EUROFEL-Report-2007-DS4-052

EUROPEAN FEL Design Study

Deliverable N°:	D 4.1
Deliverable Title:	PC-gun, gun laser and seed laser is operational at MAX-lab
Task:	DS-4
Authors:	see next page
Contract N°:	011935

Project funded by the European Community
under the "Structuring the European Research Area" Specific Programme
Research Infrastructures action

D4.1 PC-gun, gun laser and seed laser is operational at MAX-lab

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Abstract

At MAX-lab a test facility for FEL is under construction. The facility is building on the existing accelerator installations: Thermionic gun system, linac, recirculator and transport to which improvements on the RF gun side and a new optical klystron is added.
The combined gun and seed laser system has been installed and put into operation. The RF-gun has been operated with the new gun laser system to provide 7-10 ps electron pulses.

Comments on the project

While the optical klystron has been installed earlier (D4.2) the laser systems have been delayed. This is mainly due to the fact that the original concept of laser system was changed completely. Originally the gun and seed laser system where to use an already existing oscillator and first laser on a beamline at the MAX II storage ring. This was assumed to be both time and money efficient. While starting the project it was soon realised that though money could be saved it would not be in proportion to the additional complexity. As additional funding was made available by the Swedish research council (VR) the decision was made to purchase a complete new system. The call for tender was released, a supplier chosen almost within budget and the delivery has been running during 2007. This has taken additional time, but the result is a laser system which is far more flexible and better adapted to the purpose.

The laser system

The laser system is one combined system for both the electron gun and the seeding purchased as one unit, but placed separately in two laser hutches (fig 1 & 2). The two systems share one common oscillator locked to the 3 GHz RF system and are synchronised to each other by a fibre optical link.
The systems are installed and operated up to specifications. The spectral output from the two systems are given in fig 3 a and b and the pulse width of the gun laser, measured by autocorrelation, in fig 4. The results are summarised in table 1.

Table 1. Basic parameters of the laser system.

	Design requirements	**Achieved**
Gun laser	265 nm	263 nm
	500 µJ	550 µJ
	10 ps	10 ps
Seed laser	266 nm	263 nm
	100 µJ	140 µJ
	< 500 fs	350 fs

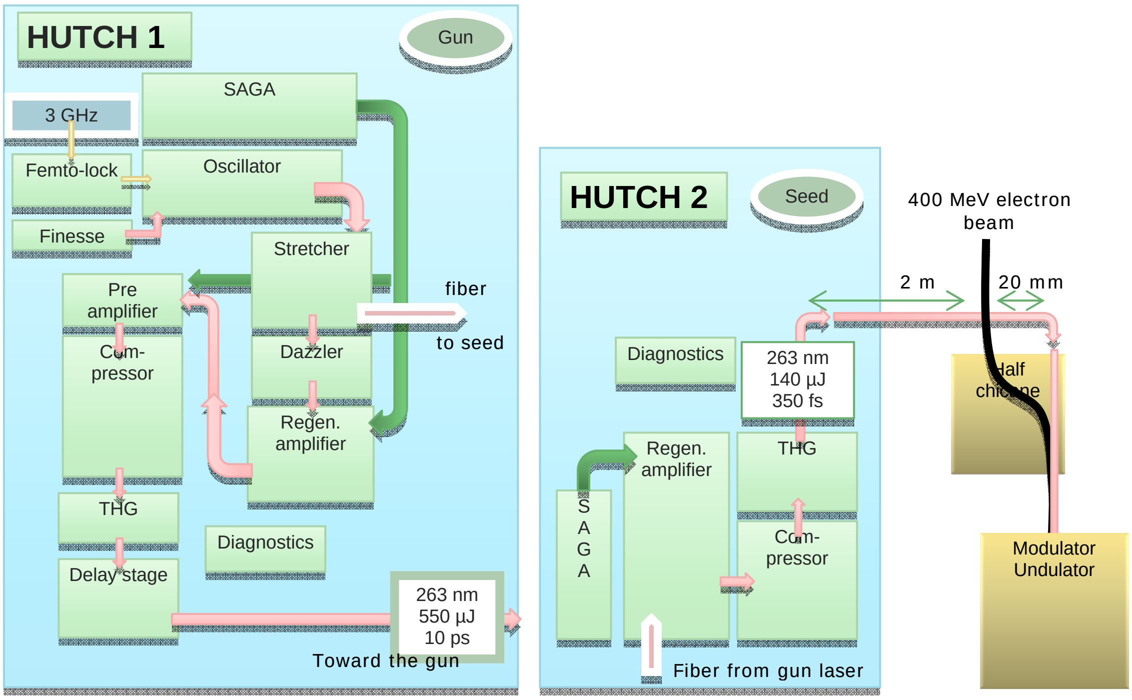

Fig 1. Layout of the gun and seed laser system.

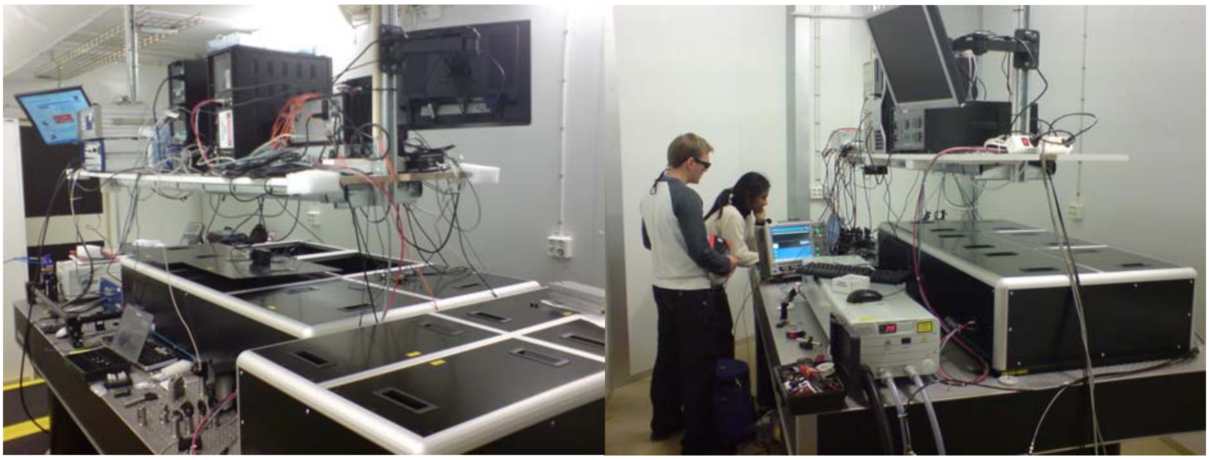

Fig 2. The gun laser system (left) and the seed laser (right) installed at MAX-lab.

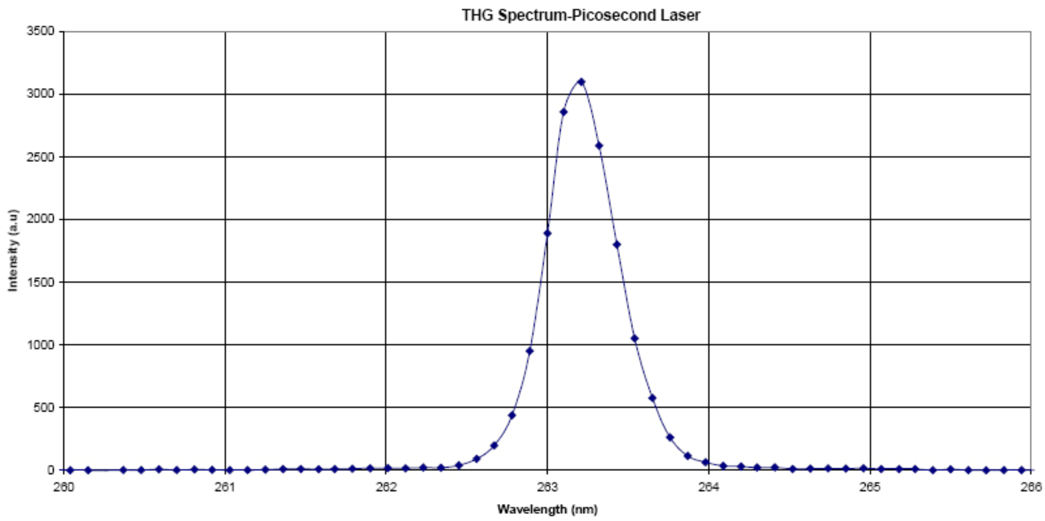

Fig 3a. Measured spectrum of the third harmonic in the output from the gun laser system.

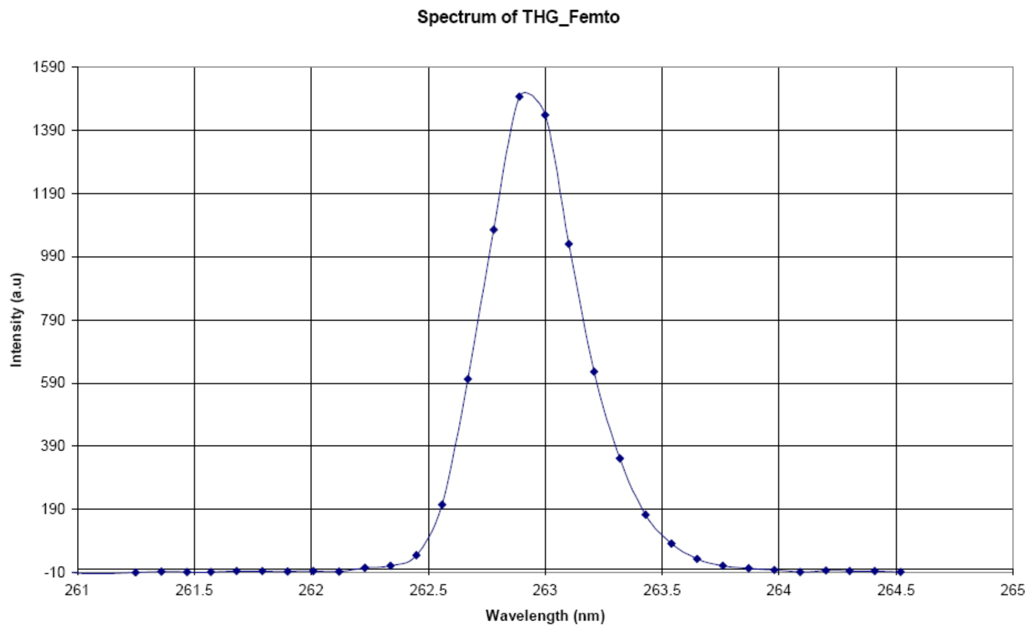

Fig 3b. Measured spectrum of the third harmonic in the output from the seed laser system.

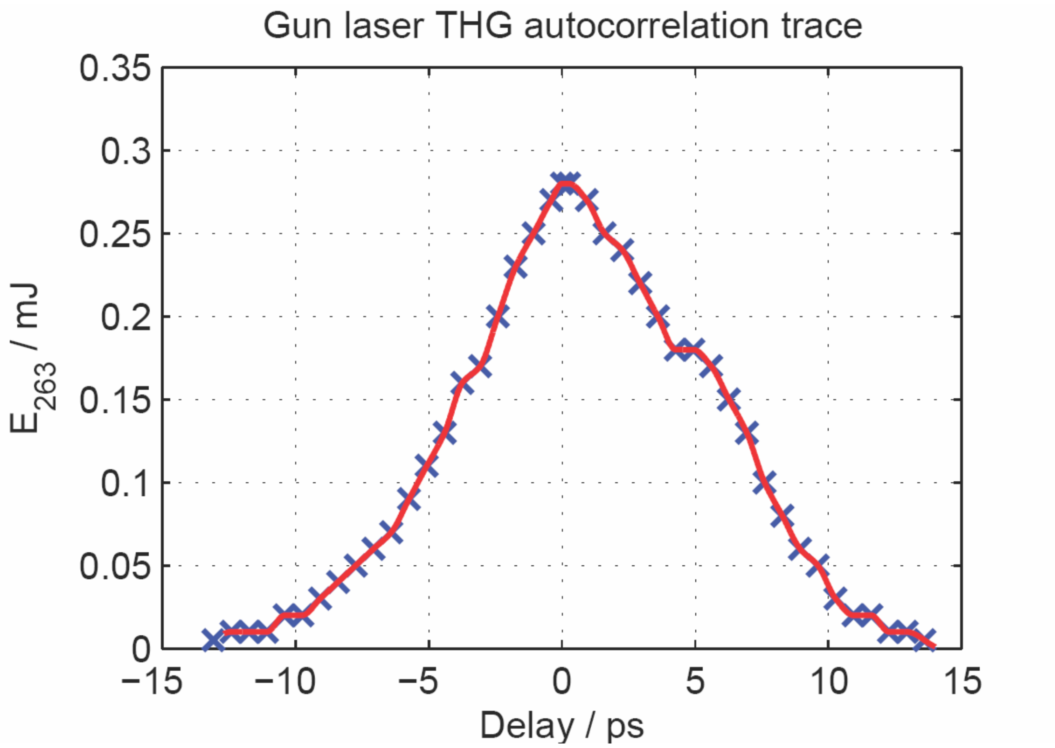

Fig 4. Autocorrelation measurement of the gun laser pulse. Assuming a Gaussian pulse gives a pulse width of 9 ps (FWHM).

The RF-gun

The electron source is a RF-gun with a BaO cathode. This system is normally operated in thermionic mode for storage ring injection. The emission is strongly space charge limited and thus the emittance is not adequate for Harmonic Generation purposes. The gun is also emitting a long pulse train not optimised for the synchronisation to the seed laser system.

The start up of the FEL test facility will be done by improving the emission process in the RF-gun by using a 10 ps laser pulse. The heating of the cathode can be reduced significantly below thermal emission and then gated by the seed laser. In thermionic mode the emission starts immediately when the accelerating fields pass the 0 phase. These first electrons carry a low energy and electrons emitted later will catch-up with the first ones creating a strong bunching on the ps scale. As the energies are low (a few 100 kV) the space charge effects are very strong disrupting the bunch both transversally and longitudinally. A method to overcome this is to gate the emission process later in the RF phase (20-30 deg). Thus the initial bunching will be reduced. A 10 ps laser pulse at an RF phase of 30 degrees will result in a 7-8 ps long electron pulse. The charge density is reduced and the acceleration quicker and thus a reduced emittance is achieved.
The RF-gun in use at MAX-lab, though, is not completely optimised for ultra low emittance operation and thus the accelerated charge has to be limited to around 0.1 nC to achieve a normalised emittance in the range of 3 mm mRad according to simulations.

The gun laser and RF-gun have been operated together and full control of the synchronisation and emission phase have been achieved. The charge and emittance have not been measured at the moment. The charge has not been available due to the short pulse structure (< 10 ps) and the emittance has not been achieved due to a shortage of beam time.

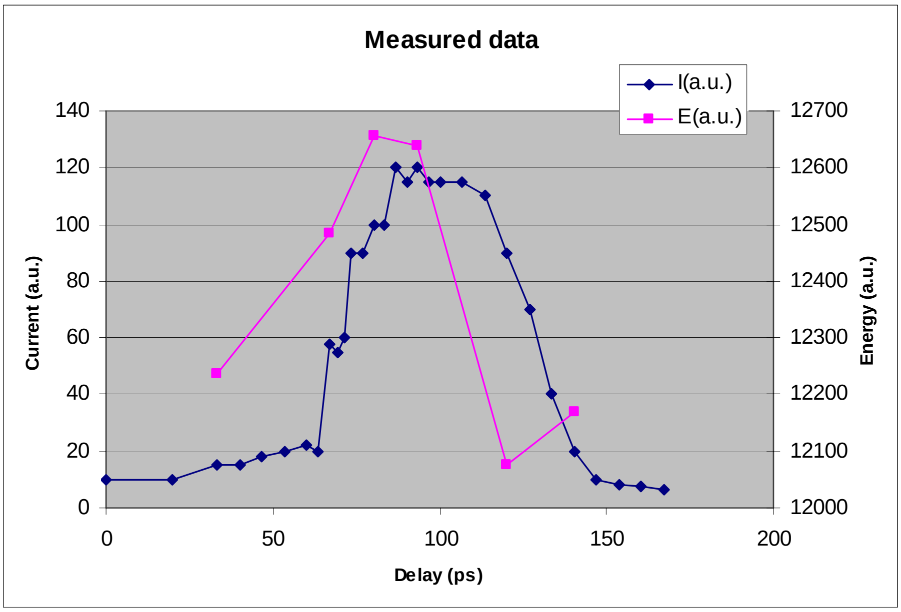

Fig 4. Measurements on the photoemission from the RF-gun system. Current (blue) and Energy (purple) as a function of the delay of the laser pulse. (1 ps ≅ 1 degree phase angle)

The phase of the gun laser pulse relative the RF phase has been scanned and the relative current and energy has been measured (fig 4). The total emission phase is 60 degrees which is good agreement to simulations. The rise time of the emission while scanning the laser pulse over the 0-degree phase is slightly longer than expected. The Gaussian profile of the laser pulse can explain the main contribution but other effects are also relevant: acceptance of the beam transport to the current transformer, response of the current transformer etc. which has to be investigated. The energy of the extracted electrons follow roughly the expected performance, where optimal operation phase is close to where the energy starts to drop (90 ps in fig 5.).

Summary

The double laser system has been put into operation with performance within specifications. The RF-gun system has been operated with the gun laser system using a 10 ps laser pulse. First measurements show a behaviour according to expectations. The next step is to transport the pulses through the linac system to the optical klystron and also to gain more information on the specifications on the generated pulses.