# CONFIGURATION AND STATUS OF THE ISRAELI THz FREE ELECTRON LASER*

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*Abstract*

A THz FEL is being built in Ariel University. This project is a collaboration between Ariel University, and Tel Aviv University. Upon completion it is intended to become a user facility. The FEL is based on a compact photo cathode gun (60 cm) that will generate an electron beam at energies of 4.5 - 6.5 MeV. The pulses are planned to be of 300 pico Coulomb for a single pulse, and of up to 1.5 nano Coulomb for a train of pulses. The FEL is designed to emit radiation between 1 and 4 THz. It is planned to operate in the super radiance regime. The configuration of the entire system will be presented, as well as theoretical and numerical results for the anticipated output of the FEL, which is in excess of 150 KW instantaneous power. The bunching of the electron bean will be achieved by mixing two laser beams on the photo-cathode. The compression of the beam will be achieved be introducing an energy chirp to the beam and passing it through a helical chicane.

We plan on compressing the single pulse to less than 150 femto seconds. The status of the project at the time of the conference will be presented.

## INTRODUCTION

At present there is an operating FEL in Ariel University, operated in collaboration with Tel Aviv University. We are in the process of building a new Tera Hertz Super Radiance FEL[1,2]. Figure 1 depicts the general layout of the system.

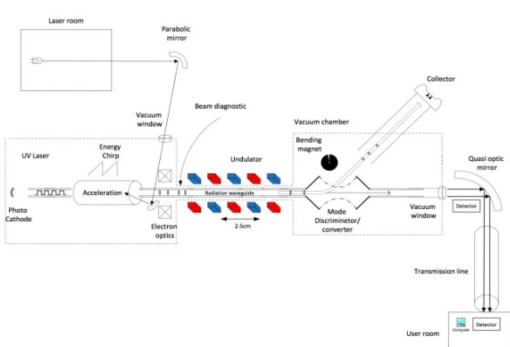


Figure 1: General layout of the Tera Hertz FEL.

The main components of the system are:

1. RF Structure.
2. Photo Cathode.
3. Laser for photo cathode.
4. Helical Chicane.
5. Wiggler.
6. Tera Hertz transmission line.

## RF STRUCTURE

The RF structure is an integration of two sections: a standing wave section in which the electrons gain most of their energy, and a traveling wave section in which the energy is set to an energy chirp that would cause the pulse to shrink in time[3,4]. Figure 2 shows a simulation of the field inside the structure; the strong field is in the standing wave section, while the weaker field is in the traveling wave section.

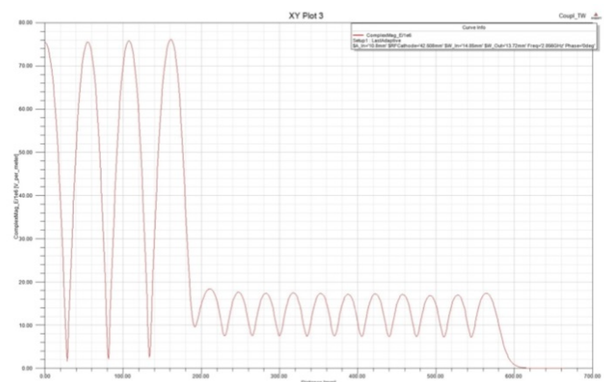


Figure 2: The electric field inside the RF structure

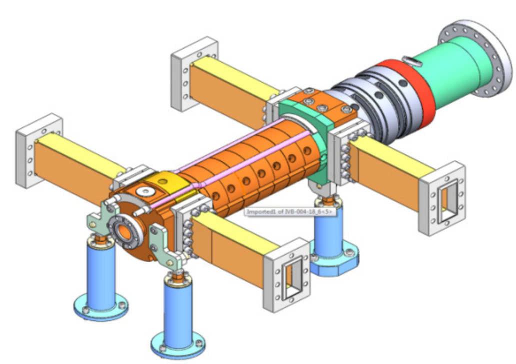

Figure 3: The mechanical design of the RF structure.

Figure 3 shows the 3D mechanical design of the RF structure including the photo cathode to the right of the picture and the input on output ports for the 3 GHz driving field.

## LASER

The laser for the THz FEL is a Coherent Laser capable of producing 100 pulses per second with a width of 35 femto seconds. The energy per pulse is about 6 mJ. Currently, the laser has been ordered.

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## HELICAL CHICANE

Once the chirped electron beam exits the gun, it requires 6 meters to compress to 150 femto seconds. In order to shorten this length significantly, and maintain the energy chirp in the beam, while maintaining its emittance, we are designing a helical chicane.

## WIGGLER

The design of the wiggler is a classical Halbach configuration as seen in Figure 4.

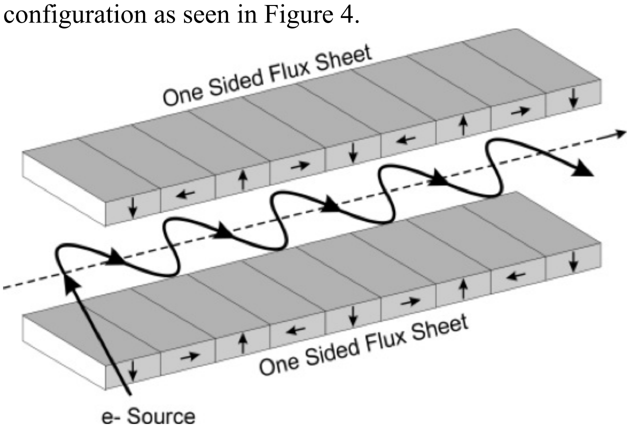


Figure 4: Halbach configuration

The design of the wiggler allows for changing the gap, with a typical gap of about 8 mm. For a wiggler period of 20 mm, this translates to a field strength on the axis of about 0.4 Tesla (Figure 5).

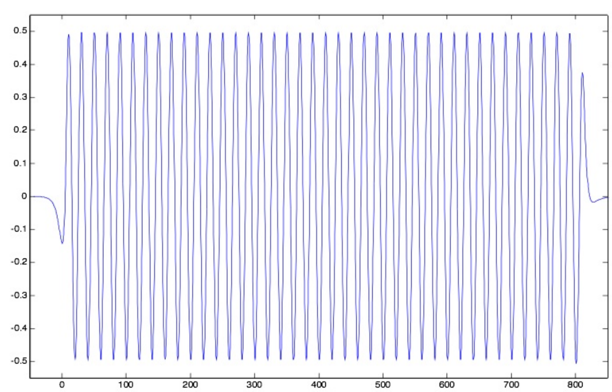


Figure 5: Wiggler field on axis

In order to make sure the electron beam does not hit the walls two magnetic bars are place on wiggle side (see Figure 6). Currently we are still working on optimization of the placement of the two magnetic bars. However the result of an electron tracing simulation can be seen in Figure 7.

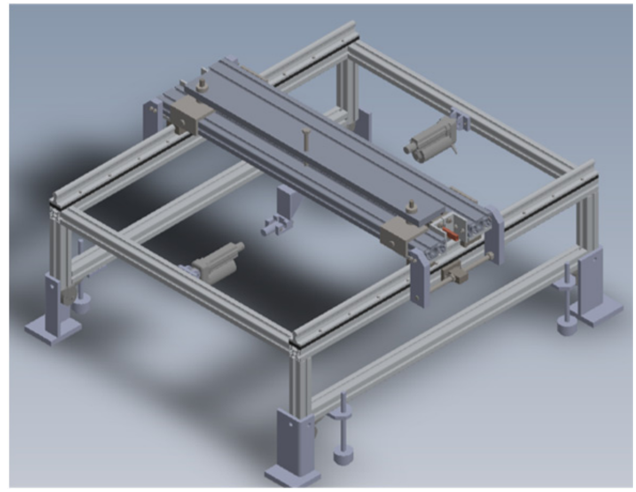

Figure 6: Wigler structure. Note that the wiggler jaws are horizontal to each other. The transverse focusing magnet can be seen on top. The wiggler is built for a variable gap.

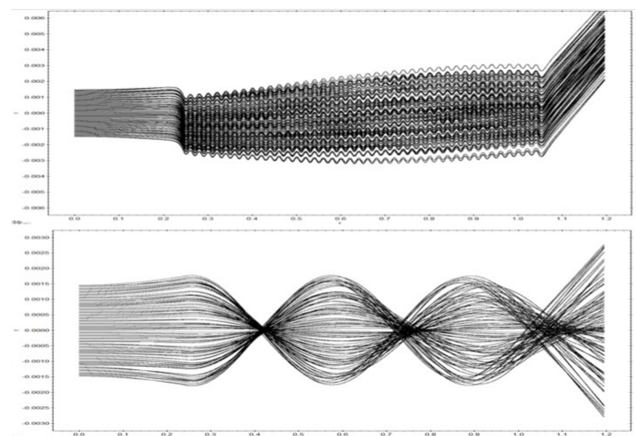

Figure 7: Electron tracing inside the wiggler using GPT. The top is the x-direction, bottom - y-direction.

We have also checked the tolerances for the electron beam entry as well as the alignment between the wiggler and the waveguide, and found to be within reason.

## TERA HERTZ TRANSMISSION LINE

An electromagnetic field operating as the Tera Hertz range (1-9 THz) behaves closer to light than to milometer waves. Thus, it is useful to use quasi optical methods to calculate its behaviour. We have written a Fourier Optics code that calculates its 3et incomplete, we have results for the free space propagation of the electric field as it exits the FEL.

In Figures 8 – 10 one can see the electric fields as it propagates away from the FEL. The field at the FEL exit was calculated with a home written code. Looking at the results it becomes obvious that we will have to use some mode conversion in order to assure that most of the energy goes into the $TEM_{00}$ mode.



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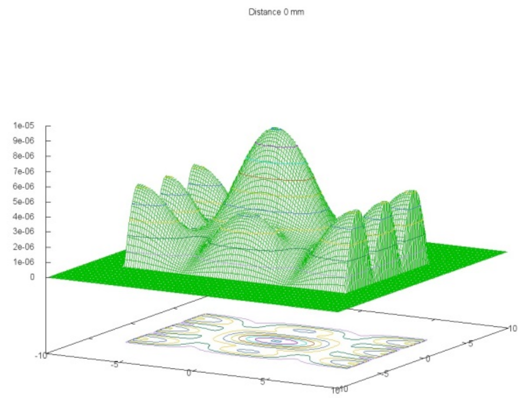


Figure 8: The electric field at the FEL exit

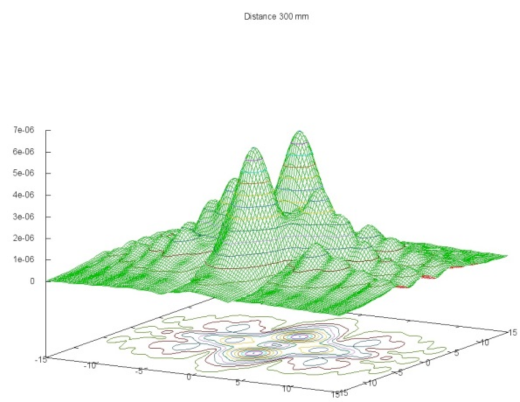


Figure 9: The electric field 30 cm from the FEL (diameter is doubled)

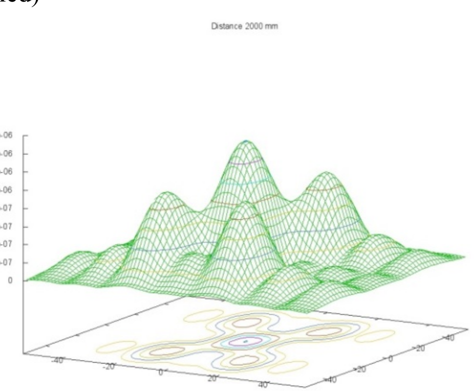


Figure 10: The electric field 2 meters from the FEL.

## FEL CALCULATIONS

A code written locally is used to simulate the FEL[5]. The code calculates the excitation of the waveguide modes inside the FEL. It takes into account space charge effects, and is completely 3D. For a wiggler field 0f 0.4 T, and a charge of 300 pC the code yields an output of 150 KW. Figure 11 and Figure 12 show the results of the latest simulation.

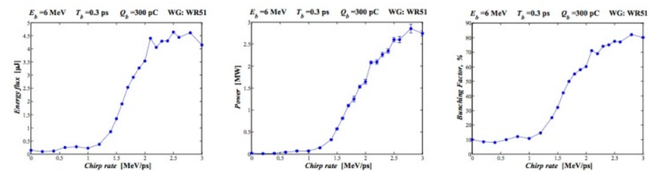

Figure 11: Energy flux (left), peak power during the pulse (in the center), and the bunching factor (right) as functions of the chirp rate. For 0.3ps e-beam pulse duration, each 1 MeV/ps of chirp rate corresponds to 300keV maximum difference of the electrons' energies.

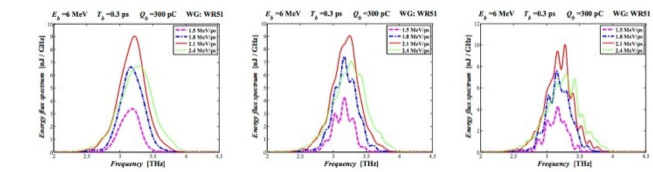

Figure 12: Spectrum of the radiation emitted after the first 20, 30 or 40 periods of the wiggler (the left, the center and the right pictures, respectively). An effective, enhanced coherent emission takes place at a first stage (first 20 periods) when a proper chirp rate is introduced (~2.1 MeV/ps), while incoherent, noisy radiation is present in the following.

## CONCLUSIONS

The Israeli FEL is a multi-year project which is well on its way. The RF Gun and the Wiggler are being manufactured at present. Because of the extremely high space charge, the project poses several challenges which are yet to be fully resolved.

## REFERENCES

[1] E.Dyunin, Y.Lurie, Y.Pinhasi, A.Gover, 25th Convention of Electrical & Electronics Engineers in Israel, (2008) 825-829.

[2] Y. Pinhasi, Yu. Lurie, and A. Yahalom, Nucl. Instrum. Methods Phys. Res., Sect. A 475 , 147 (2001).

[3] B. Spataro, et al., Nucl. Instr. And Meth. A 657 (2011) 99–106.

[4] J. Rosenzweig, et al., Nucl. Instr. And Meth. A 657 (2011) 107–113.

[5] Y. Pinhasi, Yu. Lurie, A. Yahalom, and A. Abramovich, Nucl. Instrum. Methods Phys. Res., Sect. A 483, 510 (2002).



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