COMMISSIONING STATUS OF THE FRITZ HABER INSTITUTE THZ FEL

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Abstract

The IR and THz Free-Electron Laser (FEL) at the Fritz Haber Institute (FHI) of the Max Planck Society in Berlin [1] is designed to deliver radiation from 4 to 500 microns using a single-plane-focusing mid-IR undulator and a two-plane-focusing far-IR undulator that acts as a waveguide for the optical mode. A key aspect of the accelerator performance is the low longitudinal emittance, < 50 keV-psec, that is specified to be delivered at 200 pC bunch charge and 50 MeV from a gridded thermionic electron source. We utilize twin accelerating structures separated by a chicane to deliver the required performance over the < 20 - 50 MeV energy range. The first structure operates at near fixed field while the second structure controls the output energy, which, under some conditions, requires running in a decelerating mode. "First Light" is targeted for the centennial of the FHI in October 2011. We describe progress in the installation and commissioning of this device to achieve this goal.

INTRODUCTION

The IR and THz FEL shown in Figure 1 is currently being commissioned at the Fritz Haber Institute for applications in gas-phase spectroscopy of (bio-) molecules, clusters, and nano-particles, as well as in surface science. Advanced Energy Systems (AES) has designed and installed the accelerator and electron beam transport system. STI Optronics fabricated the mid-infrared (MIR) undulator with Bestec GmbH delivering the installed MIR oscillator mirror optical equipment. The far-infrared (FIR) optical components shown are notional since the FIR beamline design has not been completed at this time. FHI is responsible for the facility, optical transport and user laboratories. In this paper, we describe the design and fabrication of the electron beam components, together with the progress that has been made in the installation and commissioning of the device within the experimental vault in Berlin.

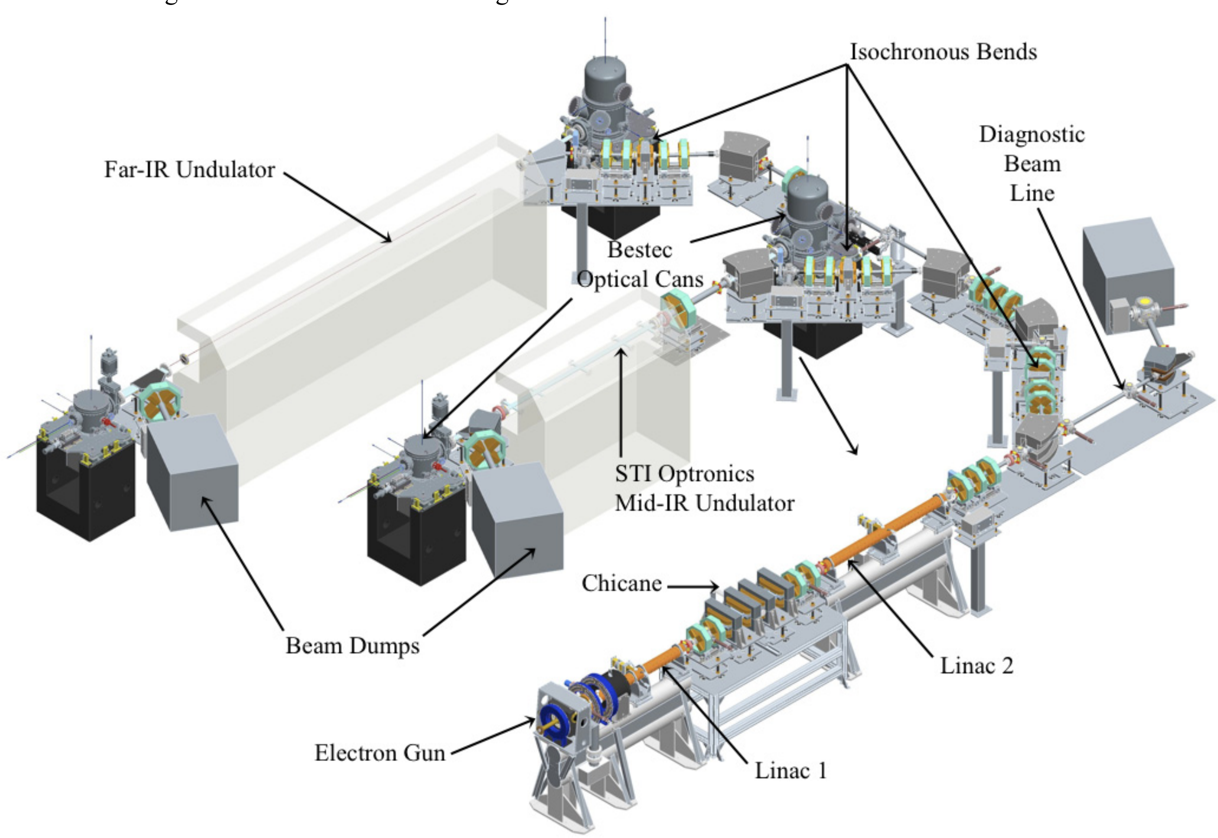

Figure 1: Schematic diagram of Fritz Haber Institute free electron laser showing key components.

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ELECTRON ACCELERATOR

The projected top-level electron beam performance is given in Table 1. The design of the accelerator, beam transport and optical systems has been described previously [2,3,4]. In brief, it consists of a 50 MeV accelerator driven by a gridded thermionic gun with a beam transport system that feeds two undulators and a diagnostic beamline. Two 3 GHz S-band, normal-conducting electron linacs and the gun-to-dump electron beam lines have been designed, fabricated, and installed by AES. The first linac will accelerate the electron bunches to a nominal energy of 20 MeV, while the second one accelerates or decelerates the electrons to deliver any final energy between 15 and 50 MeV. A chicane between the structures allows for adjustment of the bunch length as required. The accelerator components are illustrated in Figure 2.

Table 1: FHI THz FEL Electron Beam Parameters

Parameter	Unit	Specification	Target
Electron Energy	MeV	20 - 50	15 - 50
Energy Spread	keV	50	< 50
Energy Drift per Hour	%	0.1	< 0.1
Charge per Pulse	pC	200	> 200
Micropulse Length	psec	1 - 5	1 - 10
Micropulse Repetition Rate	GHz	1	1 & 3
Micropulse Jitter	psec	0.5	0.1
Macropulse Length	μsec	1 - 8	1 - 15
Macropulse Repitition Rate	Hz	10	20
Normalized rms Transverse Emittance	π mm-mrad	20	20

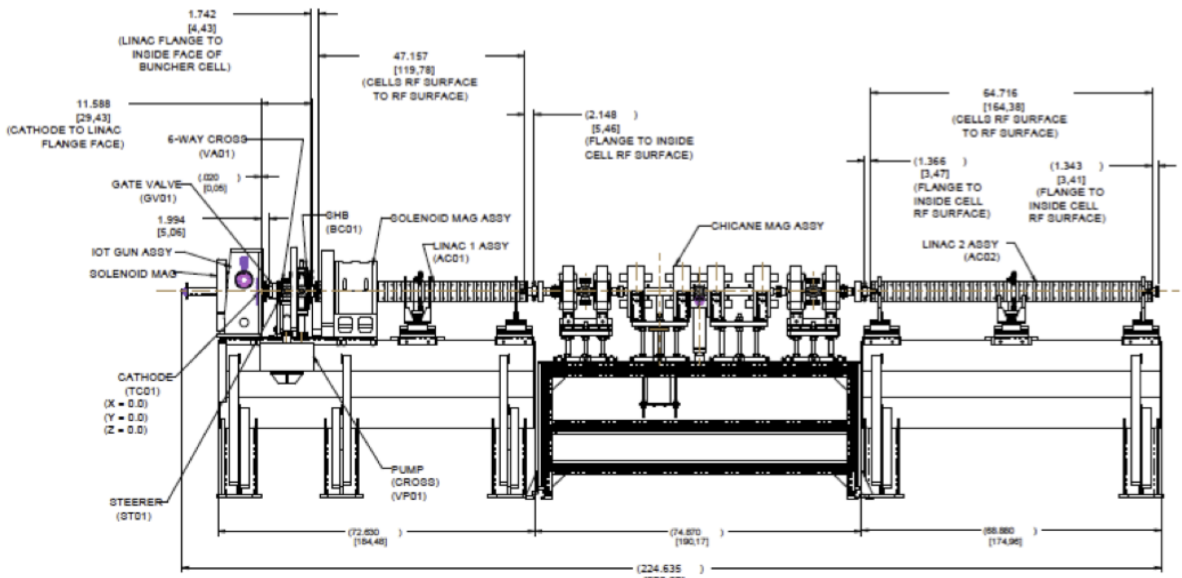

Figure 2: Layout of the FHI accelerator section from the gridded gun (left) to the linac 2 output (right).

The final design optimized the specifications of the linac that are most relevant for the IR and THz FEL performance. For instance, the maximum bunch charge of the micro-pulses, which are repeated at rate of up to 1 GHz, has been increased to 300 pC. In addition, the length of the electron macro-pulses has been increased to 15 μsec. The 3 GHz operation of Table 1 is not implemented at this time.

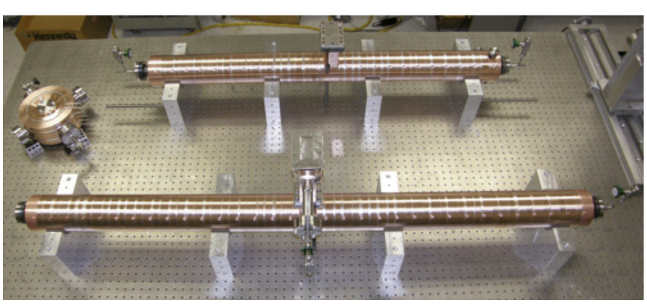
Figure 3: Completed accelerator structures after brazing.

Fabrication took place through the early months of 2011. The completed linac structures and sub-harmonic buncher are shown in Figure 3, following brazing.

The design energy of the IR-output is more than 10 μJ per micro-pulse and more than 100 mJ per macro-pulse. This corresponds to an optimized output in terms of milli-joule per micro-second, which is the figure of merit for many gas-phase spectroscopy experiments.

INSTALLATION AND COMMISSIONING

The facility building with the accelerator vault, which began construction in April 2010, has been completed. Installation has been ongoing since the beginning of 2011. The present status of the accelerator beamline, as of early August 2011, is shown in Figure 4. Here we see the electron gun in back left with the two linac structures, separated by the chicane, running to the lower right. The isochronous bends, shown in Figure 5, carry the electron beam to the MIR undulator. The undulator and optical chambers have already been commissioned. Figure 6 shows photographs of the undulator (left) as well as the MIR out-coupling mirrors (right). The 50-mm-diameter cavity mirrors are made out of gold-coated copper and have out-coupling hole sizes ranging from 0.75 to 3.5 mm. They are mounted to a translational mirror changer, which also allows for precise adjustment of the pitch and yaw angles for easy cavity alignment.

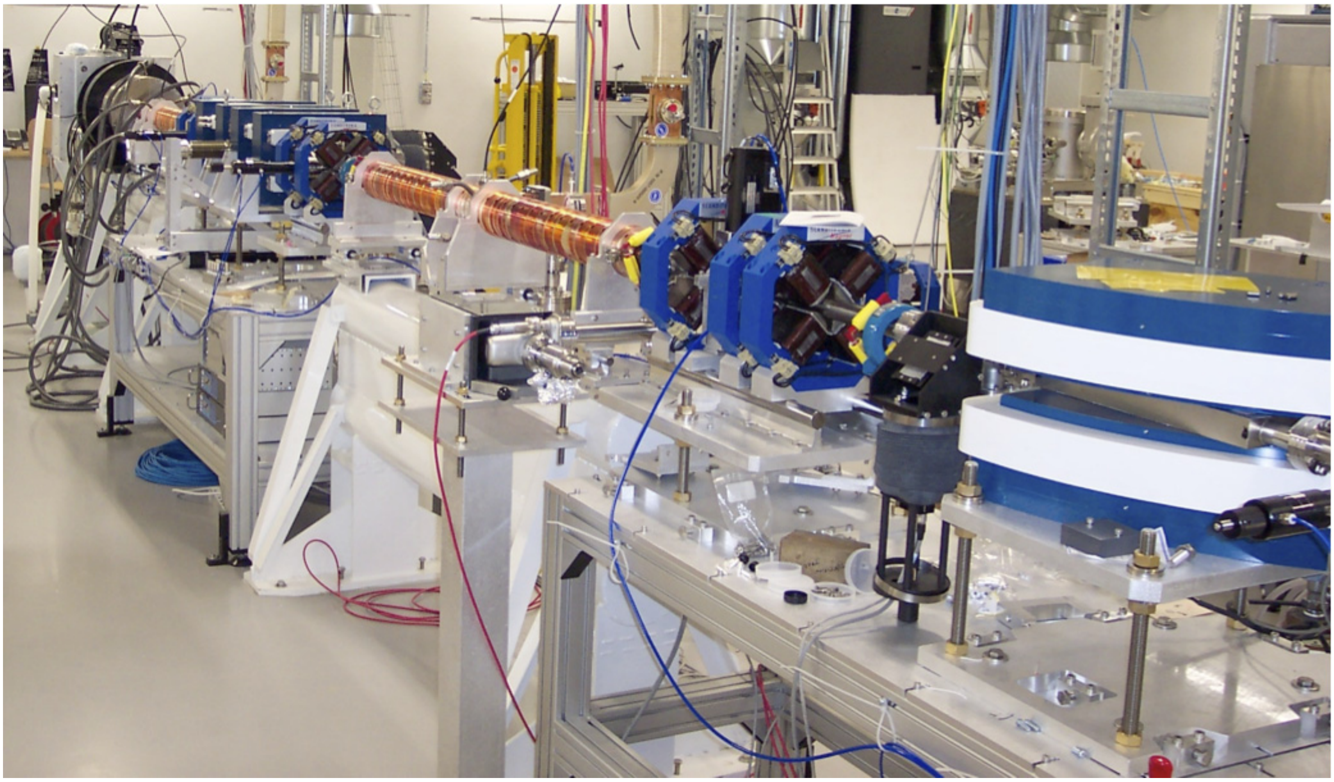

Figure 4: Electron beamline installation in the FHI vault as of early August 2011.

Figure 5: Installation of the isochronous bend leading to the MIR wiggler. The accelerator is in the upper background right and the diagnostic beamline exits at the top left.

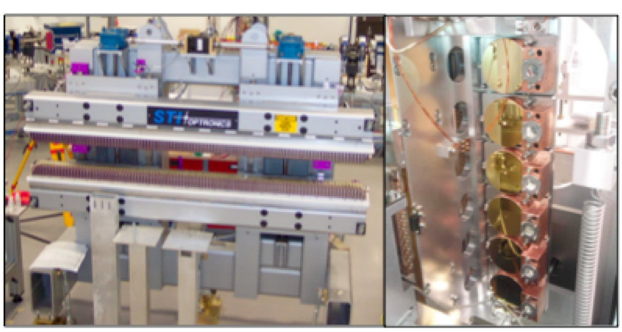

Figure 6: (left) STI Optronics MIR undulator, (right) Bestec mirror changer equipped with 6 gold-coated copper mirrors with different out-coupling hole diameters.

Figure 7: FHI FEL Facility.

SUMMARY

As shown in Figure 7, the FHI THz FEL building facility is completed with only minor external work remaining. All hardware for the device has been received in Berlin. The linac structures are installed, pumped down and baked. RF conditioning commenced at the end of August. The STI Optronics undulator and Bestec optical system are both commissioned. Beamline commissioning begins September 2011 with "First Light" targeted for October 2011.

REFERENCES

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