THz Simulation for FLASH and plans for FLASH2020+

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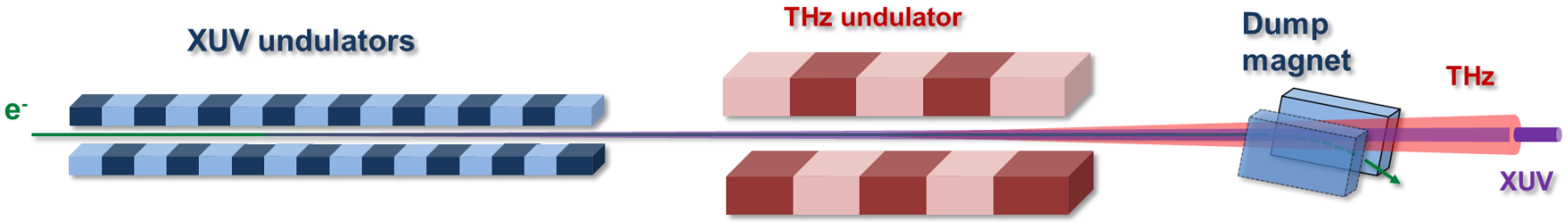
08/Dec./2022

Outline

- FLASH/THz beamline (now and future)
- Simulation by SRW
- Future perspective

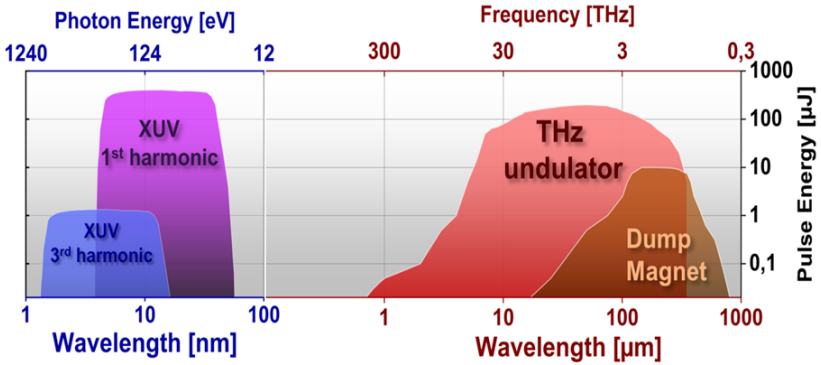
Intense THz beam

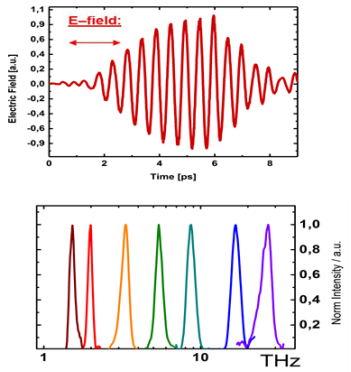


Semi- parasitic operation

Tunable + narrow band:

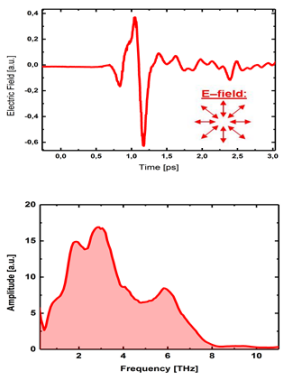
1 – 300 um (1 – 300 THz)



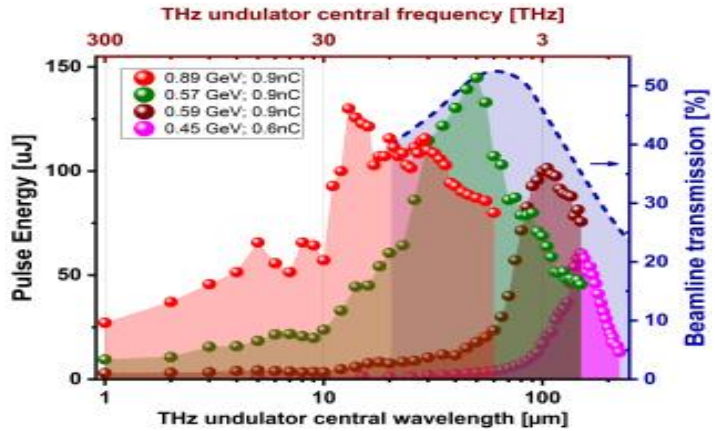


+ Single cycle

30 – 300 um (1 – 10 THz)



100% parasitic operation



Polarization:	Linear	Radial

THz beam at FLASH

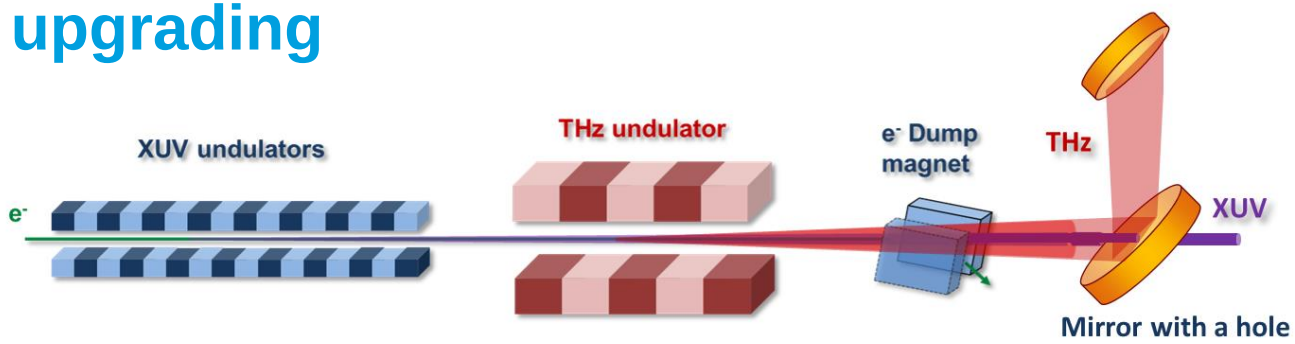
- Intense pulse energy (150 µJ)
- High-repetition rete (1MHz)
- Wavelength tunable (1-300THz)
- High THz frequency (over 3THz)

- Multi-cycle + single cycle
- Strong longitudinal e-field
- XUV/THz jitter free
- XUV+THz+Pump-probe laser

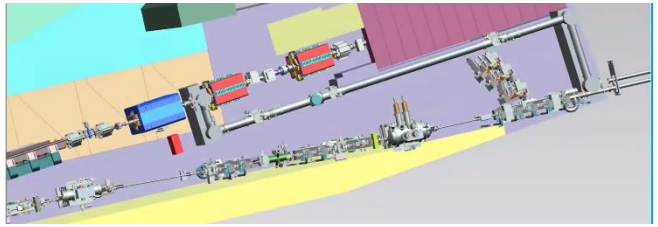
FLASH2020+: THz Beamline upgrading

THz beamline in FLASH1 tunnel

- Current: XUV undulators and THz undulator are in line
- New: THz undulator is separated from XUV source



Current THz geometry at FLASH1



New THz geometry at FLASH1

Benefits

- Completely parallel operation of THz-only experiments (laser safety)
- More freedom (flexible) on THz tuning

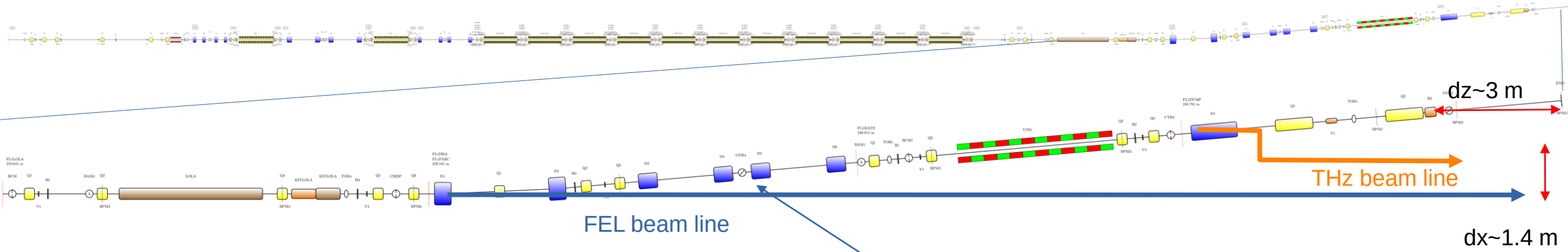
Expected parameters

	Wavelength range @ 1350 MeV	Wavelength range @ 950 MeV	Wavelength range @ 750 MeV	**Pulse energy**	**Timing jitter**
XUV	3.6nm-18.8nm	7.2nm-38.0nm	11.5nm-60.9nm	>5 µJ	< 20fs rms
THz	10µm-26µm	26µm-55µm	41µm-85µm	>100 µJ	

* 85µm-300µm covered by edge radiation and OTR

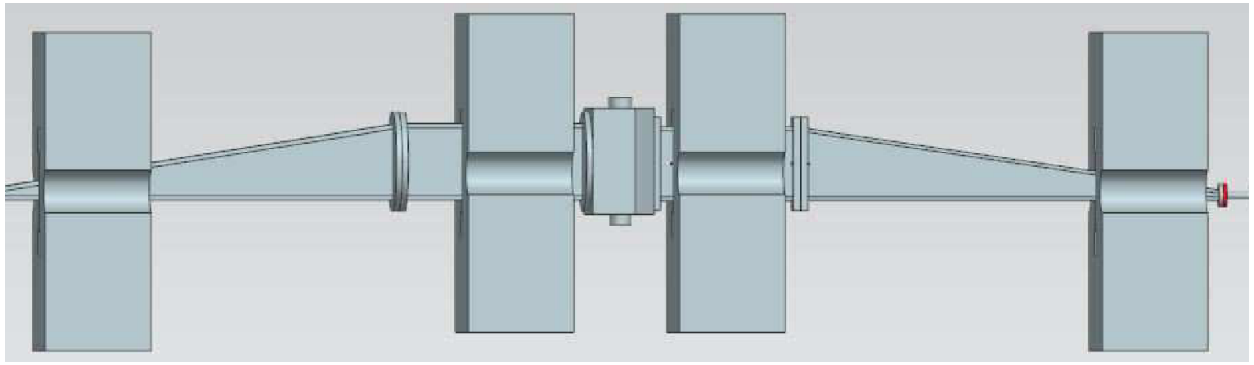
FLASH2020+: THz Beamline upgrading

Generating THz pulses decoupled from FEL pulses.



- FL1LOLA
  - Section for longitudinal Diagnostics.
- FL1PARC (Post compression ARC)
  - Section for generation offset to get into FL1DUMP
  - Post-compression for THz radiation generation in FL1RADT
- FL1RADT (RADiator for THz)
  - Section for THz radiation generation
- FL1DUMP (DUMP)
  - Dump beam line (here new concept for shifted DUMP) dx ~1.4m; dz=3m

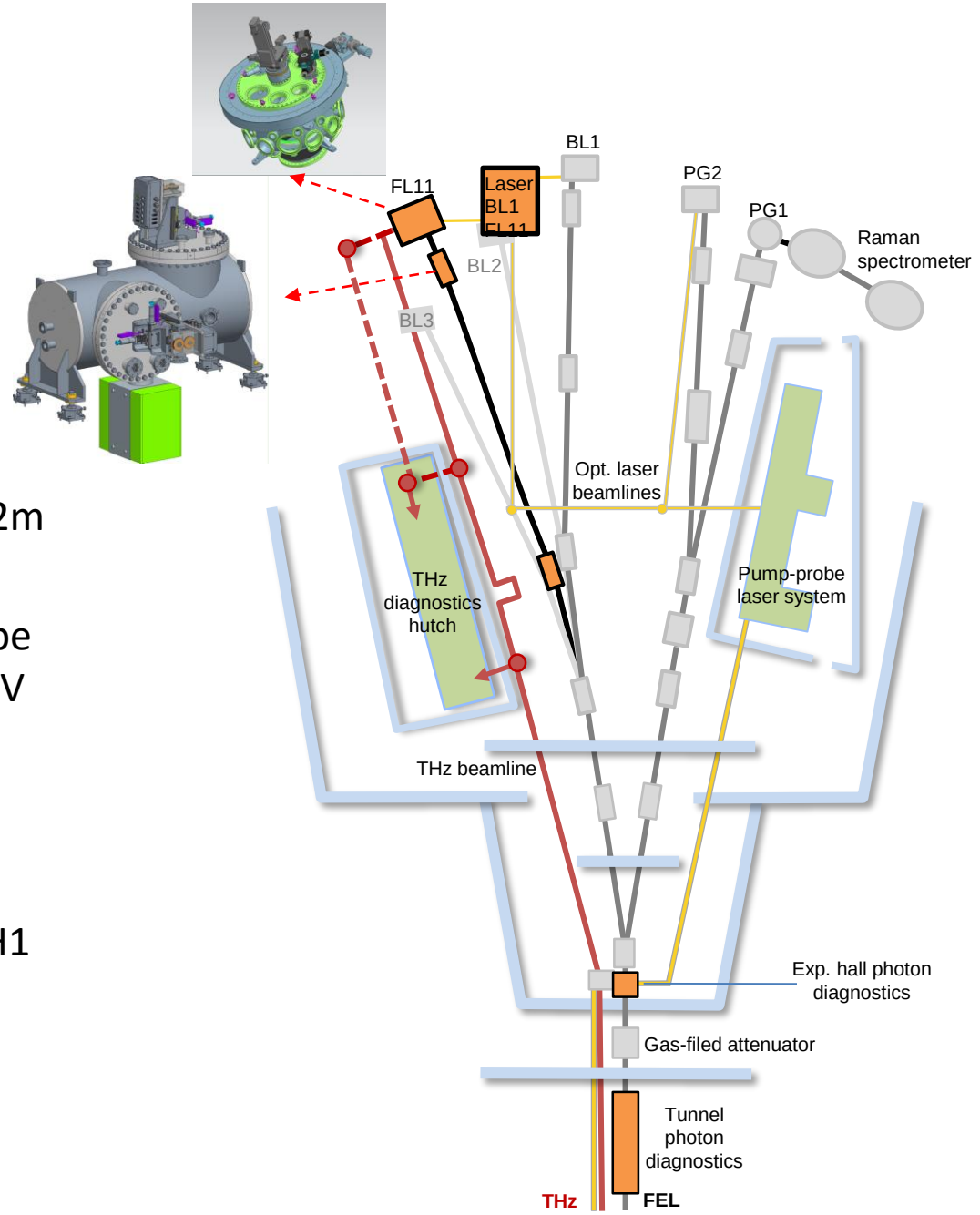
Vertical c-type bunch compression chicane to post compress the medium compressed beam used for seeded operation in order to increase THz output power.



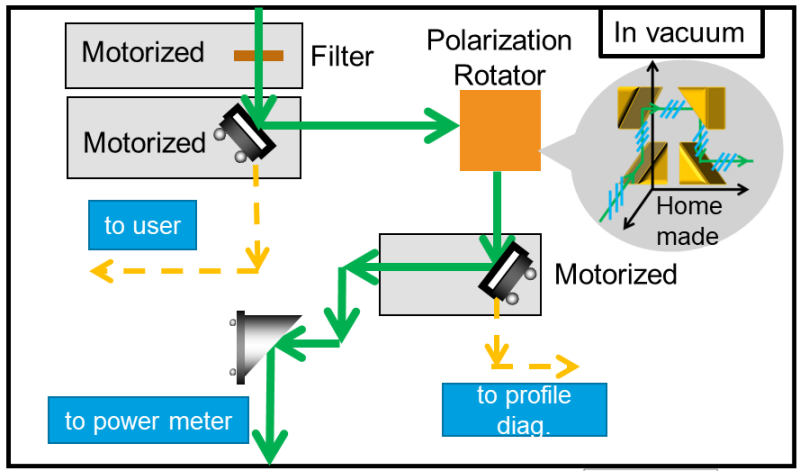
Contributed by J. Zemella and M. Vogt

New FL11 beamline

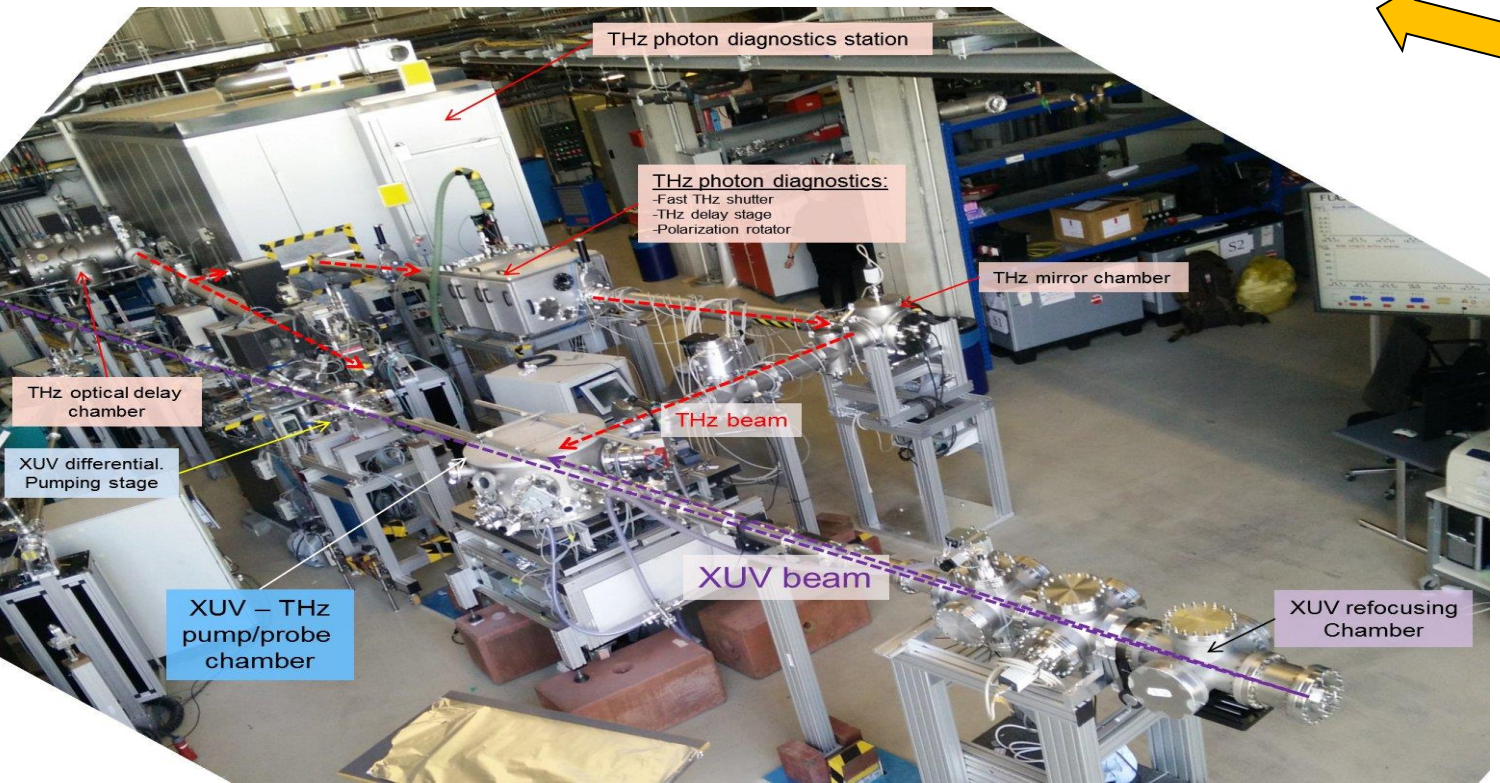
- **Reuse as much as possible the current beamline components**
- Possible for “high-energies”-beyond C k-edge with appropriate coatings and 2° grazing incidence
- bendable KB optics (2m-5m focus length; <2µm for 2m focus;)
- Semi-permanent endstation for THz-XUV pump-probe (may use the THz doubler concept and opt. laser-XUV pump-probe)
  - -- femto-magnetism
  - -- solid-state dynamics
- Regularly open port for special applications at FLASH1

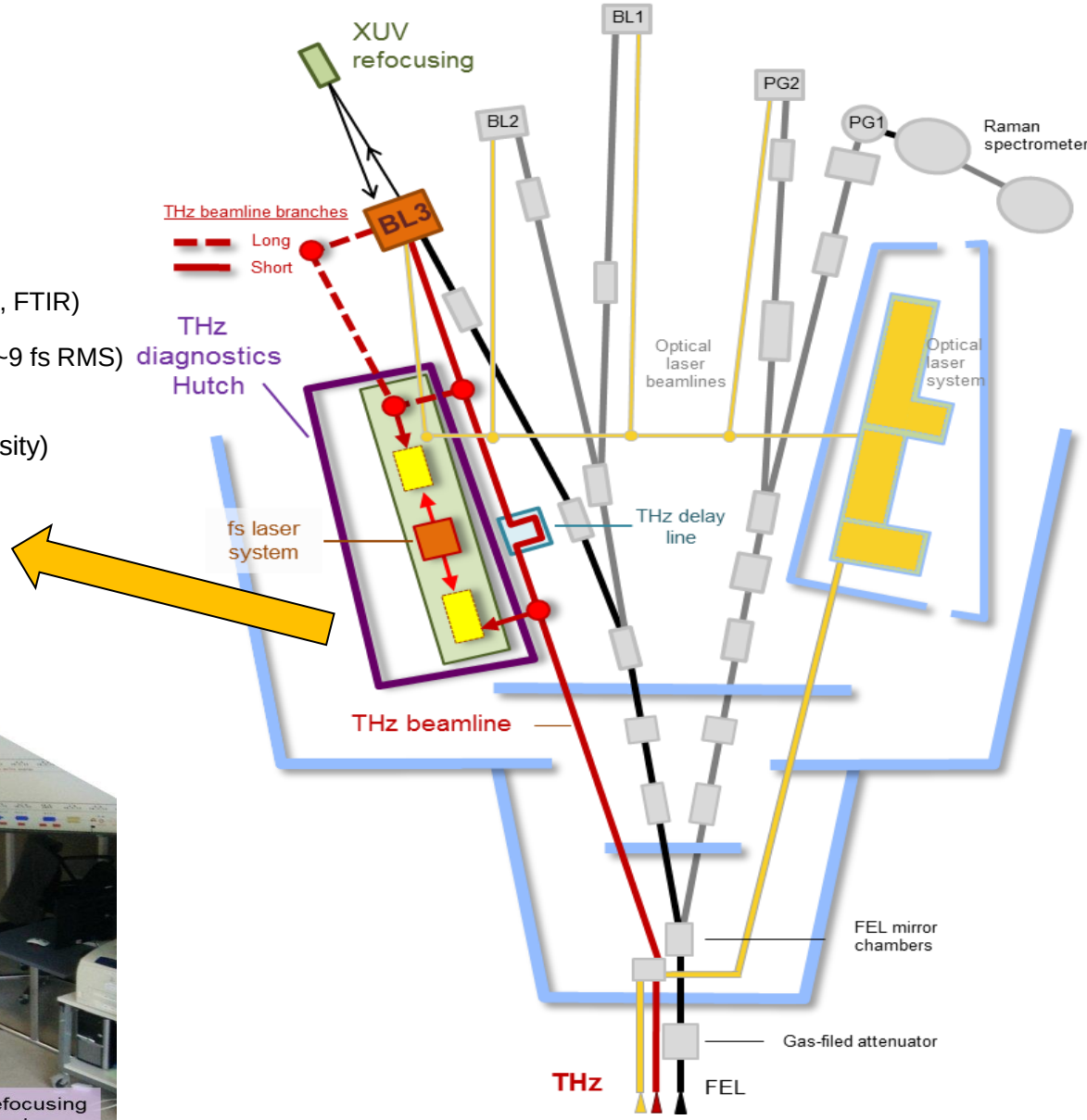


Beamline operation



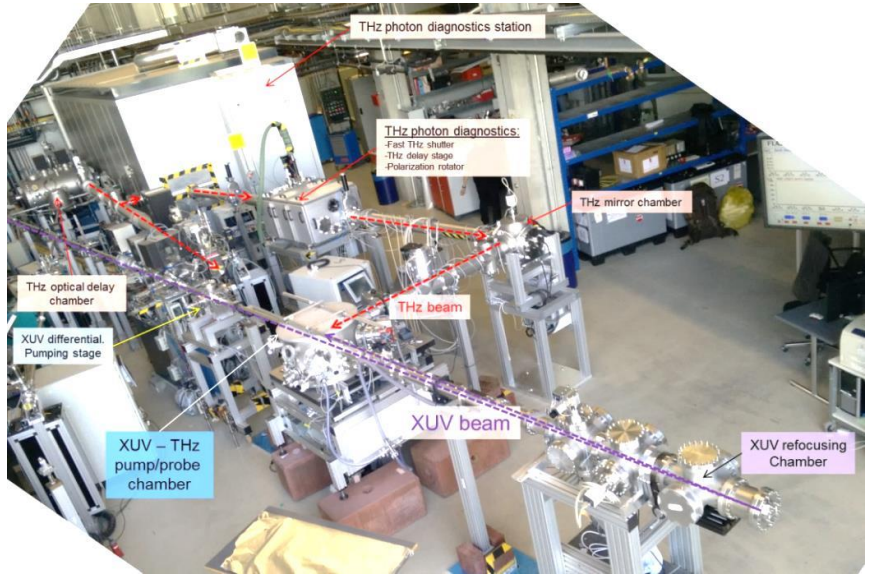
- THz diagnostics hutch
  - Synced probe laser
  - THz pulse characterization
    - Pulse energy
    - Transverse profile
    - Spectral/Temporal (TDS, FTIR)
    - Arrival time monitoring (~9 fs RMS)
  - Pulse shaping/control (polarization, spectral, intensity)
  - Time domain spectroscopy



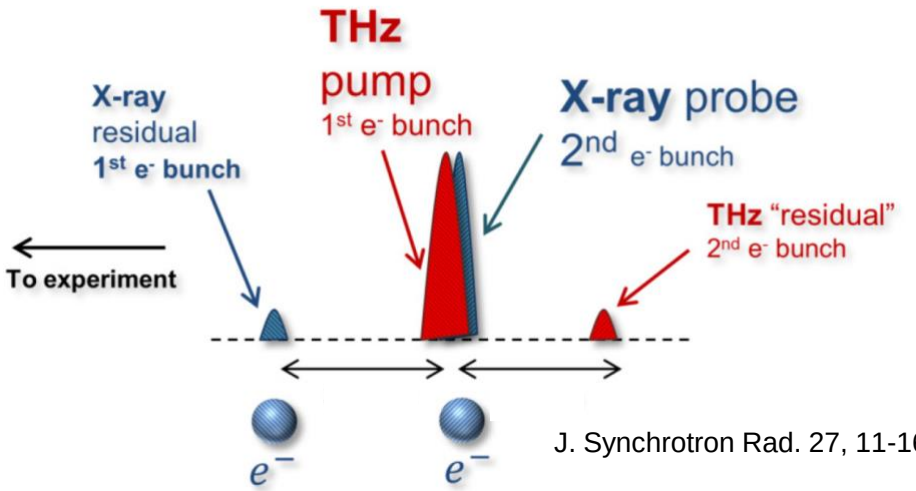


FLASH2020+: THz Beamline upgrading

THz Operation modes



Backup plan: Back reflection scheme



J. Synchrotron Rad. 27, 11-16., (2020).

36 periods (27.6 ns, or 8.29m)

Normal operation: THz doubler scheme

+	-
• Mature scheme • Max THz pulse energy (150 uJ) • Max XUV pulse energy • Timing jitter 5fs • Pure pulse	• XUV reflection mirror(narrow bandwidth, limited wavelength selection, reduced energy, beamsize>100um) • Complex geometry in chamber

+	-
• Without XUV reflection mirror (full energy, full bandwidth, small beamsize) • Simpler geometry in chamber	• **In development** • XUV suppression (SASE): 1:100 • Current THz pulse energy: 4 uJ • Current XUV pulse energy: 40 uJ • Timing jitter <19fs (limited by detection) • Online diagnostics

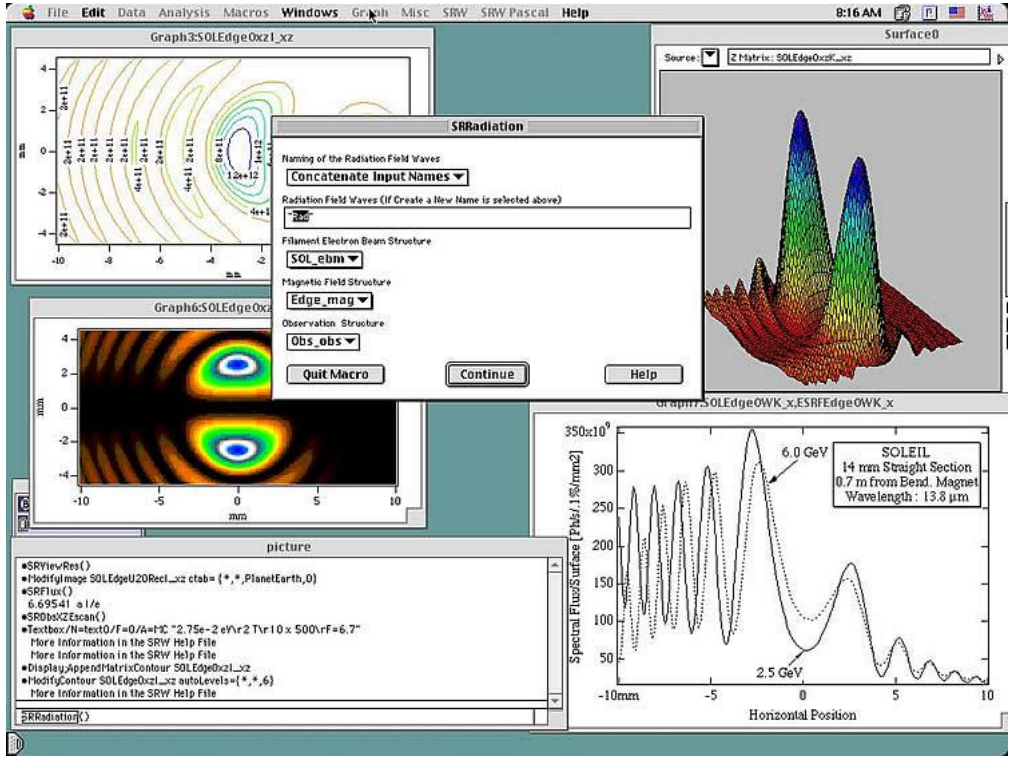
THz simulation

SRW overview (Igor Pro based): **T. Golz -01/2017 - in collaboration is V.Agekar**

- http://www.esrf.eu/Accelerators/Groups/InsertionDevices/Software/SRW

- calculates spectral, spatial and polarization characteristics of radiation in near and far field (produced by relativistic electrons)

- Processing is done (for example) in Igor Pro (get from UCO)
- Uses (like matlab) predefined functions that are called with defined parameters

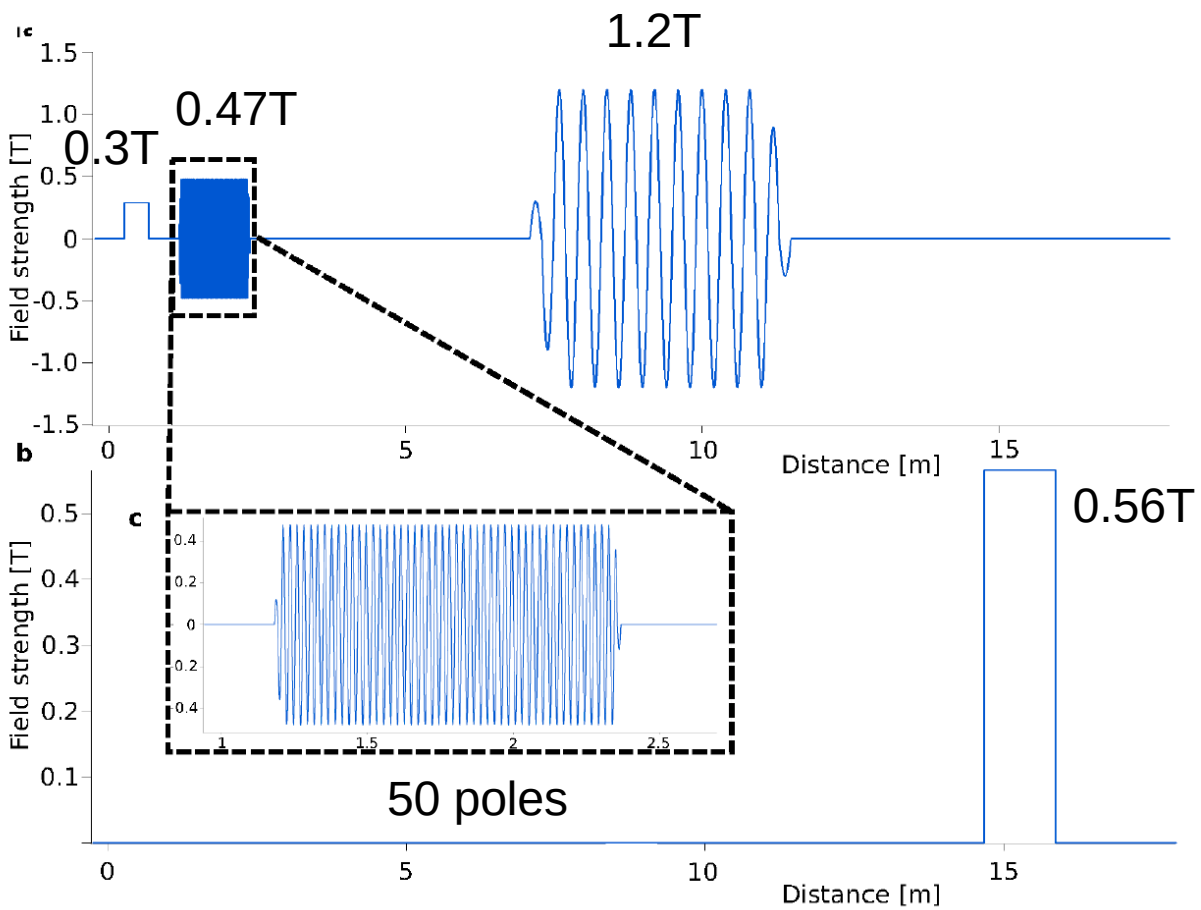


WaveProperGator (WPG): Python based SRW

for coherent and partially coherent X-ray wavefront propagation simulations

https://wpg.readthedocs.io/en/latest/index.html

THz simulation by SRW



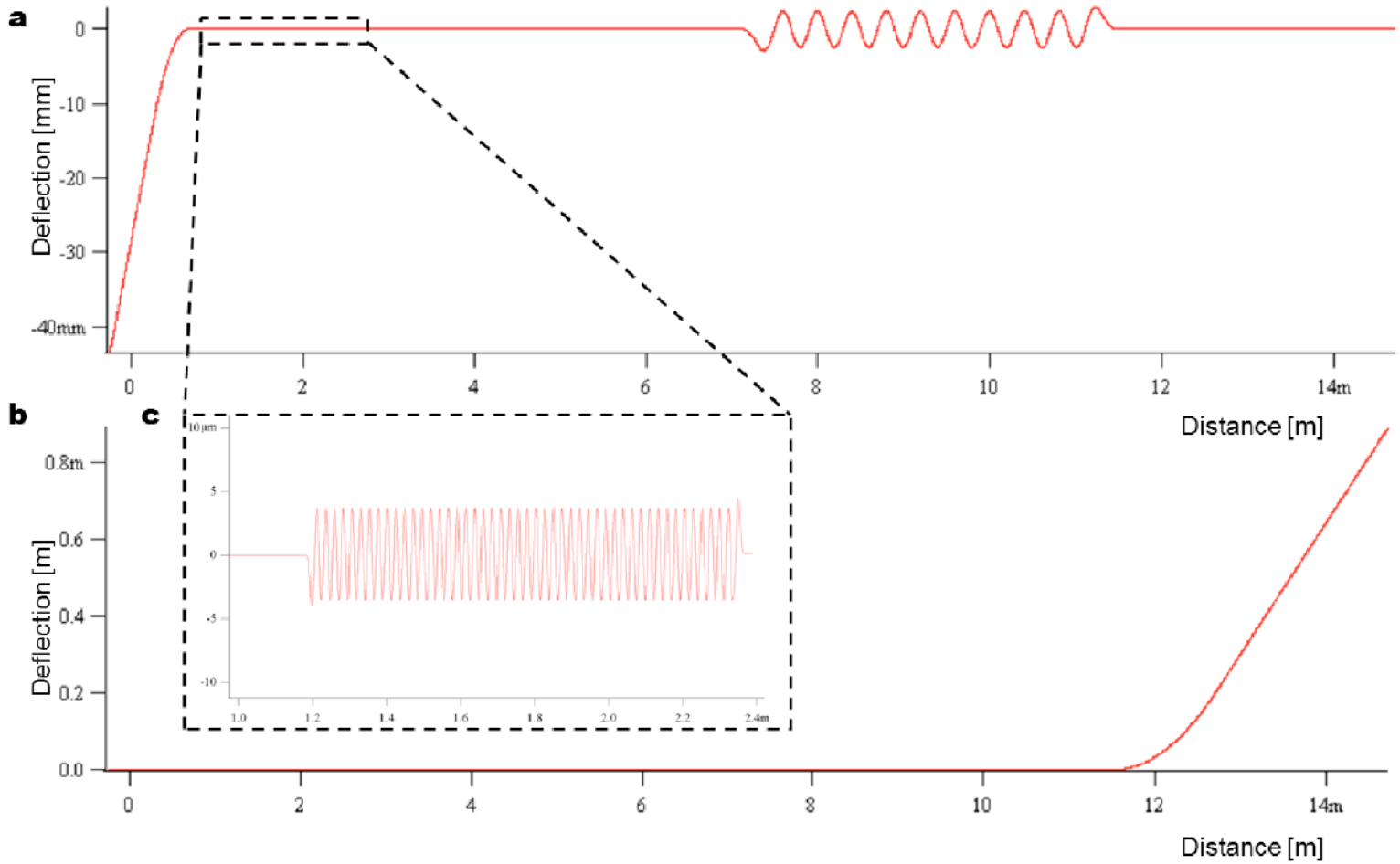
Z, vertical

Y, horizontal

Magnetic structure constructed to approximate the section around the THz undulator at FLASH1

Adapted from T.Golz PhD Thesis

THz simulation by SRW

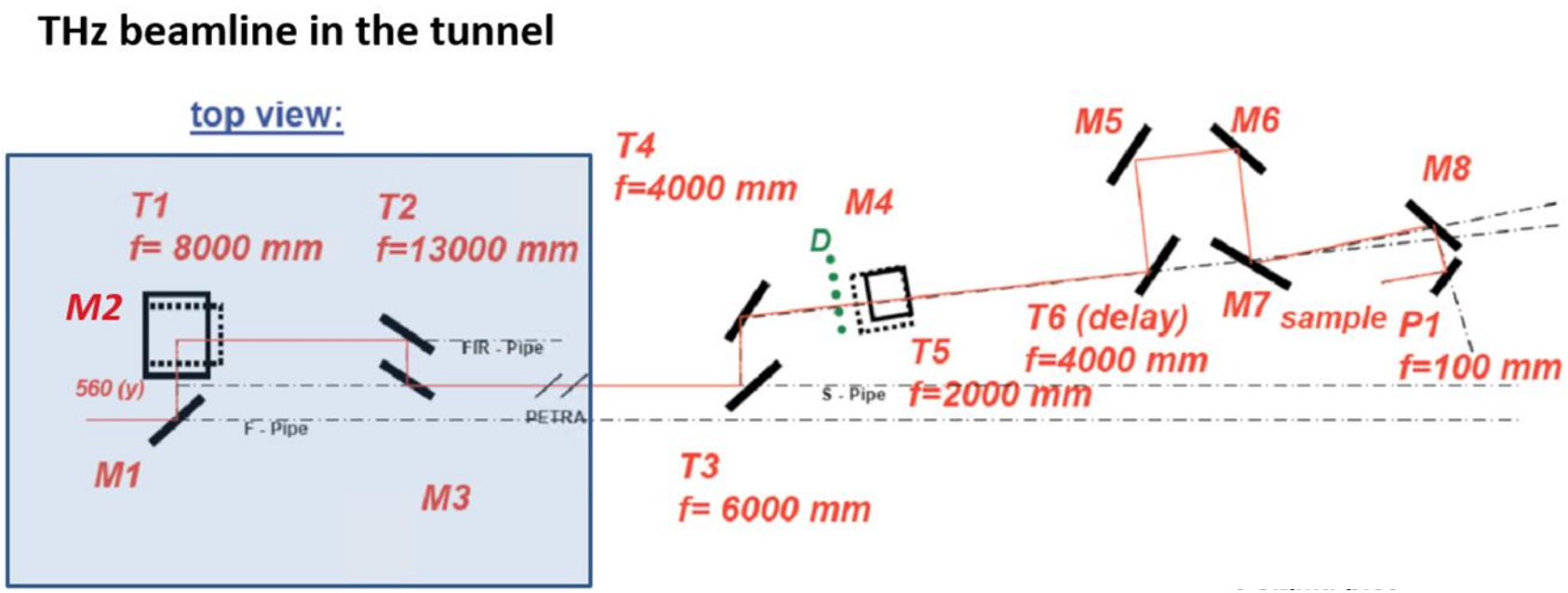


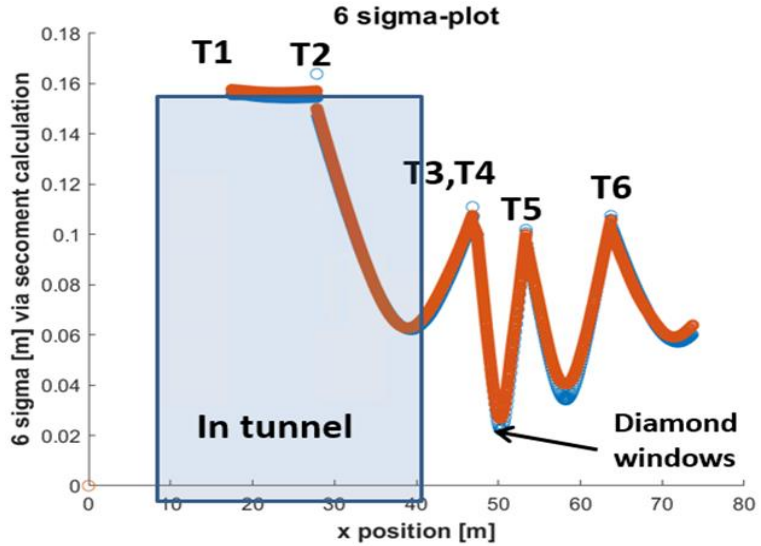
The trajectory of the electron traveling along the magnetic structure

Generate wavefront
Propagate backward
Add aperture
Propagate forward

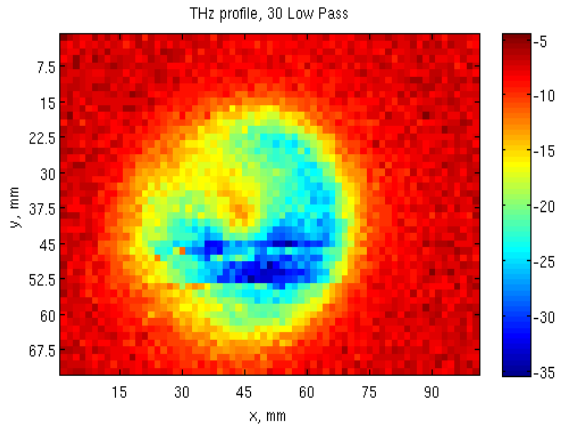
Adapted from T.Golz PhD Thesis

THz simulation by SRW

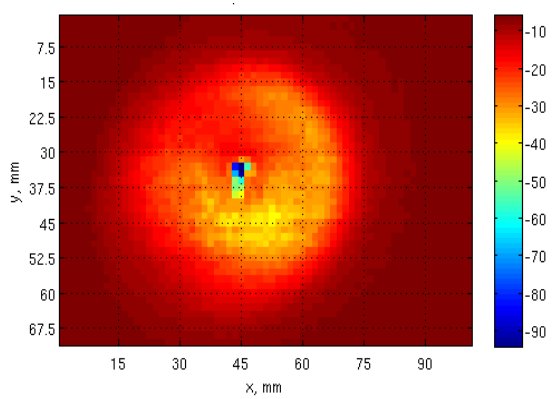




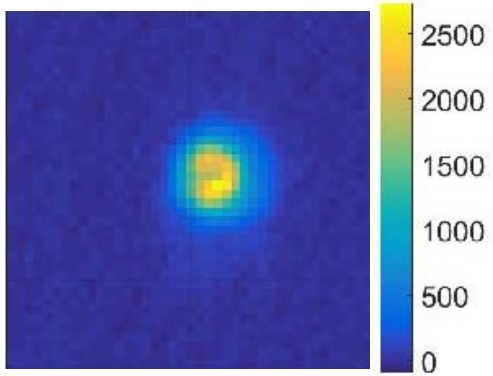
THz simulation by SRW



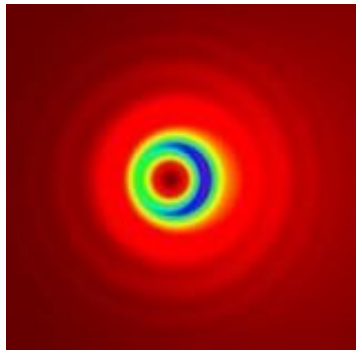
2D scan, 30 µm Low Pass Filter



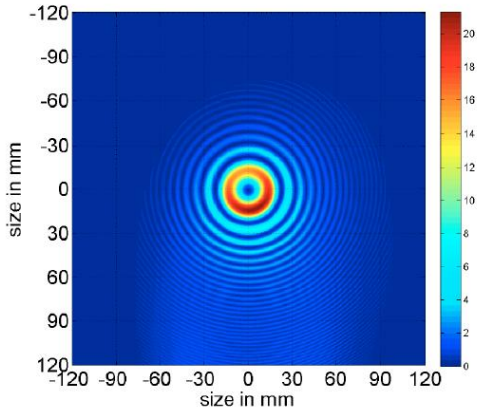
2D scan, No Filter



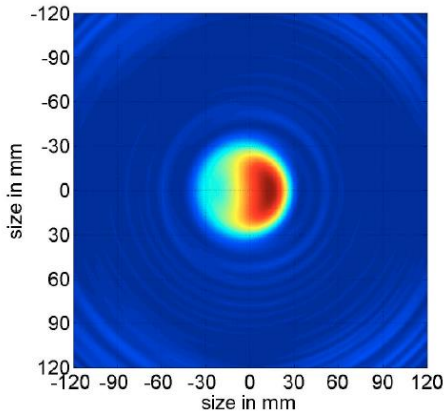
By Spiricon camera



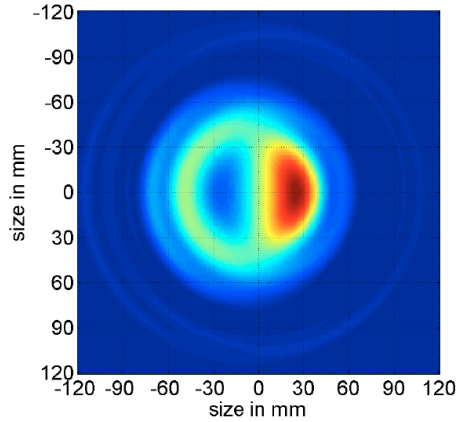
Simulation by SRW



Sim. of edge radiaton intensity with all polarizations



Sim. of only THz undulator radiation intensity with all polarizations



Sim. of edge radiation and THz undulator radiation intensity

Dump radiation profiles

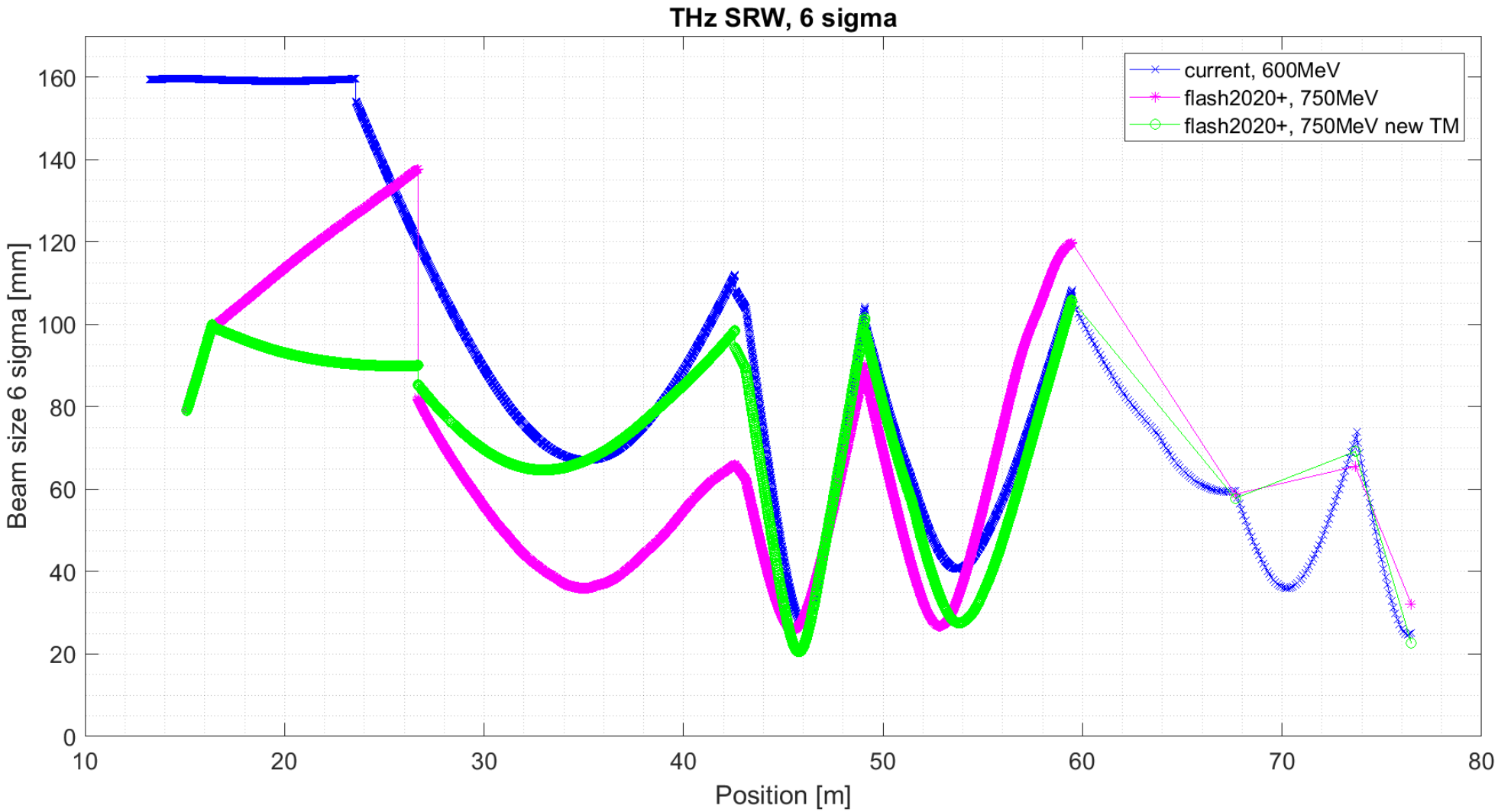
Pyro-detector 2D scanning

- Resolution on 2mm
- Measured in air, after a quartz window

Published in PhotonDiag2018

Adapted from T.Golz PhD Thesis

THz simulation by SRW



Beam size: by second moment method

Future perspektives on simulation

Simulation contents

- **THz Undulator** + OTR screen + **Dump magnet** by genesis/elegant
- **With bunch compressor or without bunch compressor**
- THz doubler scheme (Unseeded beam and seeded beam)

- **Wavefront** (import to WPG)
- Spectrum (broad bandwidth)
- **Power/energy**
- Polarization
- Temporal profile
- With e-bunch, not only an electron

Further discussions

- Pre-modulations in the e-bunch by laser heater to enhance THz generation (to be simulated)
- Discuss about high current for THz generation

THz simulation at HZDR

done by Ulf Lehnert from HZDR
THz simulation:
https://github.com/lehnertu/TEUFEL

Propagation:
https://github.com/lehnertu/pyOPC

THz beamline: people

THz team (FL-FS-B)

Seung-gi Gang: Scientist
Marc Temme: Engineer
Rui Pan: Scientist

Alumni

Nikola Stojanovic
Ekaterina Zapolnova
Torsten Golz

And people contribute:

Thanks for your attention!

Acknowledge

The whole **FLASH Team** and FS groups**: FS-BT, FS-EC,…**

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