Exploring the capabilities of the Trojan Horse method to drive X-ray FEL's*

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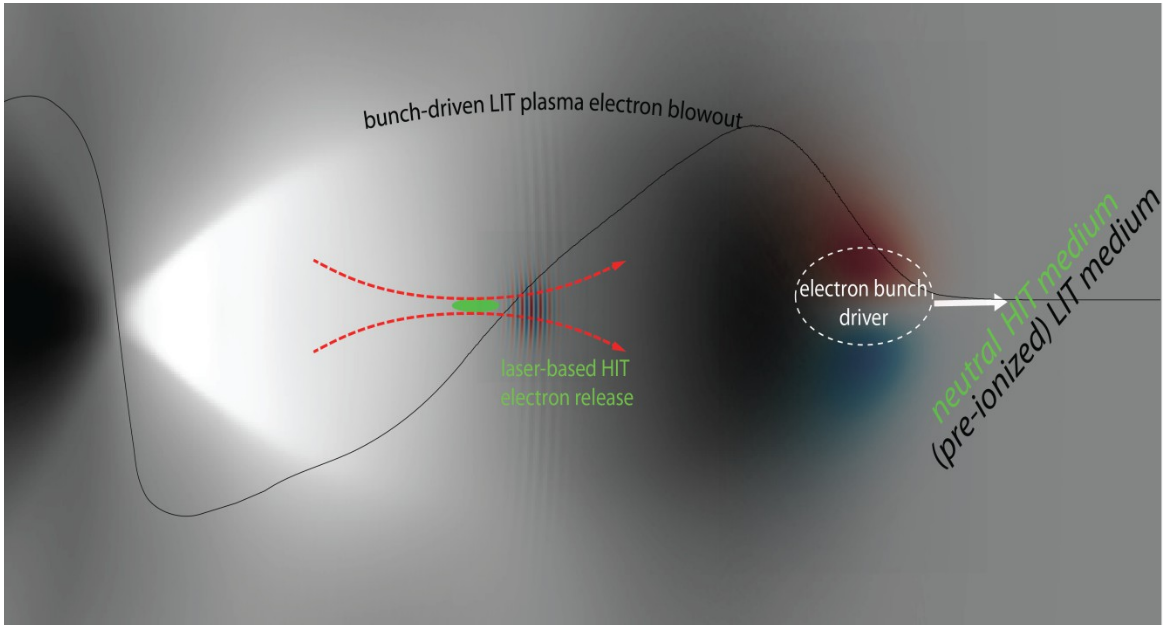
Motivation

The Trojan Horse technique[1] is used to create extreme electron witness bunches utilized in a free electron lasing process to produce few nm level wavelengths. We present results of coupled PIC and FEL code simulations and discuss the capabilities and limits of the Trojan Horse method to create suitable free electron laser drive bunches as well as the undulator configuration for them to generate high gain X-ray radiation.



[1] B. Hidding et al., Phys. Rev. Lett. **108**, 035001 (2012)

Trojan Horse requires:

- low/high ionization threshold medium (LIT/HIT)
- strong drive bunch to set up the blowout in LIT
- synchronized, low-intensity laser pulse to release HIT electrons within blowout

1. Optimization of the Trojan Horse Method

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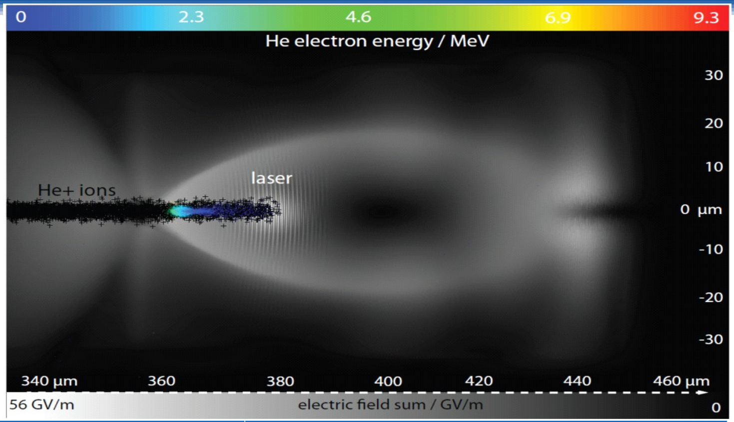


directly accessible parameters

hydrogen density n_H, helium density n_{He}

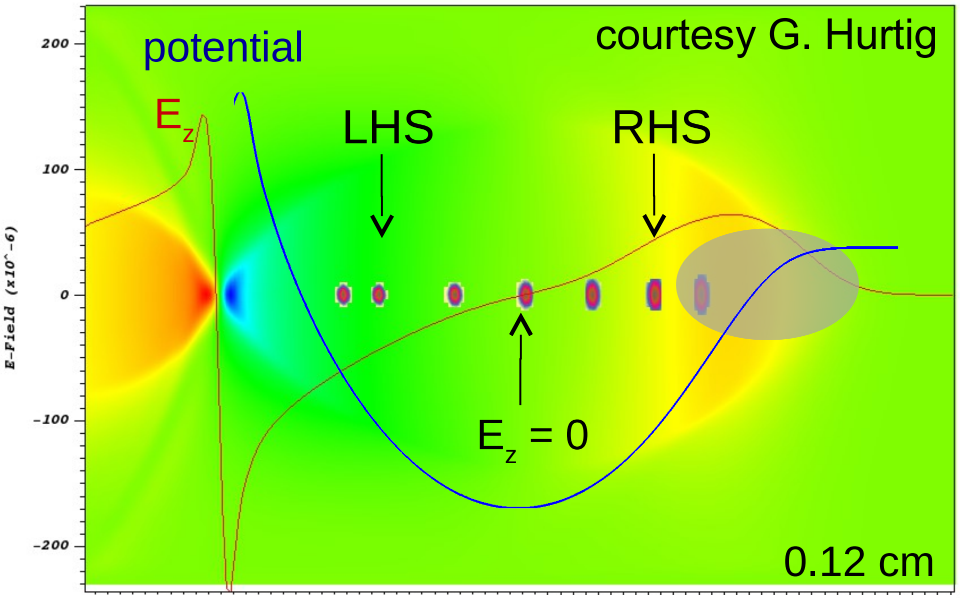
laser parameters w_0, a_0, τ_{laser}, focal position

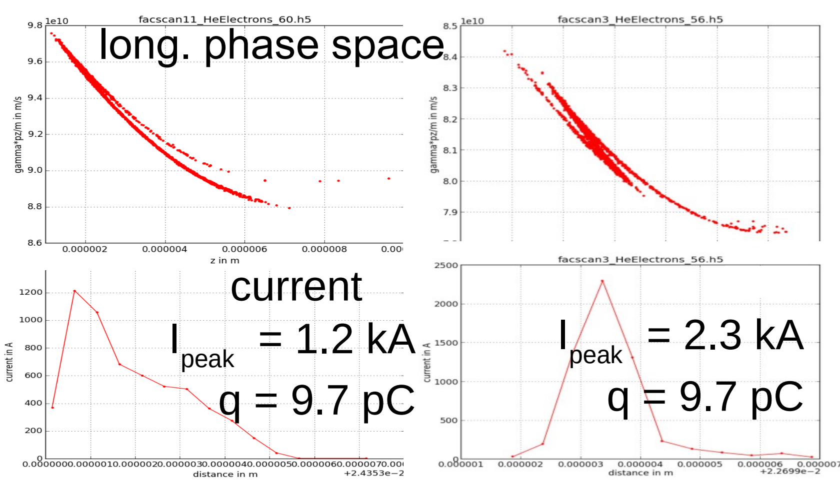
requirements for high amplification at few nm wavelengths

	required quality	limiting condition	influeced by
slice energy spread σ_E/E	<1 %	pierce parameter	dE_z/dz
energy E	0.5 – 5 GeV	wavelength	E_z
peak current I_{peak}	>1 kA	pierce parameter	q, distribution of charge
charge q	>10 pC	# photons	n_{He}, τ_{laser}, a_0
bunch length σ_z	1-10 µm	slippage	$\lambda_p(n_H)$, τ_{laser}
emittance ε_n	<5e-7 m rad	overlap	w_0, a_0

1. Optimization of the Trojan Horse Method

Injection: different laser foci (release positions)





Vsim simulation conditions:

n_H = 5e+21 /m³

n_{He} = 5e+23 /m³

a_0 = 0.018

w_0 = 7 µm

τ_{laser} = 25 fs

RHS bunch at 15 cm

charge = 9.75 pC

rms bunch length = 0.72 µm

bunch length = 5.5 µm

mean energy = 1.09 GeV

energy deviation =13.5 MeV

energy spread = 0.012

rms emittance z = 2.34e-08 m rad

peak current = 2.3 kA

2. Beam Transport & Matching

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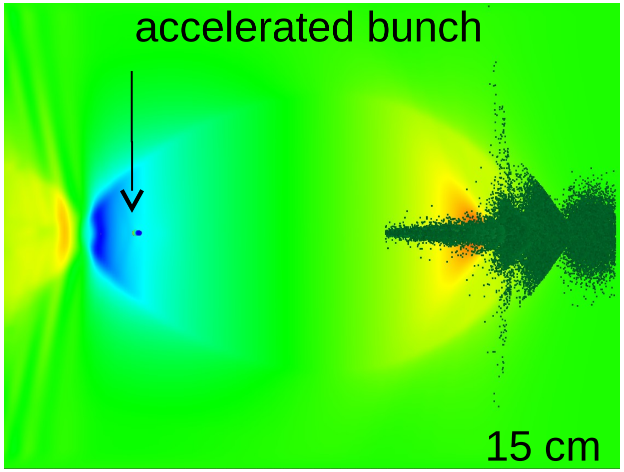
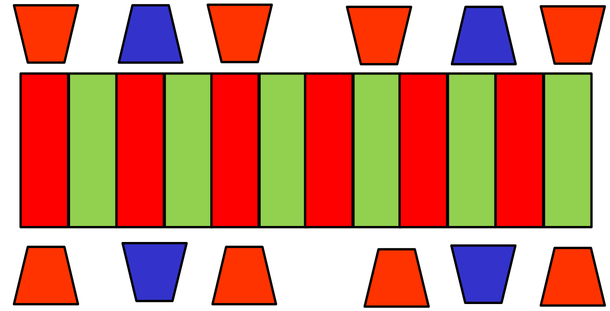
plasma

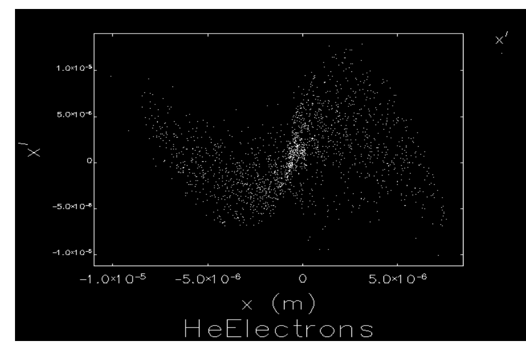


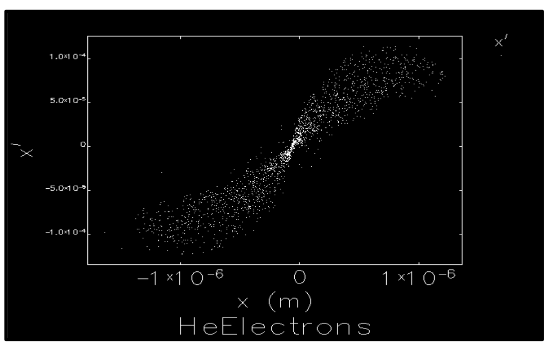
beam transport and matching

undulator
with focusing



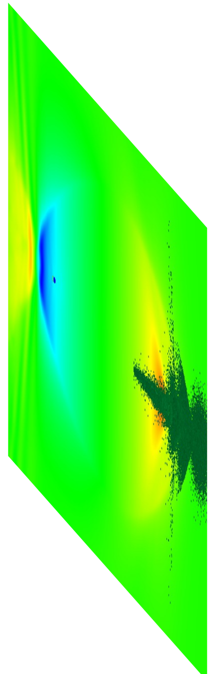
β_x[m]	β_y[m]	α_x[m]	α_y[m]	ε_x[m rad]	ε_y[m rad]
2.65e-2	2.60e-2	-2.67	-2.62	2.34e-8	2.33e-8

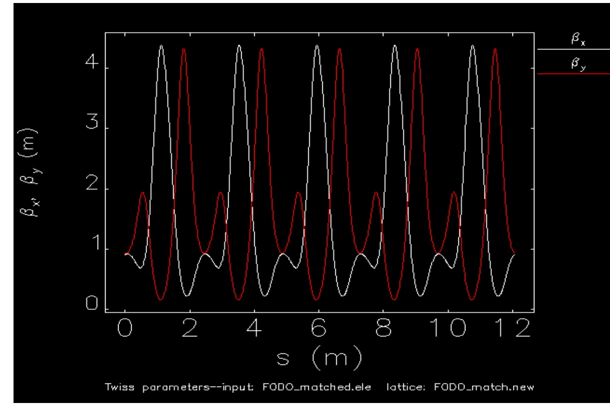


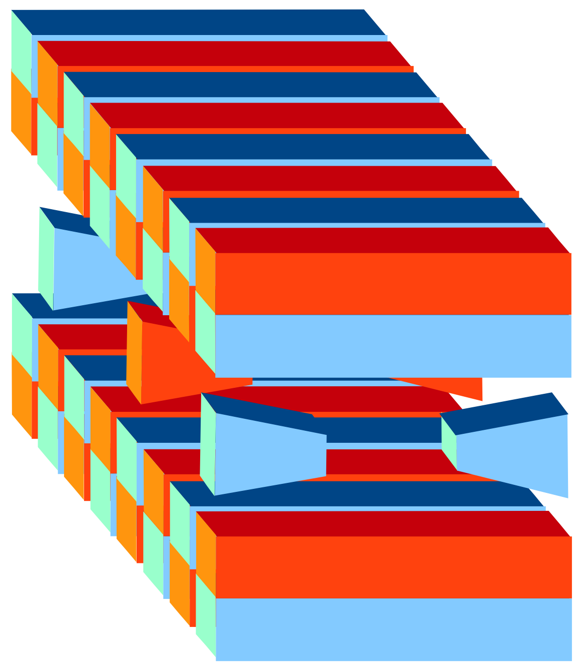


β_x[m]	β_y[m]	α_x[m]	α_y[m]	ε_x[m rad]	ε_y[m rad]
90.6e-2	94.2e-2	-18.4e-2	18.7e-2	2.58e-8	2.47e-8

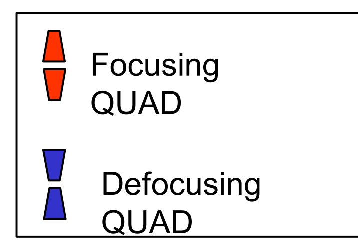
The “water window”—the soft x-ray wavelength range from 2.3 to 4.5 nm—holds great interest for biologists, chemists and physicists alike.





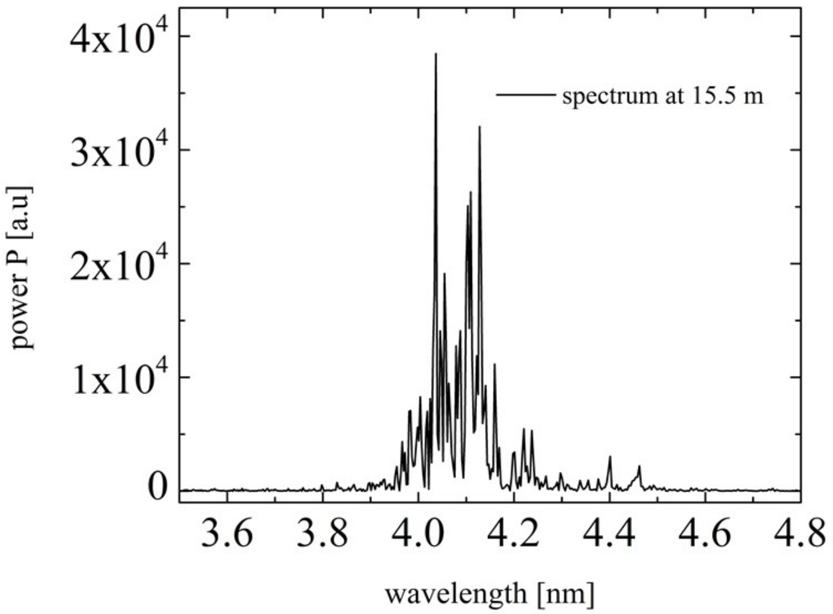


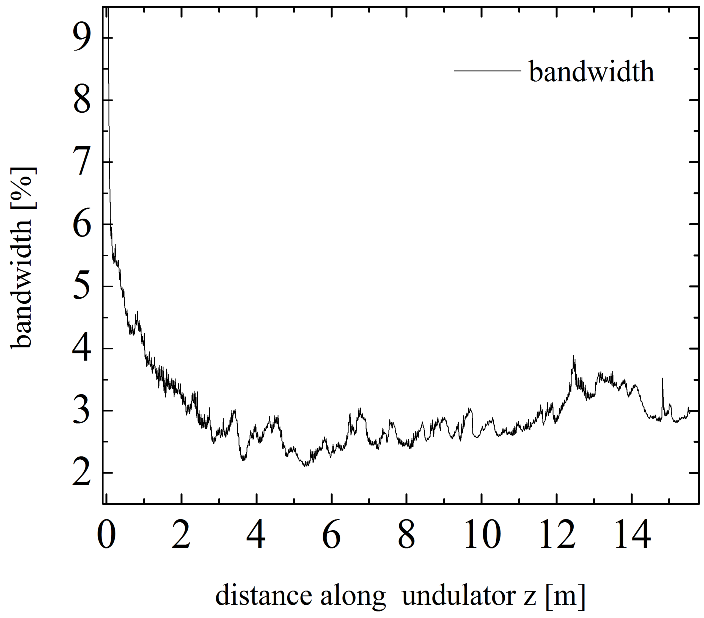
undulator
$a_u = 1.2$
$\lambda_u = 1.5$ cm



	quad strengt [1/m²]	Length [m]
QF 7.4	3.8	0.3
drift		0.152
QD	-10.7	0.3
drift		0.152
QF	7.4	0.3

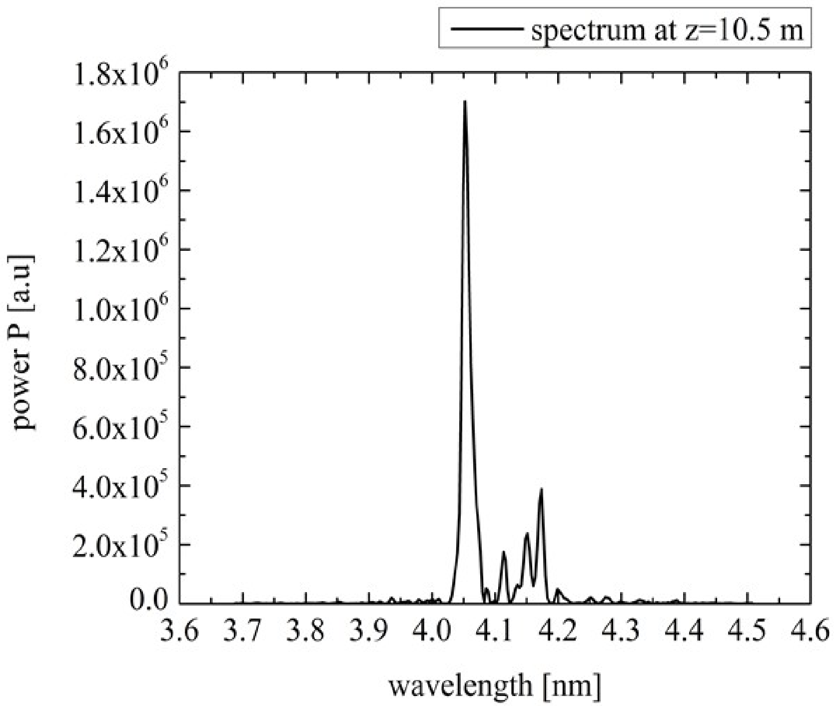
FEL radiation at 4nm resonant wavelength without focusing

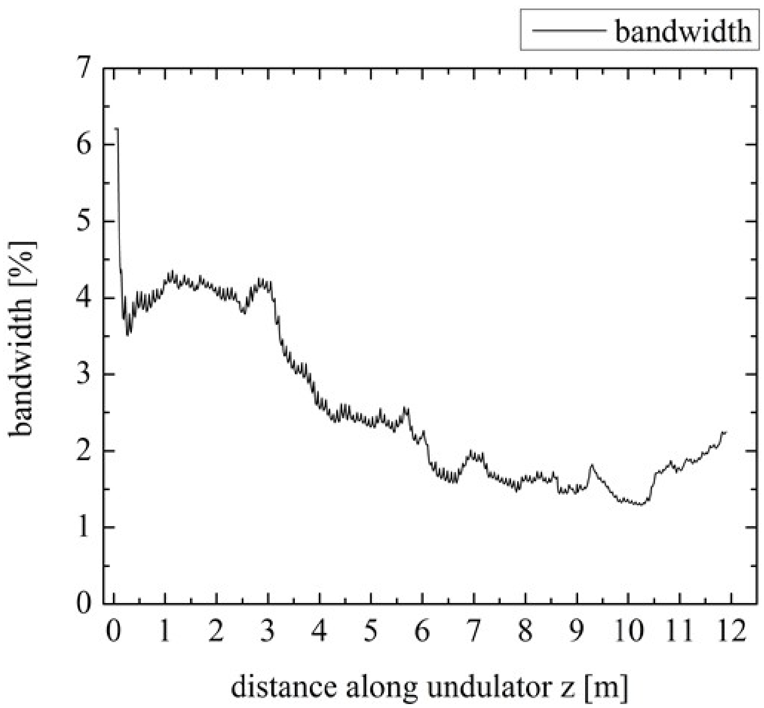




courtesy F. Habib

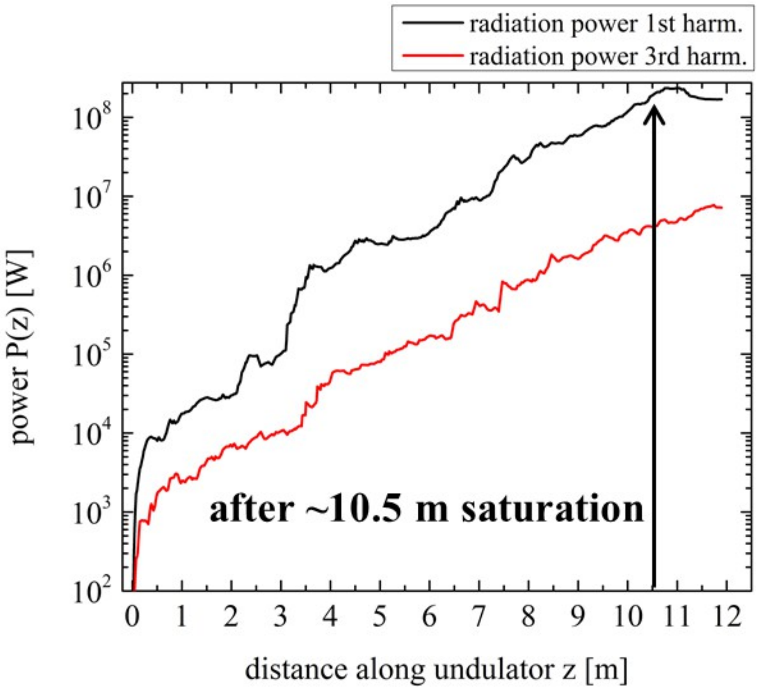
FEL radiation at 4nm resonant wavelength with focusing

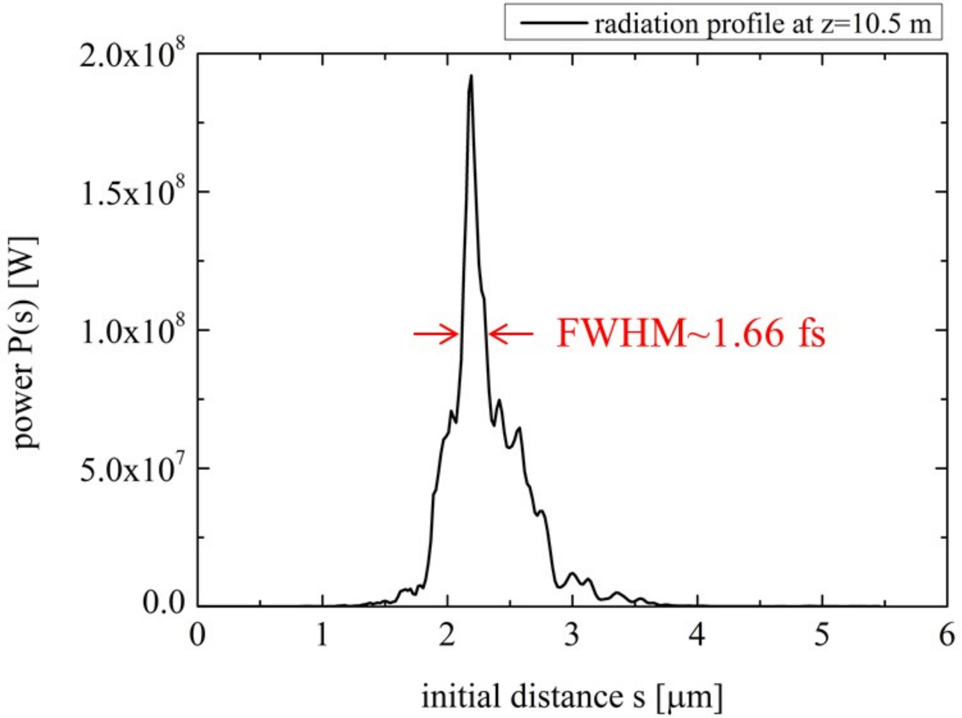




courtesy F. Habib

FEL radiation at 4nm resonant wavelength with focusing





Lsat ~ 10.5 m
Psat ~ 0.19 GW
FWHM pulse duration ~ 1.66 fs
max pulse duration ~ 7.5 fs

4. Conclusion & Outlook

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- realization will be challenging, many problems need to be solved: experimental realization of Trojan Horse, extraction from the plasma, transport & matching ...
- Trojan Horse bunches are natural candidates for generation of short-wavelength radiation in novel compact light sources
- Hundreds of MW's power can be gained with external focusing and matching in state-of-the-art undulators

4. Acknowledgements

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[1] B.W.J. McNeil, "desXie - an MATLAB code for solving the Free Electron Laser design formulae of M. Xie", http://phys.strath.ac.uk/eurofel/rebs/desXie/desXie.htm (2004)

[1] Ming Xie, 'Design Optimization for an x-ray free electron laser driven by SLAC linac', Proc Of 1995 Part. Accel. Conf. (1996), 183-185

Grazie per l' attenzione