible future research topics..

INTRODUCTION

MAX IV [1] is a facility for the production of synchrotron radiation. Currently, the initial user operation of the 3 GeV storage ring is commencing after the summer, and comissioning of the short pulse facility (SPF) [2] and small ring are ongoing. Plans for a future soft x-ray free electron laser (SXL) [3] is under consideration. The facility has two pre-injectors, one with a thermionic source and one based on a photocathode. The design and performance of the thermionic pre-injector is in reference [4], and the initial performance from the photocathode pre-injector was presented in reference [5]. The current beam quality for the photocahode pre-injector has been improved and is close to the target for SPF operations at a transverse emittance of 1 mm mrad at 100 pC. The future operation of a FEL requires an emittance less than half of what is currently produced, so further improvements to the photocathode pre-injector is required. The facility is currently moving into user operation mode, and the available experimental time for the pre-injectors are decreasing, so a gun test facility (GTF) is needed to make further improvements possible. At the old Max-Lab facility there was a gun test facility [6], and most of that equipment will be reused in the new gun test facility. The GTF is currently under construction, and in this paper we report on the design and current progress of the GTF, as well as experimental properties and planned experiments.

THE MAX IV FACILITY

Current Facility

The MAX IV facility has two storage rings, one 1.5 GeV and one 3 GeV both for the production of synchrotron radiation. There is also the SPF where short pulses of radiation is produced in vacuum undulators. Both storage rings are operated with full energy injection, and there is a normal conducting S-Band linac [7] with a maximum energy of a bit over 3 GeV that provides electrons, both for ring injections and for the SPF. There are two separate pre-injectors, one based around a thermionic gun and one based on a photocathode gun. The thermionic pre-injector is based on a thermionic electron gun with a BaO cathode, and there is also a chopper system to provide the correct bunch structures for ring injection [8]. The photocathode pre-injector is based on the BNL/SLAC 1.6 cell gun for FERMI@Elettra [9] adapted to 2.9985 GHz with a fine machined, but not polished, copper cathode followed by an emittance compensating solenoid by Radiabeam. The laser system for the photocathode pre-injector is a KM Labs Dragon with cryogenic cooled Ti:Sapphire crystals and the oscillator is at 76.9 MHz, and the pulses are amplified and frequency tripled to a wavelength of 263 nm. More details on the laser system can be found in [10]. Currently pulse stacking is used for creating longer pulses and pulse lengths of 3 and 6 ps FWHM are currently in use at charges between 50 and 200 pC. A new pulse shaper [11] is also being commissioned.

Future Plans

Currently there are ongoing investigations into the feasibility for a SXL at the MAX IV site. It is suggested that this will be a new branch at the end of the current LINAC, and as far as possible the current LINAC and pre-injector should be used as the driver for the SXL. Also, the SPF desires an increase in repetition rate to 100 Hz but the current installed photocathode gun can operate up to about 30 - 40 Hz. A new low-emittance 100 Hz gun is under manufacture to both improve beam quality and enable 100 Hz operation. There is also some ongoing work on a new thermionic gun to improve stability and provide a spare if some issue would arise in the current gun in operation.

The Requirement for a GTF

Due to the start of user operations later in 2017, the available time for experiments with the pre-injectors are decreasing. The requirements for a future FEL also requires improvements to the beam qualities and it is also foreseen that RF conditioning and characterization of some components will be required. Based on this there was a strong need for a gun test facility/RF conditioning facility where experiments on beam quality can be done as well as conditioning and verification of new components. During the last years of operations at the old MAX-Lab facility, there was also a gun test stand in operation. The equipment from this test stand has been preserved, and creates the possibility to create a GTF for a smaller cost.

GUN TEST FACILITY

Overview

The design of gun test facility is largely based on the components from the the old gun test stand. One of the major improvement for the new GTF is a dedicated RF power

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source, which greatly improves the available experimental time and stability. The GTF is constructed around the gun and the SPARC emittance meter [12] but there will also be additional diagnostics like a spectrometer available. Two rooms are available for the GTF, one equipment room and one radiation shielded room. The equipment room is for the klystron/modulator and other related electronic equipment like power supplies and control system. The emittance meter and other accelerator based components is in the shielded room, and a design layout of the GTF can bee seen in Fig.1.

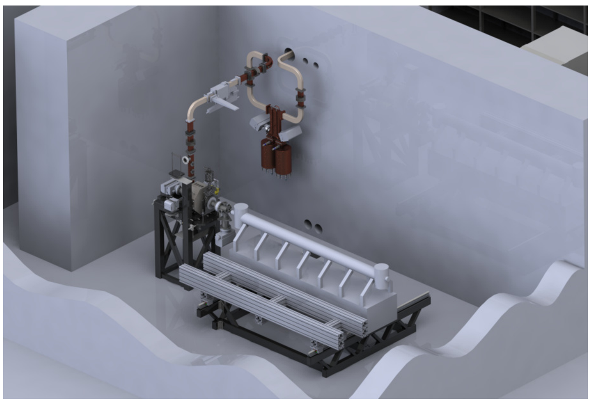

Figure 1: Design overview of the GTF.

In the figure the radiation shielded room is shown with the equipment room behind it. The design of the new GTF was made to be as versatile as possible including a possibility to construct to parallel diagnostic lines. In Fig 1 the base mounts for these two lines can be seen with the inner line occupied by the emittance meter. The outer line is empty in the shown figure but is being prepared for a spectrometer setup. The cradle with both lines can be shifted transversely thus enabling the possibility to switch without moving the gun or reconstruct the diagnostic line.

RF System

The RF system is a 10 MW klystron with a repetition rate of 10 Hz and modulator from Scandinova, the same klystron-modulator combination that is used for the thermionic gun currently in operation. The RF power is then feed into the shielded room by waveguides that connect to a swich, enabling the selection between two different RF destinations. One destination will be the photocathode gun through a SLED cavity, and the other can be used for example for conditioning of structures. These connections can be seen in Fig. 1. The systems are based on 2.9985 GHz and are able to provide RF pulses lengths of between 0.5 and 6 μs depending on requirements.

Laser System

A transport line of about 20 m has been installed between the laser room and the GTF. This transport line is built with relay optics to transport the pulse from the laser table in the laser lab to the laser table in the GTF. There are two available laser systems for experiments in the GTF, the pulse from the operation laser system for the photocathode pre-injector can be split off and transported to the GTF. There is also a possibility to modify the pulse, for example by a pulse stretcher or other setups, before the pulse is transported. This pulse is one of the options for available laser having the same characteristics as in the real pre-injector, or to test new setups and changes to the operational beam. In the laser lab there is also the laser system from the old gun test, also a Ti:Sapphire system with amplifiers and frequency tripling to 263 nm, and the pulse from this system can also be transported to the GTF. There is a laser table in the radiation shielded room where lenses for final focusing will be done as well as a motorized aperture to remotely control the beam size on the cathode. There are also motorized mirrors to control the beam position on the cathode. More details on the laser system can be found in [10].

Accelerator Components

The first setup in the GTF will be based on a duplicate of the gun currently in operation, connected to an emittance compensating solenoid from Scanditronix. For diagnostics this setup will initially be connected to the emittance meter. This setup is currently being constructed, and in Fig. 2 and 3 a view of the setup at the current point is shown.

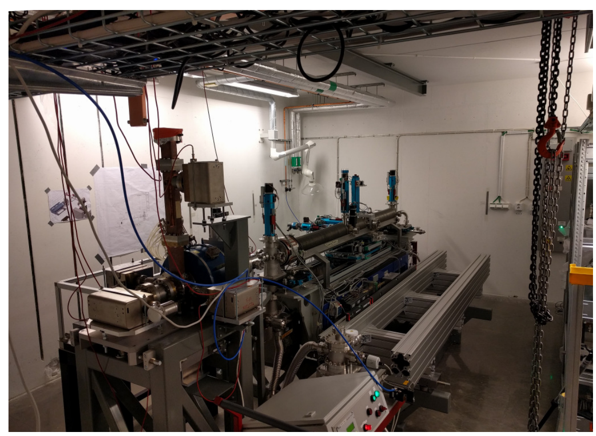

Figure 2: View of the GTF with the gun to the left and emittance meter to the inner left. The second free diagnostic line is on the inner right.

Diagnostics

There are two diagnostic branches in the setup. The emittance meter will be used to measure the transverse emittance evolution in both planes as a function of the longitudinal position along the drift after the gun. The emittance meter was recommissioned in the old gun test stand [13] and no changes are being made to the emittance meter. The spectrometer setup will be used to measure the energy and energy spread out from the gun. Figure 4 shows the layout of the spectrometer setup with dipole magnets, focusing quadrupoles and available screens.

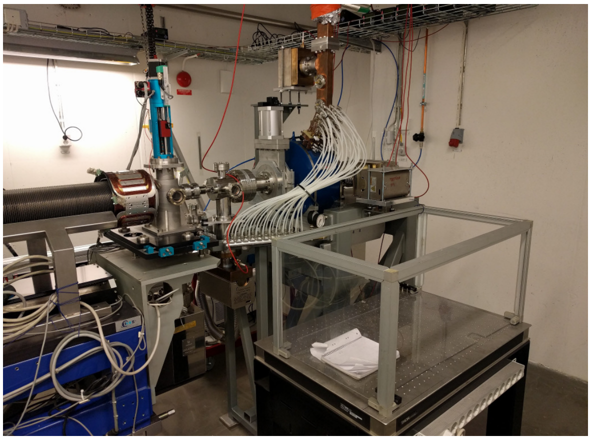

Figure 3: View of the gun, solenoid, start of emittance meter and empty laser table.

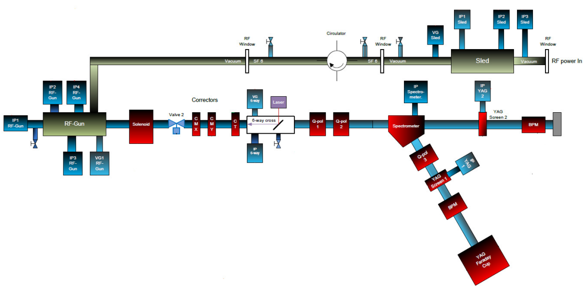

Figure 4: Overview of the spectrometer beamline.

Control System

All components will be connected to a separate instance of the MAX IV control system based on TANGO. There will be a possibility to control phases, solenoid currents, position on the cathode, aperture size, emittance meter motors, screens and so on from the control room in order to maximize the experimental time and minimize the number of access needed.

PLANNED EXPERIMENTS

The plan is to take the GTF into operation during the end of 2017. Initially it will be recommissioned to verify equipment and the new setup. It is foreseen that roughly the same beam qualities will be measured but with an increased stability and availability due to the dedicated RF source and rooms.

After the recommissioning, the first task in the GTF will be to change the cathode. Both the test setup and the operational setup has been operated with a cathode that had fine rotational machining but no polishing. New polished cathodes were prepared to a mirror like quality, but have not yet been installed. The cathode in the test setup will be replaced with one of the new polished cathodes, after cathode cleaning. A recipe based on well established procedures for cleaning (alcohols, ultrasound, etc) are currently being investigated and will be tried for the first cathode to be installed into the GTF. The improvement in quality will be measured using available diagnostics, and the cathode will be conditioned and prepared for movement into the operational setup at a longer shutdown. Once this move is completed, another polished cathode will be installed in the gun test for conditioning, and that cathode will remain in the gun test stand for further development.

There next task will be more detailed experiments on beam quality using the emittance meter. The target is to reach a transverse emittance of 0.4 mm mrad at 100 pC and roughly 6 ps top hat pulse, and that these settings can then be transferred to the operational setup.

FUTURE WORK

A new low-emittance 100 Hz gun is being produced later this year, or beginning of 2018, and once this gun is produced it will be installed in the GTF replacing the current gun. This gun will be then initially commissioned to 10 Hz and the beam quality investigated in order to prepare the future replacement of the current gun in operation for the SPF and LINAC.

Discussions are ongoing about putting a new cathode materials, for example like a plug of magnesium on a copper cathode. This is a possible avenue for future development although no definite time plan has been set.

There are also ideas to create double pulses in the gun to enable the possibility for laser plasma wakefield experiments [14], or two-color FEL operation. A pre-injector setup for both these experimental setups can be investigated in the GTF, and discussions are ongoing on how to realize this.

The versatile setup of the GTF also enabled the possibility for more experiments not foreseen today, and the idea is to be able to invite other labs to do experiments in the GTF if there is an interest for this.

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