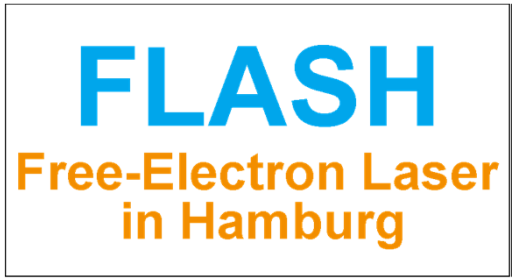
DESY Summer Student Program

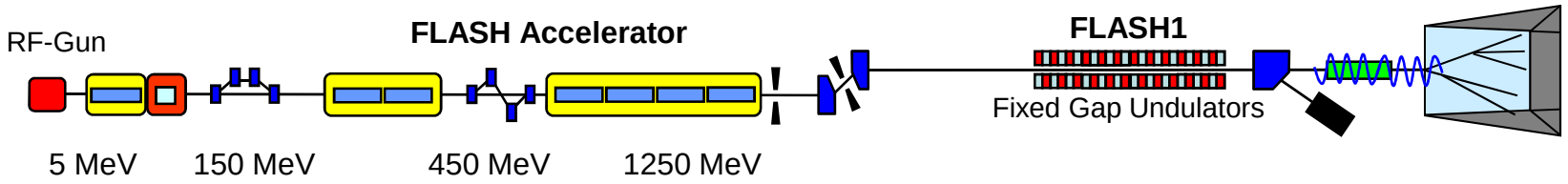
FLASH Reaching the Transition Metals

Valeri Vardanyan

Supervisor: Bart Faatz



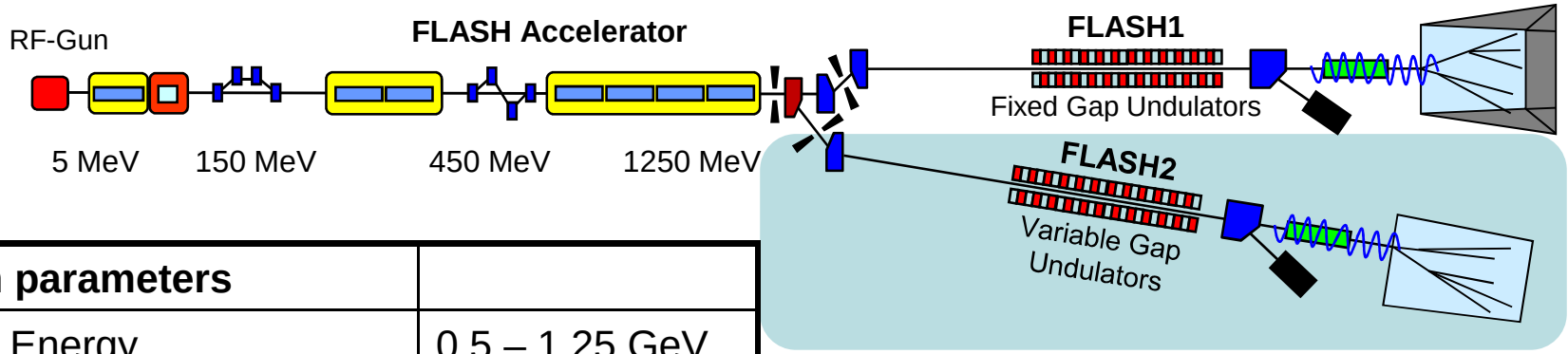
FLASH Layout



Beam parameters	
Beam Energy	0.38 – 1.25 GeV
Normalized emittance (proj.)	1.4 – 3 mm mrad
Energy spread	0.2 MeV
Peak Current	2.5 kA
Bunches per second	<8000
Bunch Charge	0.07 – 0.7 nC
Undulator parameters	
Period	27.3 mm
Segments length	4.5 m
Number of segments	6
Focusing Structure	F0D0

Radiation	**SASE**
Wavelength	4.2 – 44 nm
Pulse duration (FWHM)	10 – 500 fs
Peak power	1 – 5 GeV
Bandwidth	0.5 – 2 %
Number of pulses	< 8000
Peak Brilliance	10^{28} – 10^{31}
Pulse Energy	1 – 500 uJ

FLASH Upgrade: FLASH II



Beam parameters	
Beam Energy	0.5 – 1.25 GeV
Normalized emittance (proj.)	1.4 – 3 mm mrad
Energy spread	0.5 MeV
Peak Current	2.5 kA
Bunches per second	<8000
Bunch Charge	0.02 – 0.7 nC
Undulator parameters	
Period	**31.4 mm**
Segments length	2.5 m
Number of segments	12
Focusing Structure	F0D0

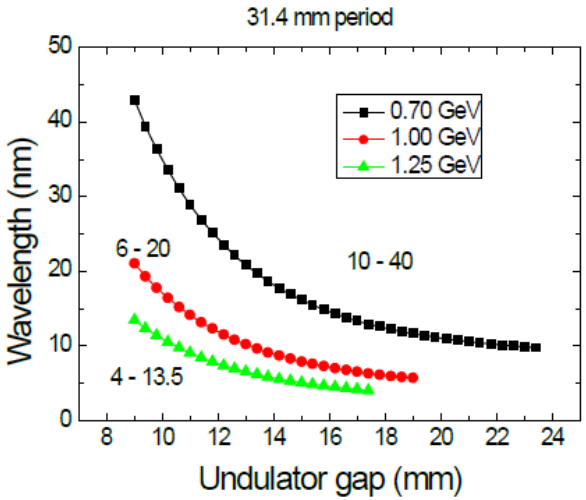
New tunnel for undulator

New Hall for experiments

FLASH Upgrade: FLASH II

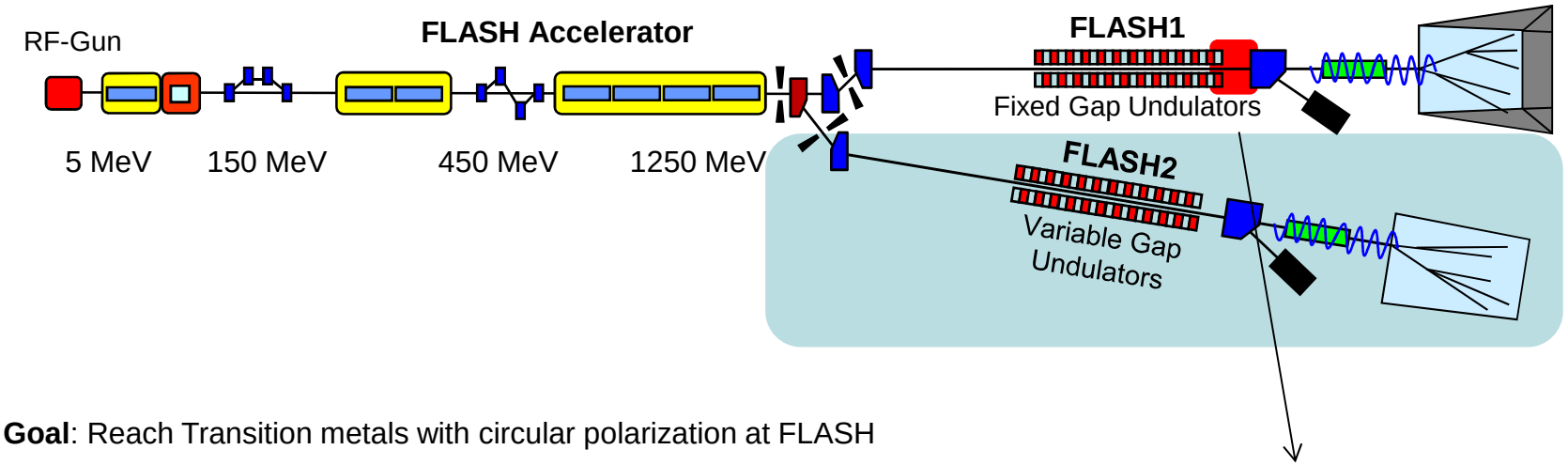
Radiation	SASE
Wavelength	4 – 60 nm
Pulse duration (FWHM)	10 – 500 fs
Peak power	1 – 5 GeV
Bandwidth	0.5 – 2 %
Number of pulses	< 8000
Peak Brilliance	10^{28} – 10^{31}
Pulse Energy	1 – 500 uJ

Expected beam parameters



Tunability > factor 3

FLASH Layout: Proposed



Main Goal: Reach Transition metals with circular polarization at FLASH

Cu: 1.33 nm

Ni: 1.45 nm

Co: 1.59 nm

Needed: energy upgrade to 1.6 GeV or higher and new undulator

2nd harmonic afterburner

Main Undulator

3.0 nm	1.5 nm
2.6 nm	1.3 nm

Possible intermediate step:

1. Energy upgrade to 1.4 GeV (easy to achieve) and a new undulator
2. Energy upgrade to 1.467 GeV (at the limit) with the existing one.

→Reach same wavelengths at reduced pulse energy at the 2nd harmonic (to be explained later)

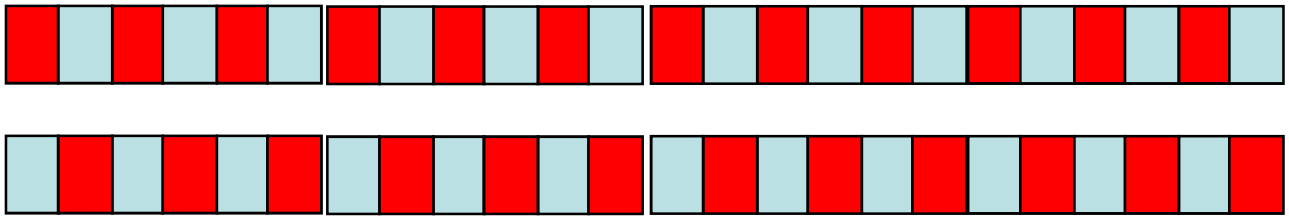
Questions:

Do we get enough pulse energy and short enough pulses for the experiments with this intermediate step

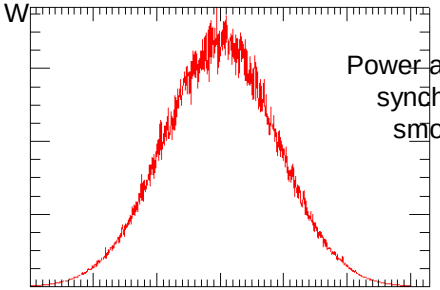
Harmonic Generation

Main Undulator

Afterburner

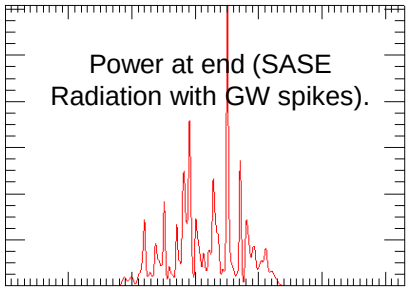


800 W

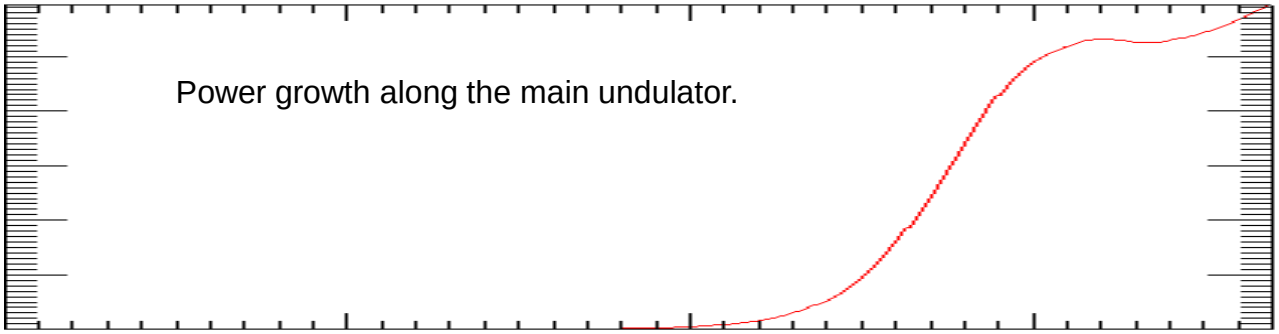


Power at beginning (normal synchrotron radiation): smooth at kW level.

10 GW

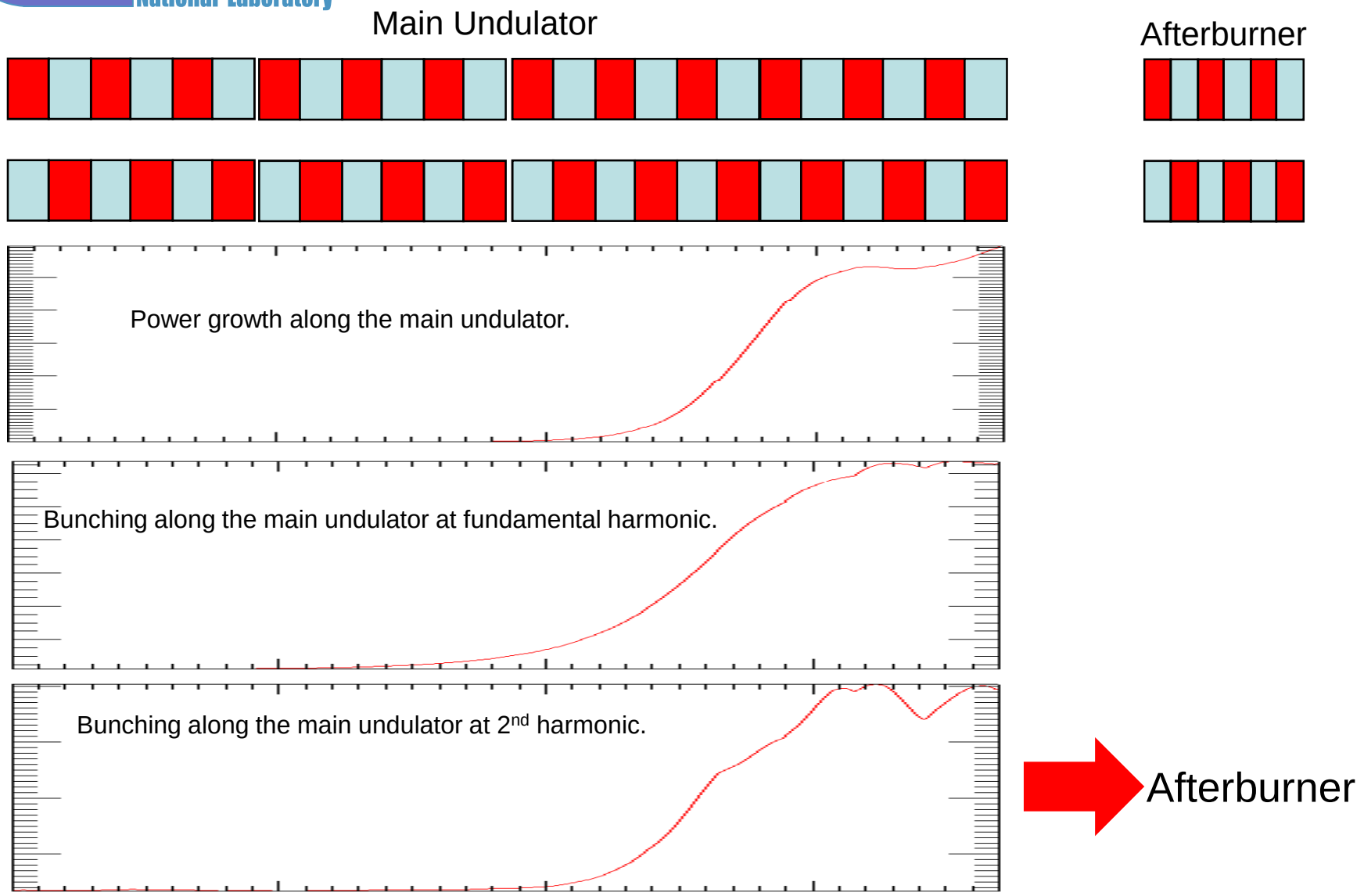


Power at end (SASE Radiation with GW spikes).



Power growth along the main undulator.

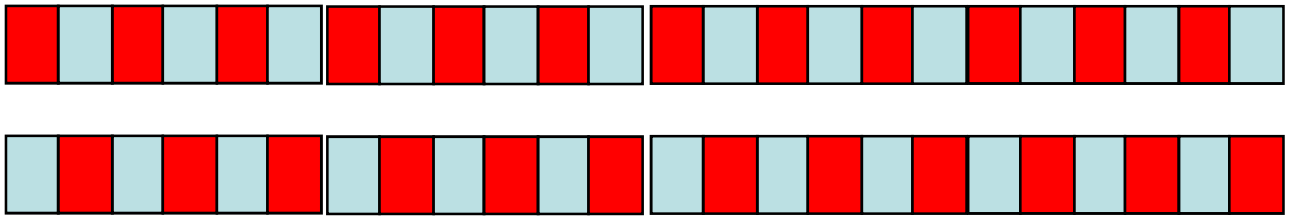
Harmonic Generation



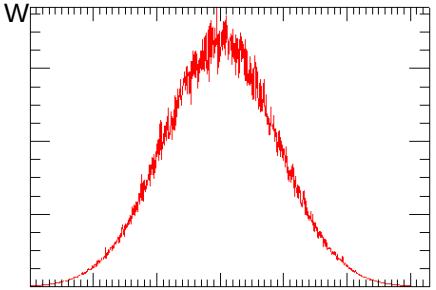
Harmonic Generation

Main Undulator

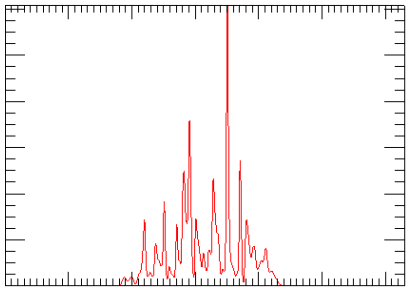
Afterburner



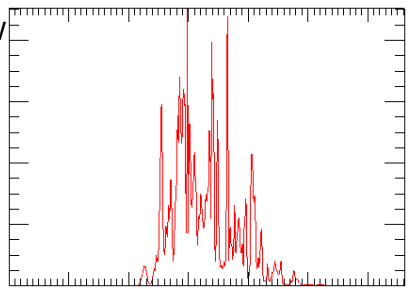
800 W

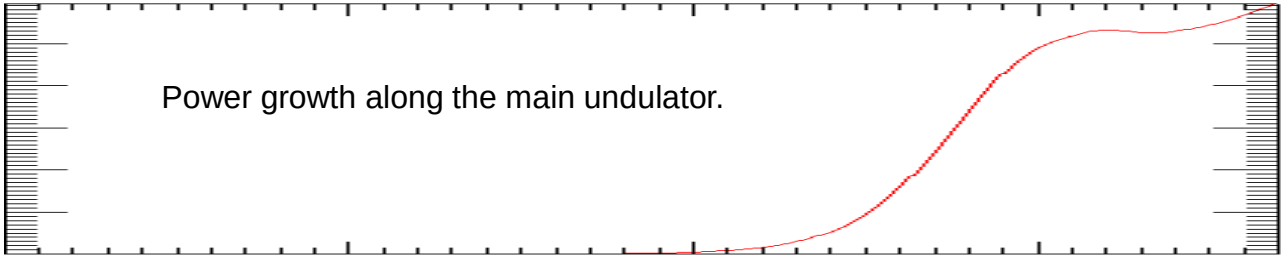


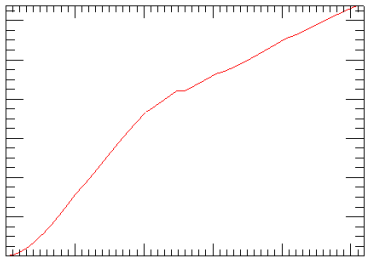
10 GW



80 MW







The Simulation Code

A. ALIKHANYAN National Laboratory

DESY

And God Said

$$\nabla \vec{D} = \rho_{\text{free}},$$
$$\nabla \vec{B} = 0,$$
$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t},$$
$$\nabla \times \vec{H} = \vec{J}_{\text{free}} + \frac{\partial \vec{D}}{\partial t},$$

And Then There Was Light.

Deusque Dixit Fiat Lux Et Facta Est Lux. (Bible, Genesis 1.3)

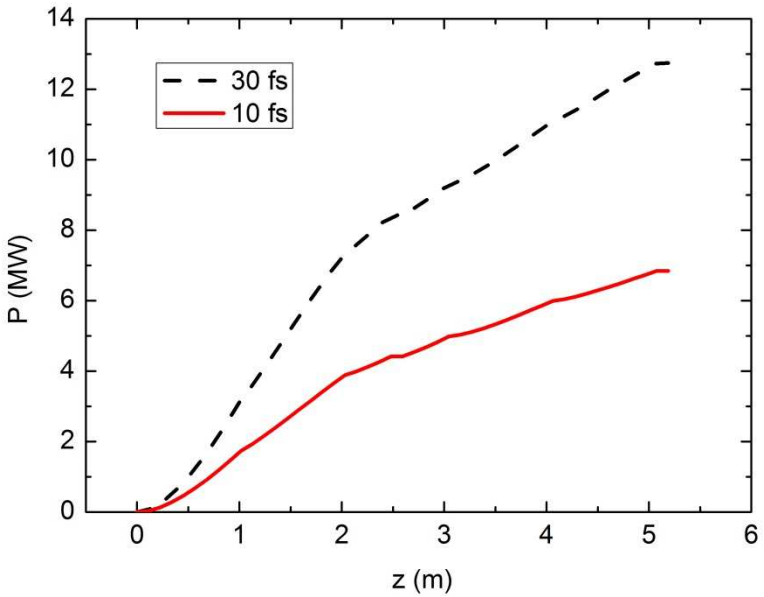
The Simulation Code

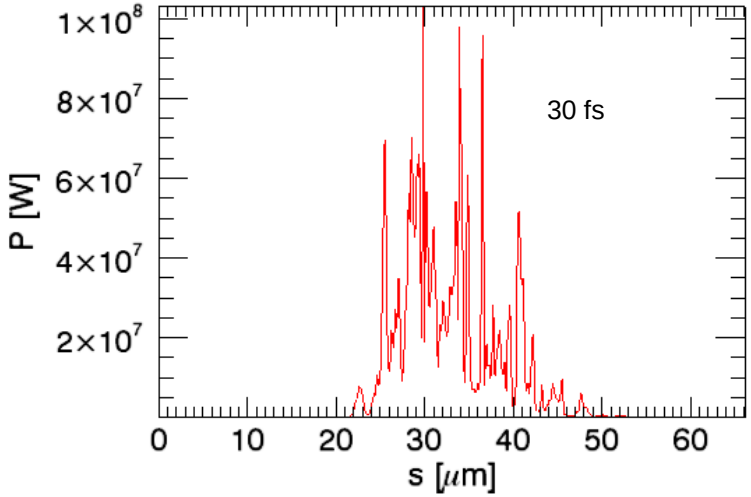
Genesis 1.3

- Simulates Interaction of electrons and radiation field.
- Assumes small bandwidth with radiation in the forward direction
- Solves ODEs by 4^{th} order Runge-Kutta method for particle dynamics and PDEs by method of finite differences for radiation.
- Time dependent simulations!

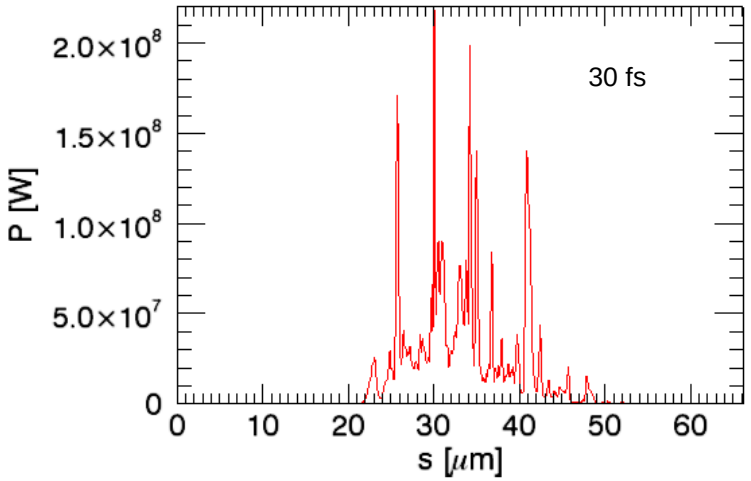
Results for 1.4 GeV, 1.5 nm

Undulator period main	30 mm	
K main	0,7	
Undulator period afterburner	18,8 mm	
K afterburner	0.4417	
Pulse energy, 10 fs	0.4 (uJ)	0.7 (uJ)
Pulse length, 10 fs	34 (fs)	35.7 (fs)
Pulse energy, 30 fs	1.9 (uJ)	2.8 (uJ)
Pulse length, 30 fs	99.3 (fs)	93.8 (fs)





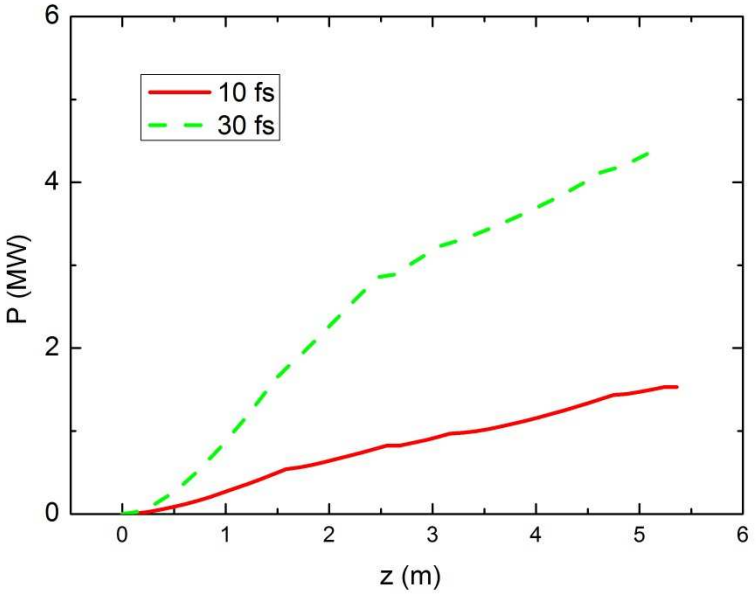
After 2.5 m Afterburner Undulator

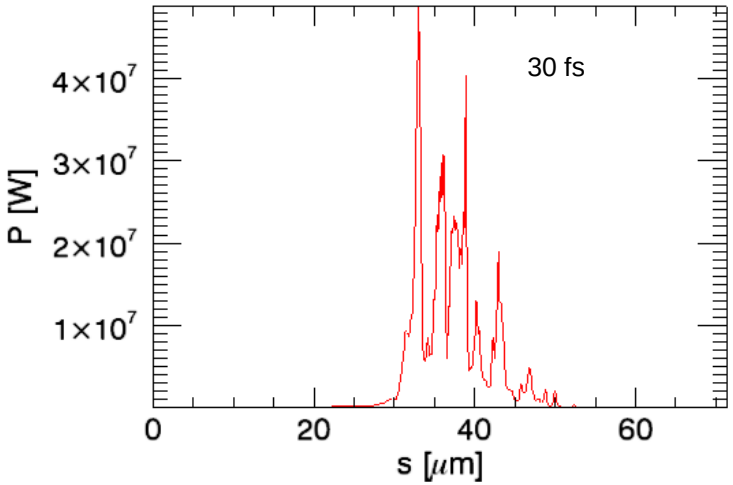


After 5 m Afterburner Undulator

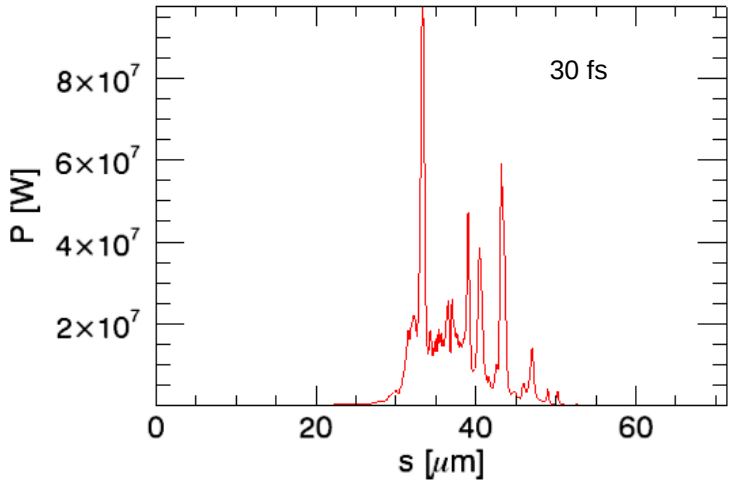
Results for 1.4 GeV, 1.3 nm

Undulator period main	26 mm	
K main	0,7	
Undulator period afterburner	17,4 mm	
K afterburner	0.3464	
Pulse energy, 10 fs	0.1 (uJ)	0.18 (uJ)
Pulse length, 10 fs	36.5 (fs)	31.1 (fs)
Pulse energy, 30 fs	0.68 (uJ)	1.04 (uJ)
Pulse length, 30 fs	90.27 (fs)	89 (fs)





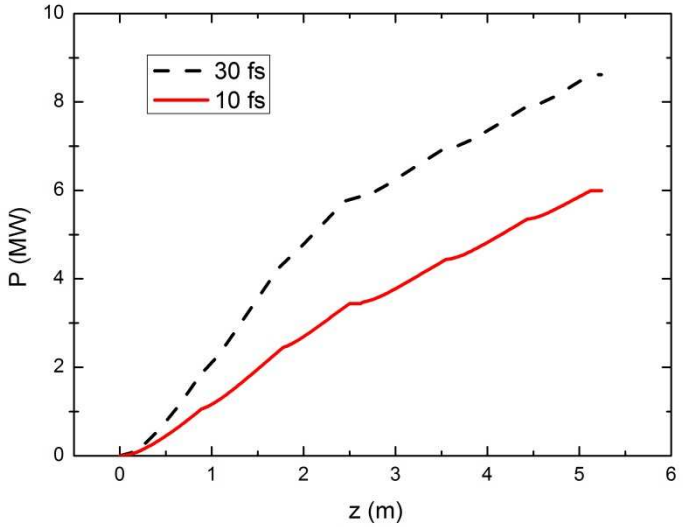
After 2.5 m Afterburner Undulator

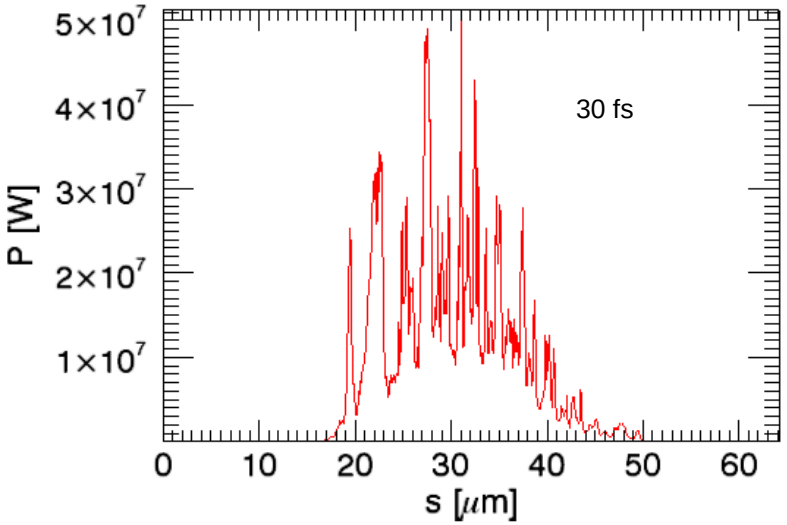


After 5 m Afterburner Undulator

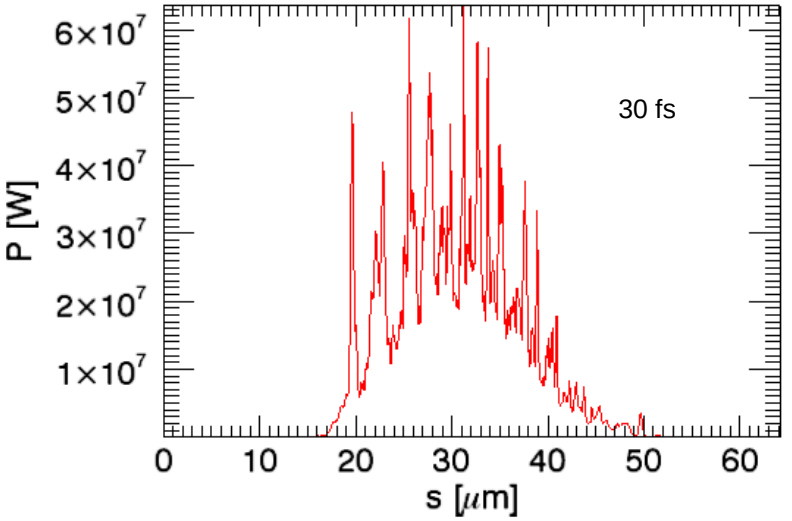
Results for 1.467 GeV, 1.5 nm

Undulator period main	27,3 mm	
K main	0,9	
Undulator period afterburner	19,7 mm	
K afterburner	0.505	
Pulse energy, 10 fs	0.29 (uJ)	0.56 (uJ)
Pulse length, 10 fs	42.4 (fs)	42.8 (fs)
Pulse energy, 30 fs	1.25 (uJ)	1.84 (uJ)
Pulse length, 30 fs	113.8 (fs)	119.7 (fs)





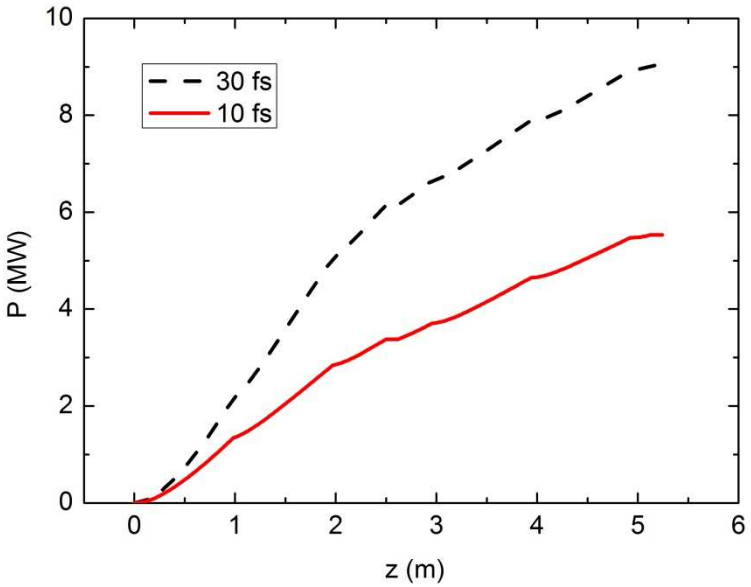
After 2.5 m Afterburner Undulator

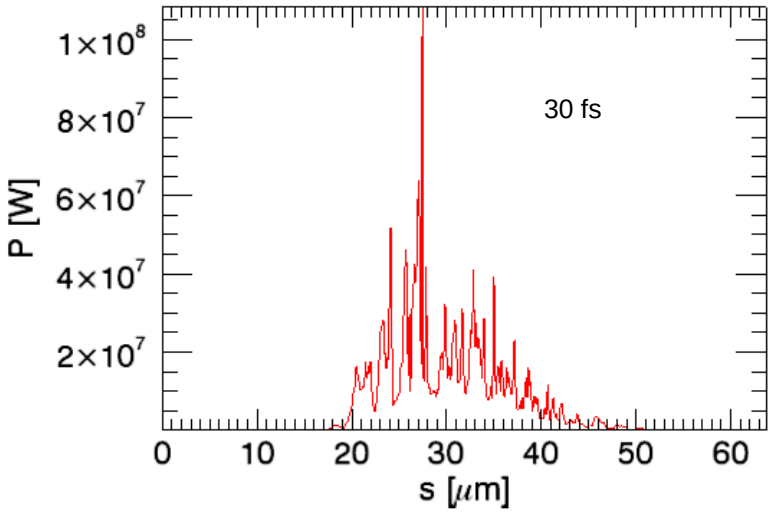


After 5 m Afterburner Undulator

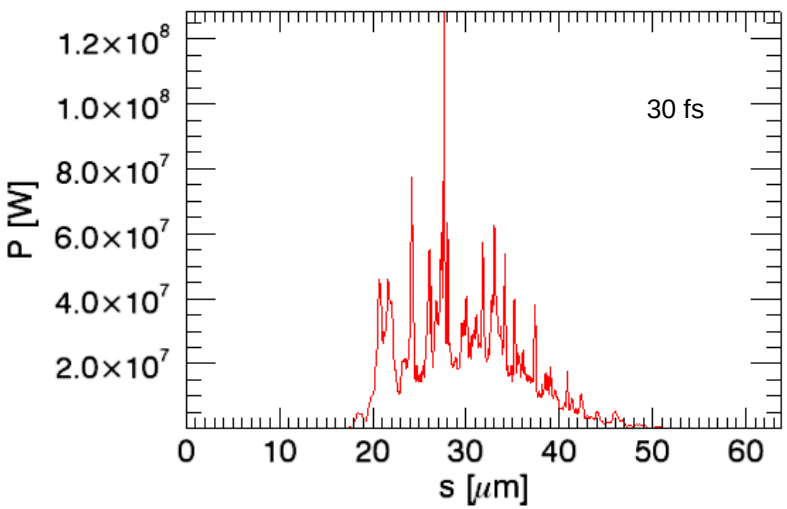
Results for 1.575 GeV, 1.3 nm

Undulator period main	27,3 mm	
K main	0,9	
Undulator period afterburner	19,7 mm	
K afterburner	0.505	
Pulse energy, 10 fs	0.29 (uJ)	0.5 (uJ)
Pulse length, 10 fs	42.6 (fs)	42.6 (fs)
Pulse energy, 30 fs	1.3 (uJ)	1.9 (uJ)
Pulse length, 30 fs	105.5 (fs)	114.1 (fs)





After 2.5 m Afterburner Undulator



After 5 m Afterburner Undulator

Conclusion

We can make radiation at the wavelengths for transition metals.

Level of 0.1 to 2 uJ.

Pulse duration of 30 to 120 fs.

Danke Schöne