New Scheme to Generate a Multi-Terawatt & Attosecond X-ray Pulse in XFELs

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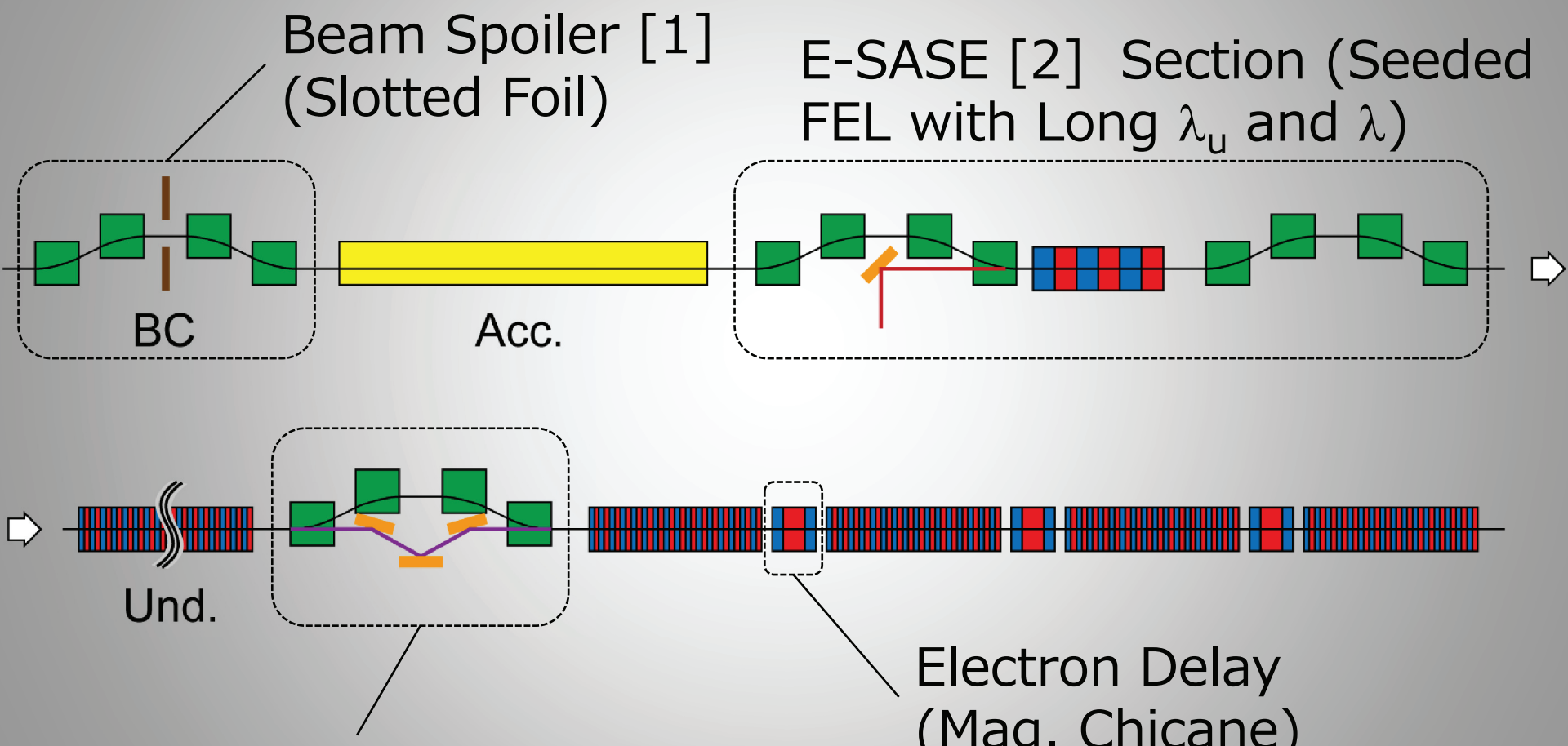
Laser Pulse Compression

- Pulse compression is a normal technique in optical lasers (T^3 laser)
  - Ultra-short pulse (a few cycles)
  - High peak power (TW level)
- How about in XFELs?
  - A number of techniques for “pulse shortening”, but not “pulse compression”
  - Traditional scheme with optics seems challenging

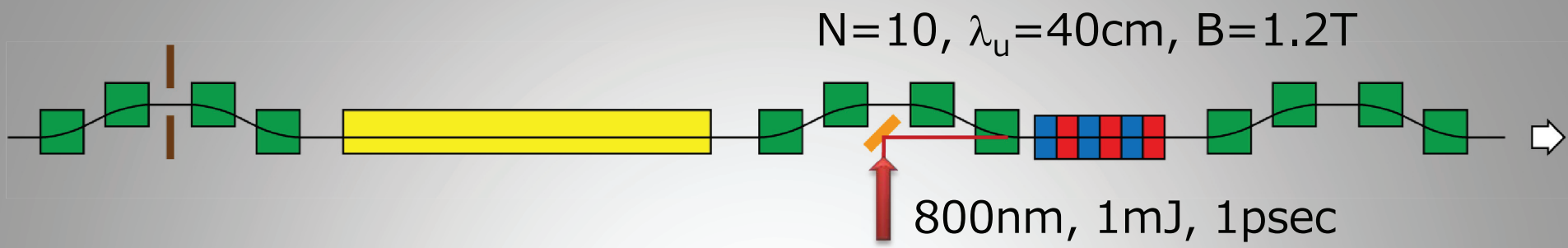
New Scheme for Pulse Compression*

*T. Tanaka, PRL 110, 084801 (2013)



[1] P. Emma et al. PRL 92, 074801 (2004)
[2] A. A. Zholents, PRST-AB 8, 040701 (2005)
[3] G. Geloni et al., DESY 10-004

Current Profile Before Undulator



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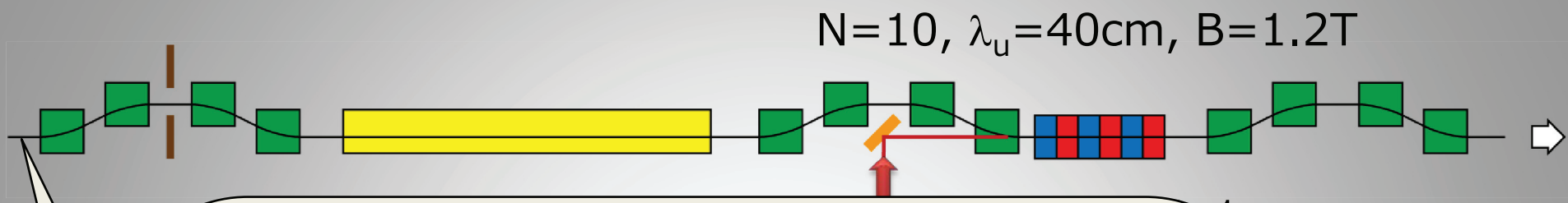
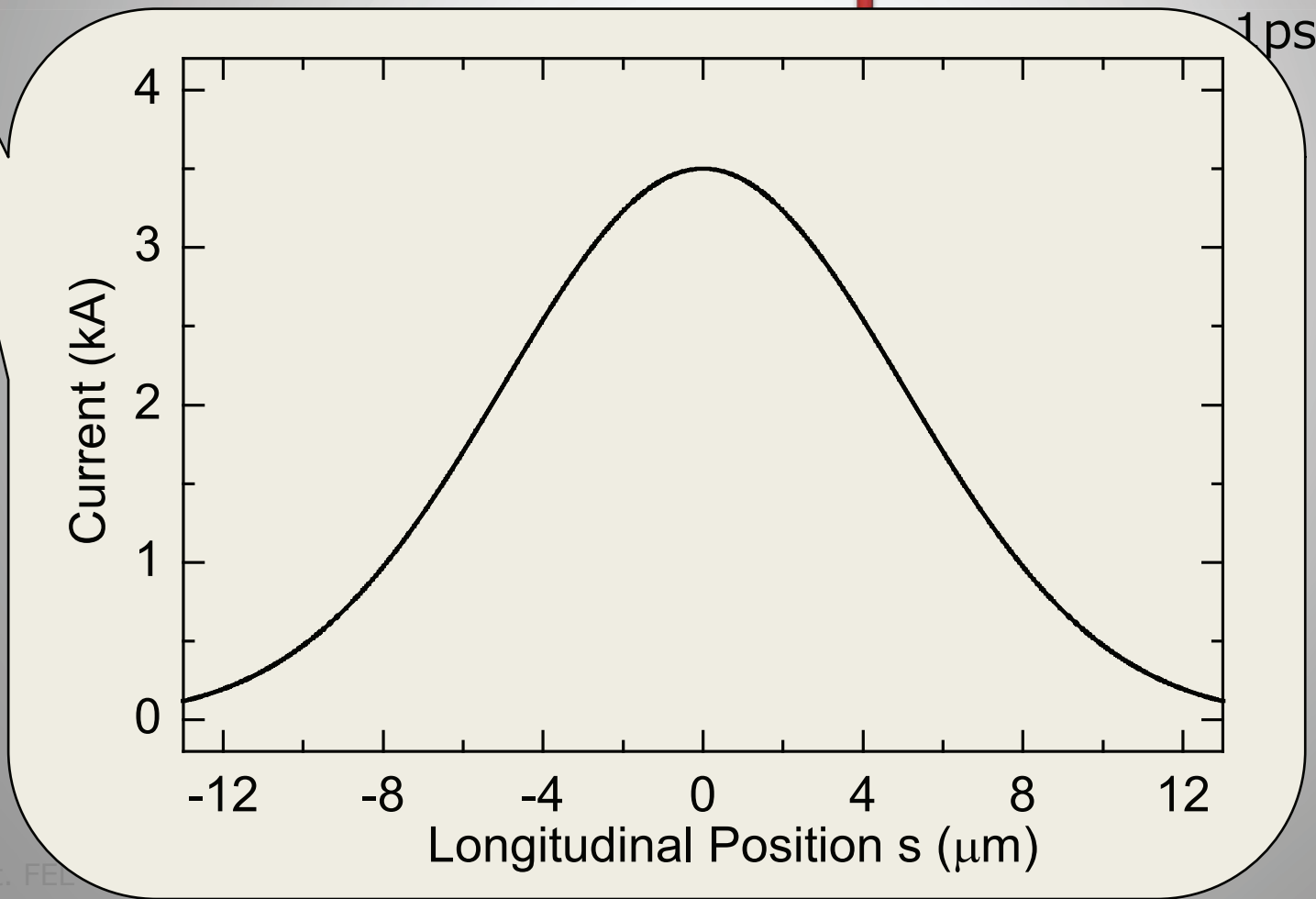
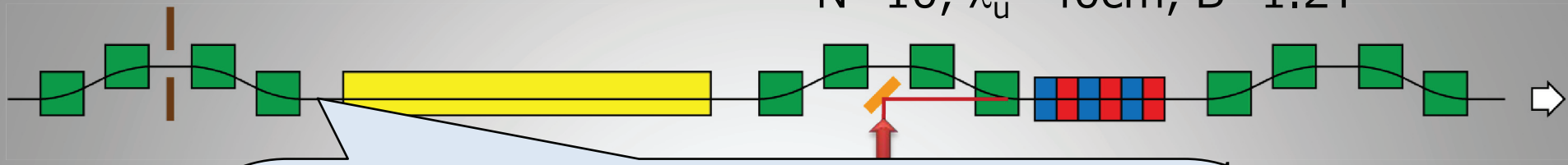
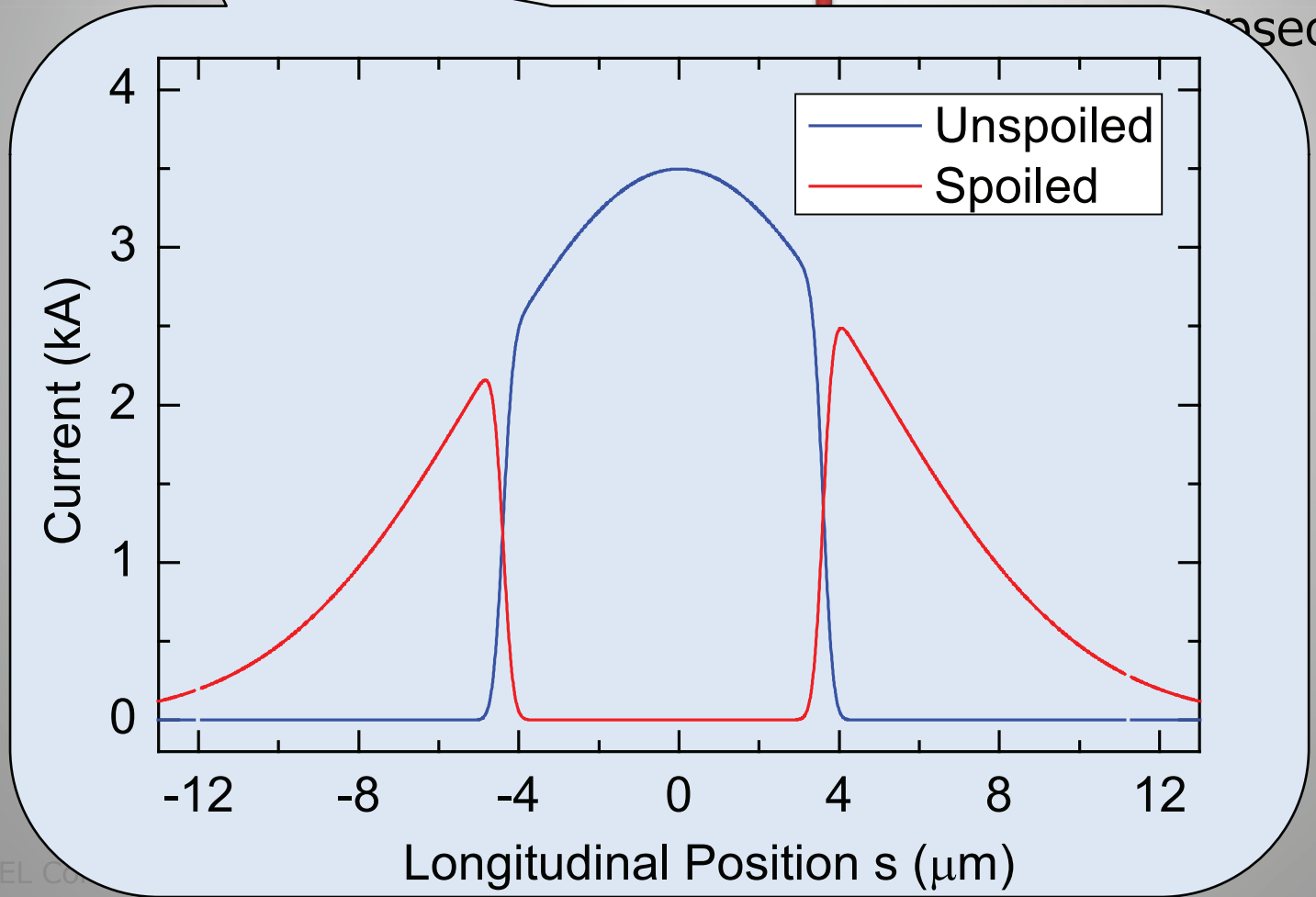




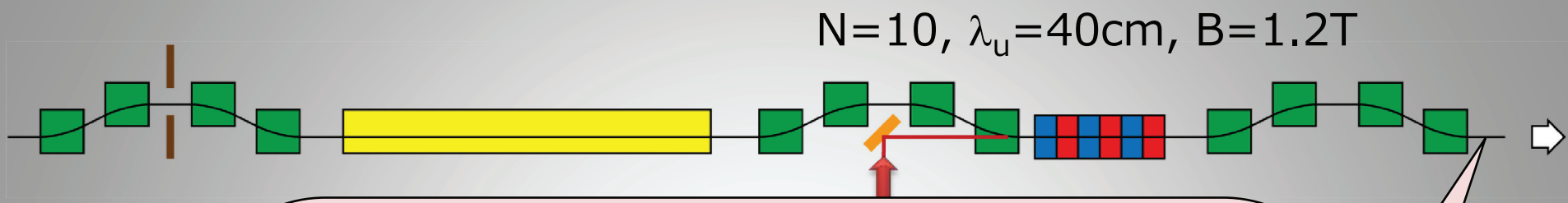
Current Profile Before Undulator

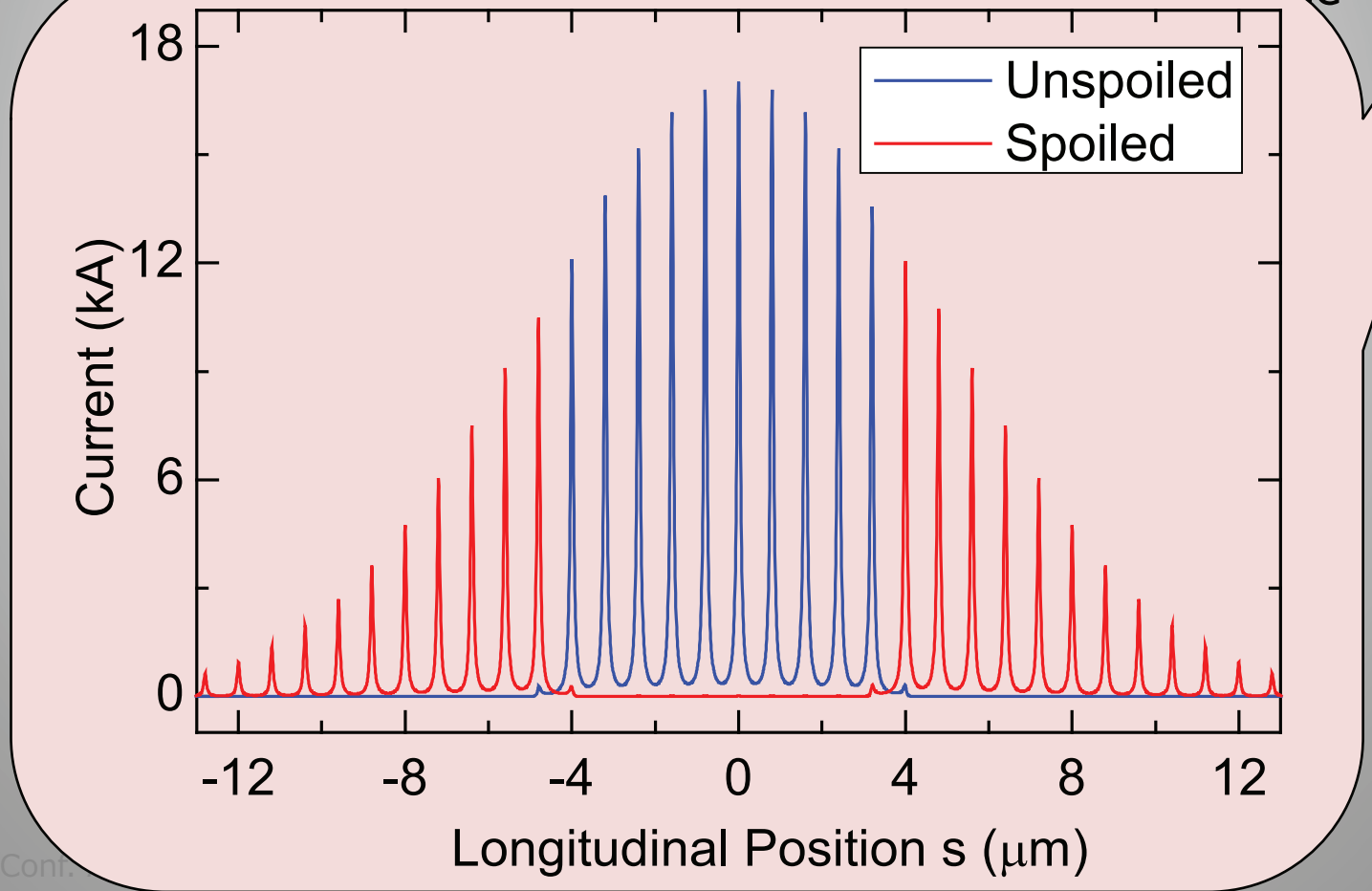
N=10, λ_u=40cm, B=1.2T



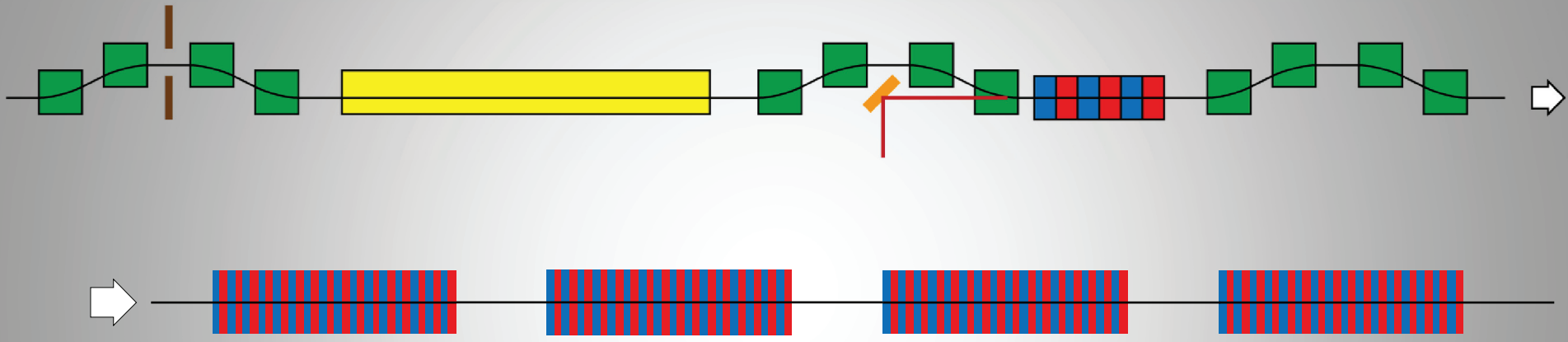


Current Profile Before Undulator





How It Works?



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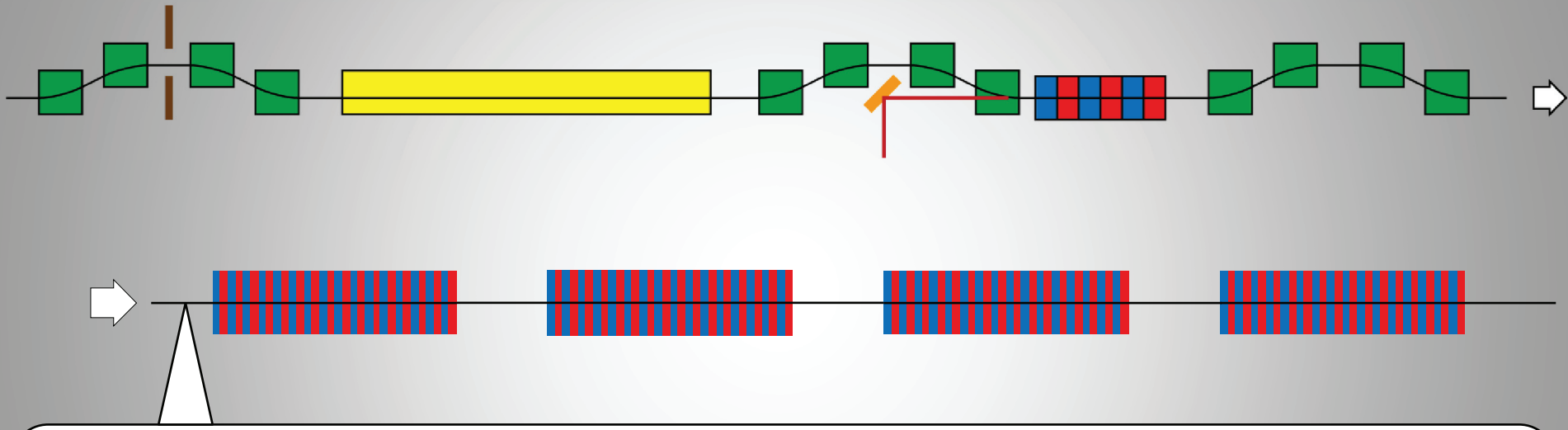
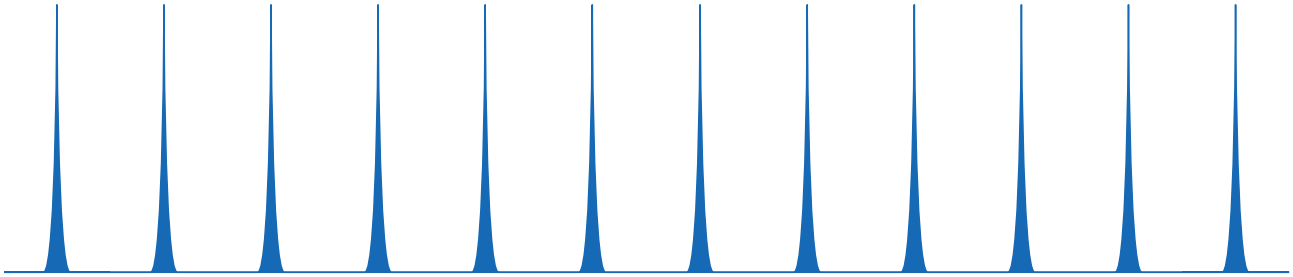


Electron Beam



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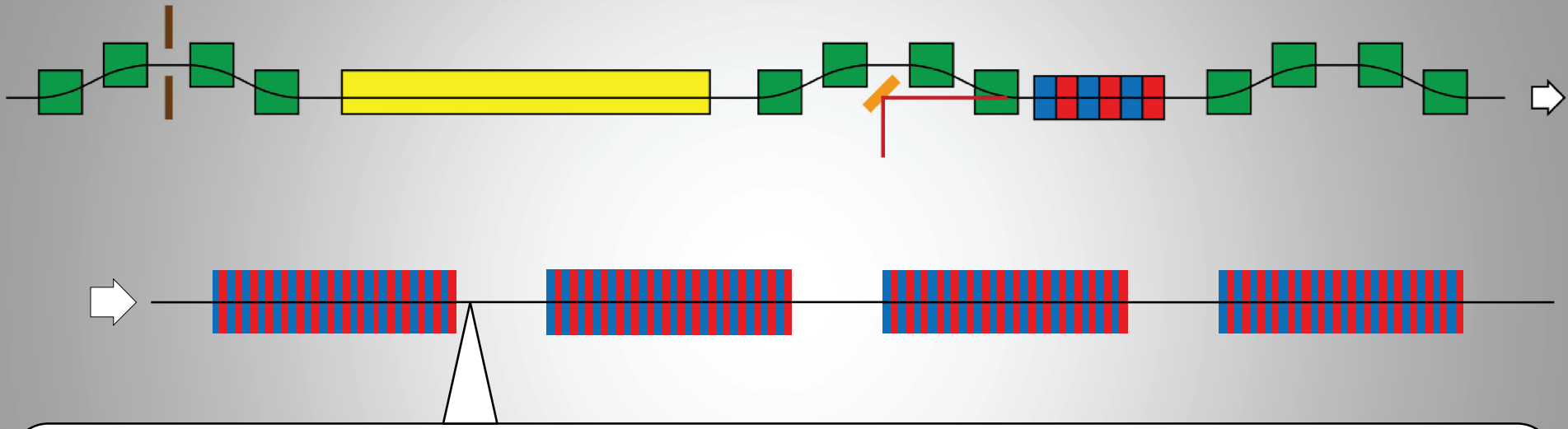

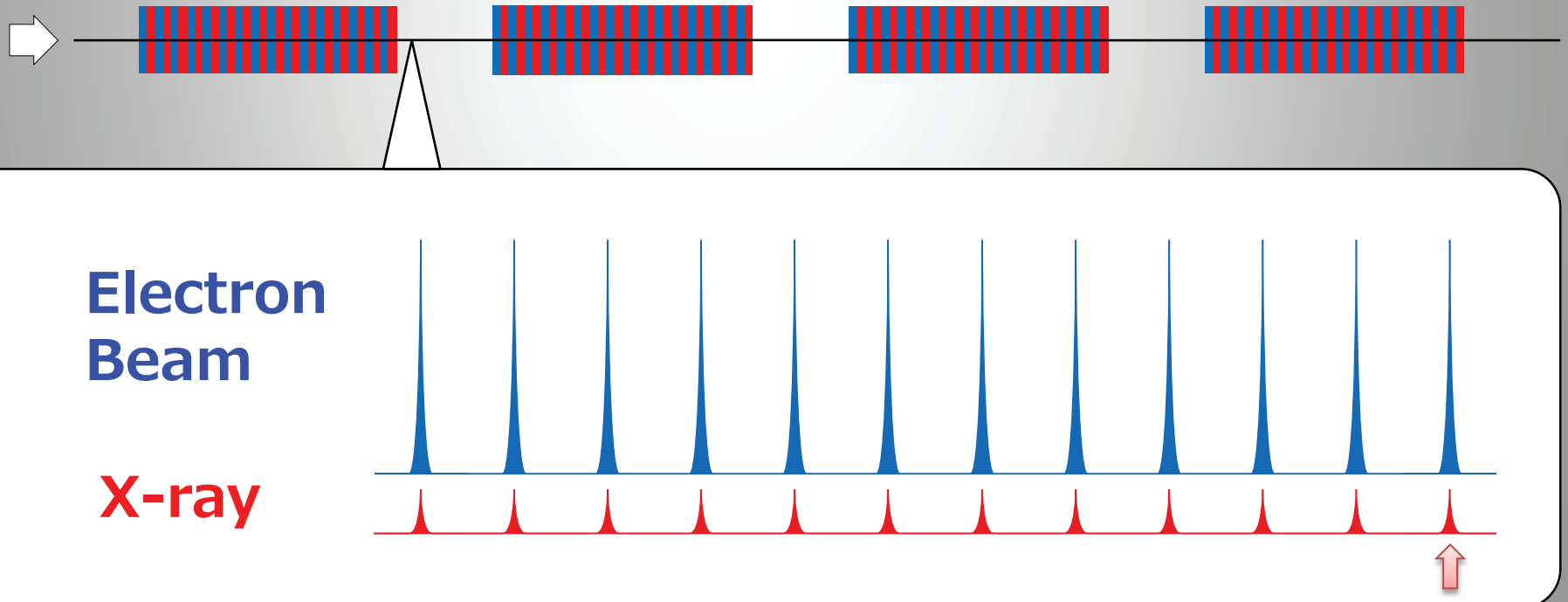

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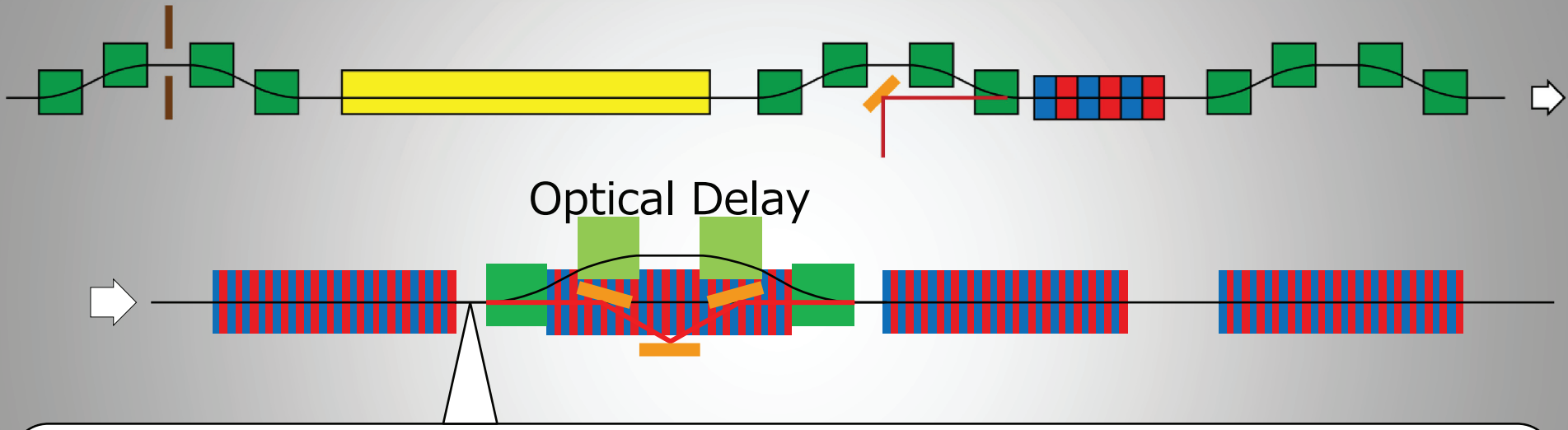

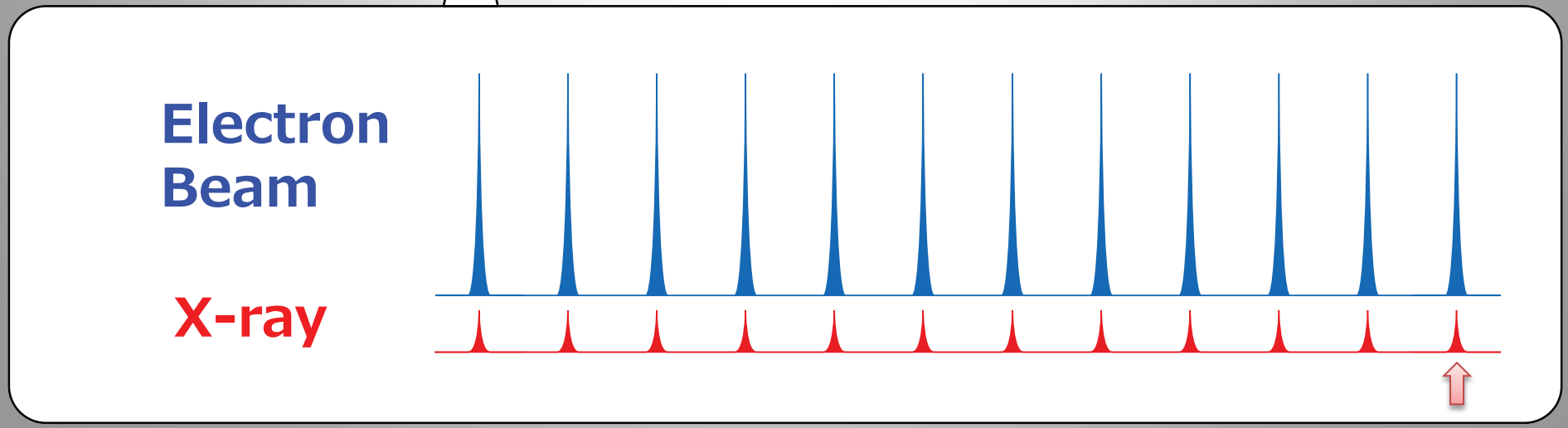

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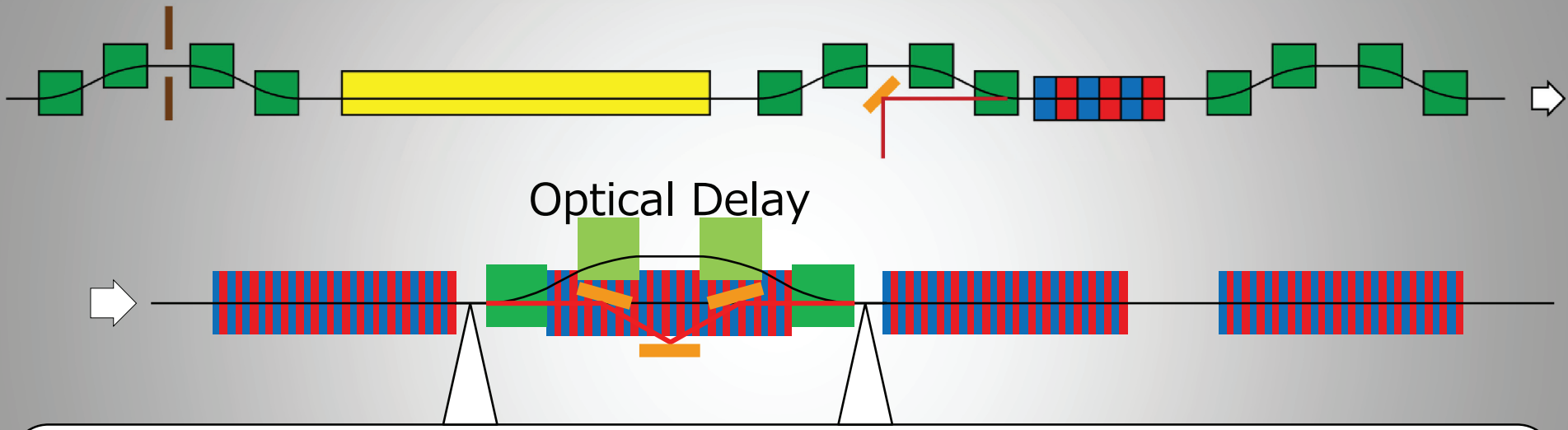

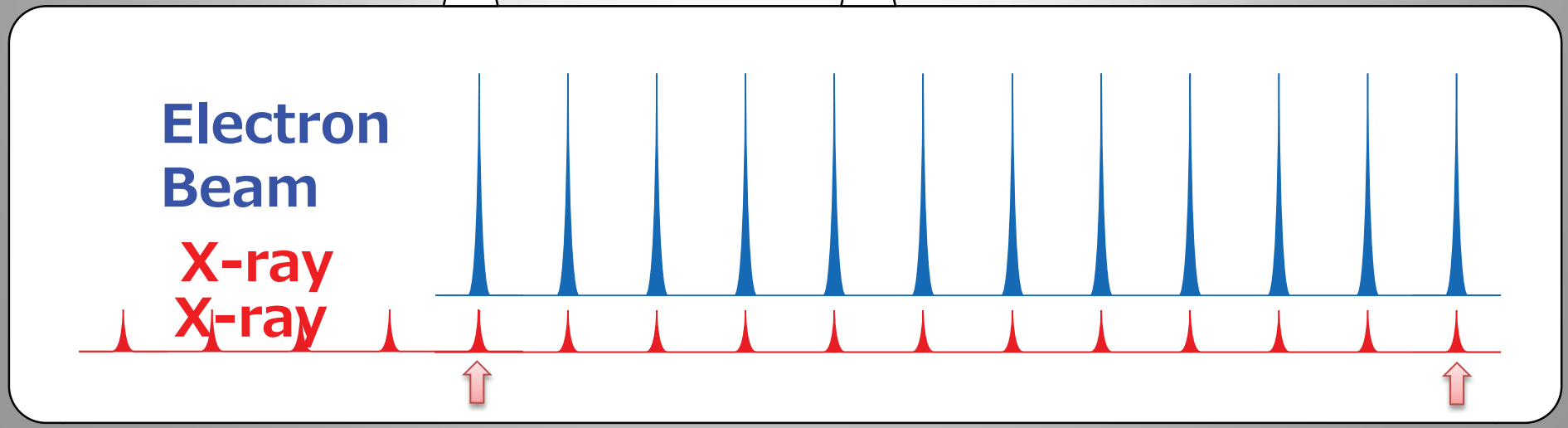

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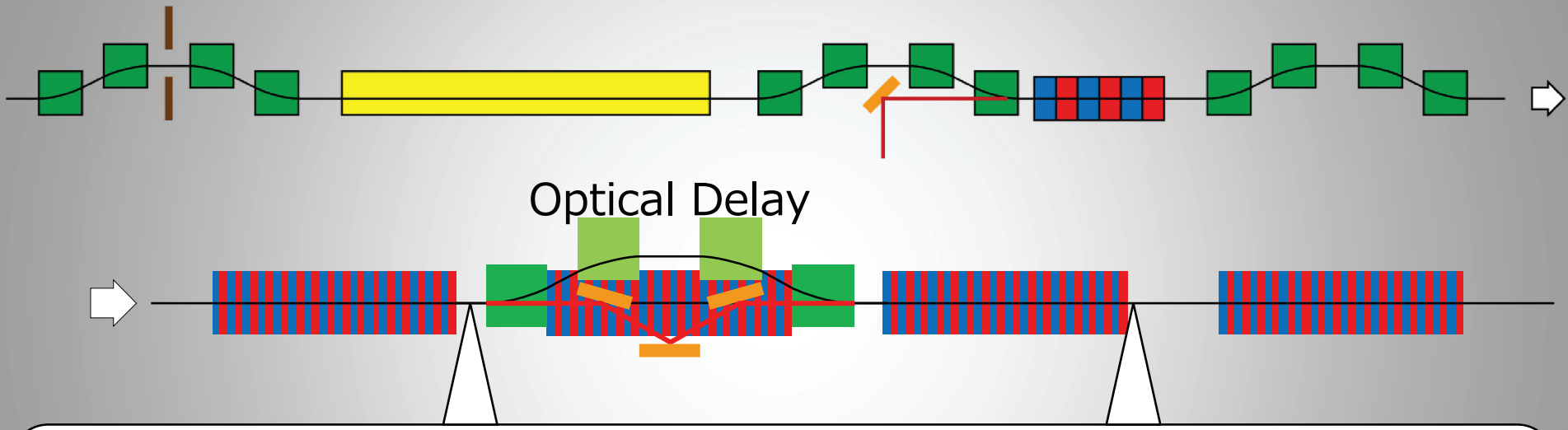

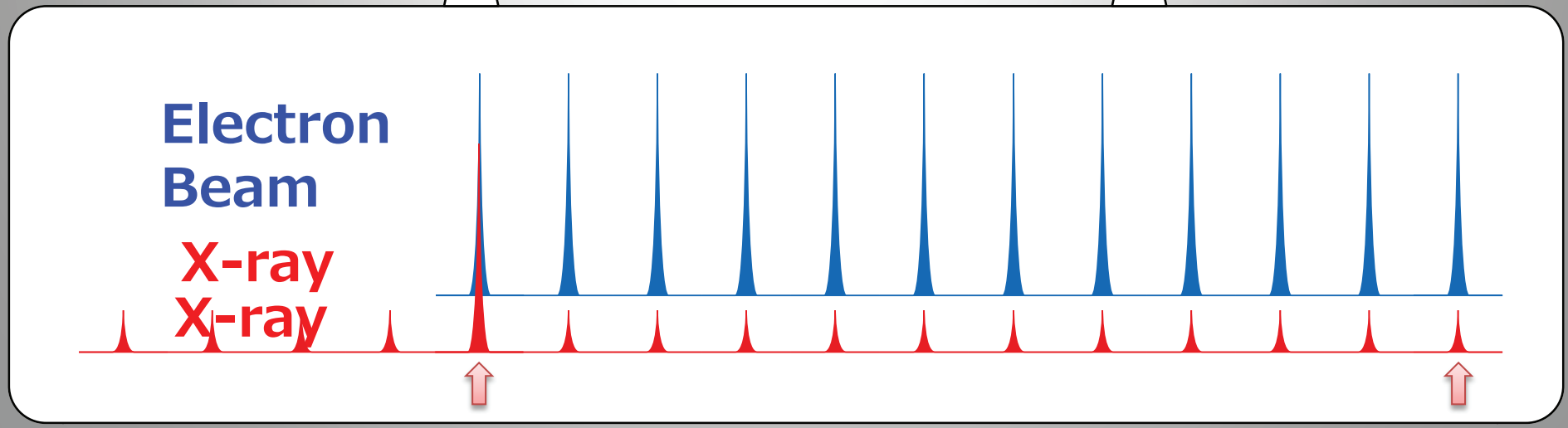

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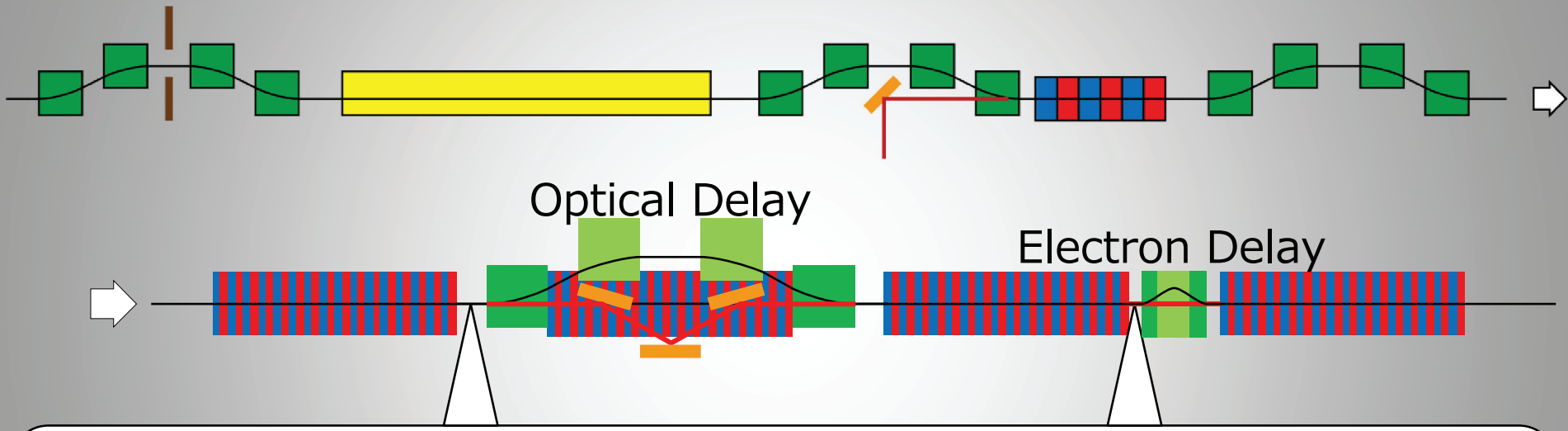

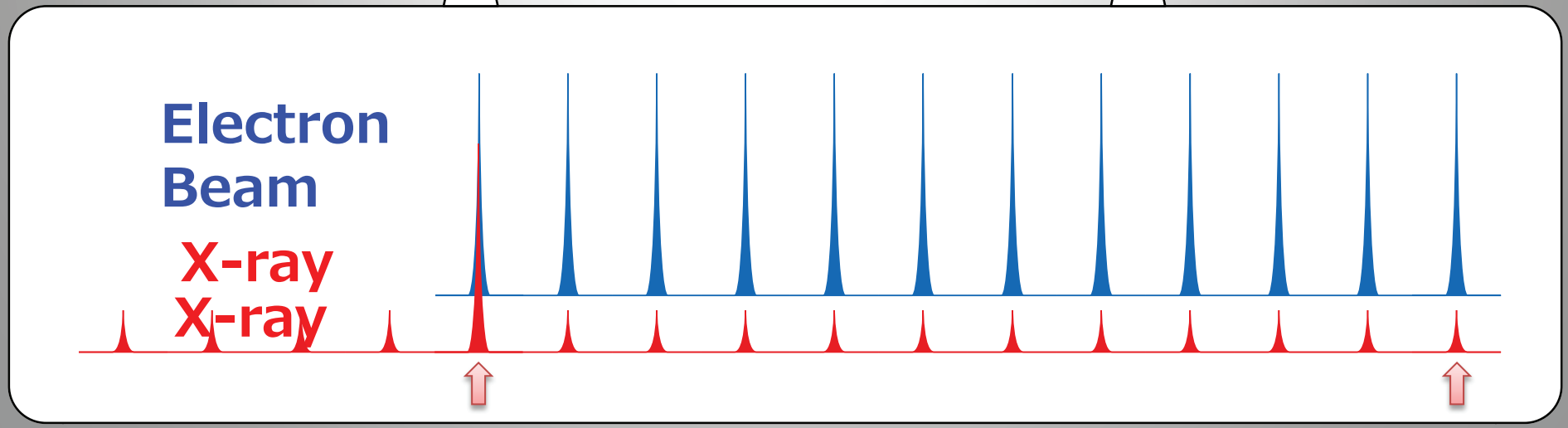

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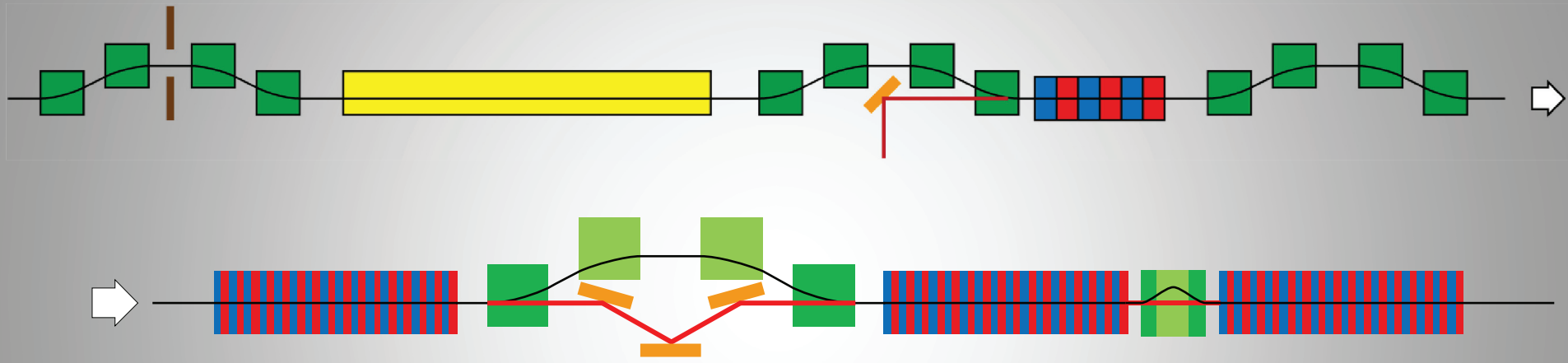
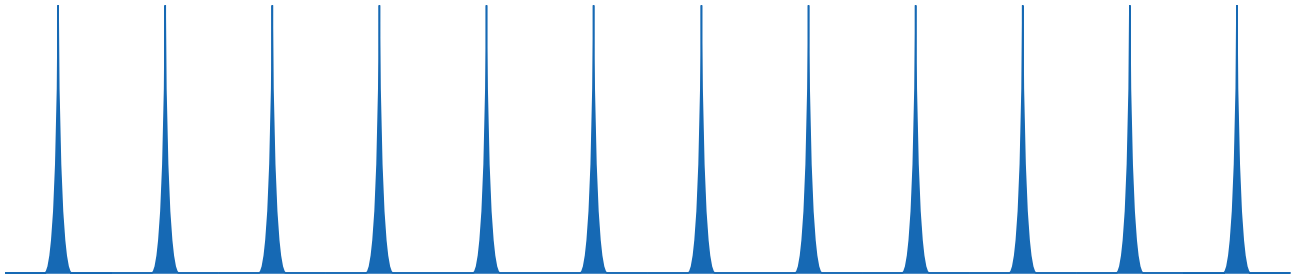


Electron Beam



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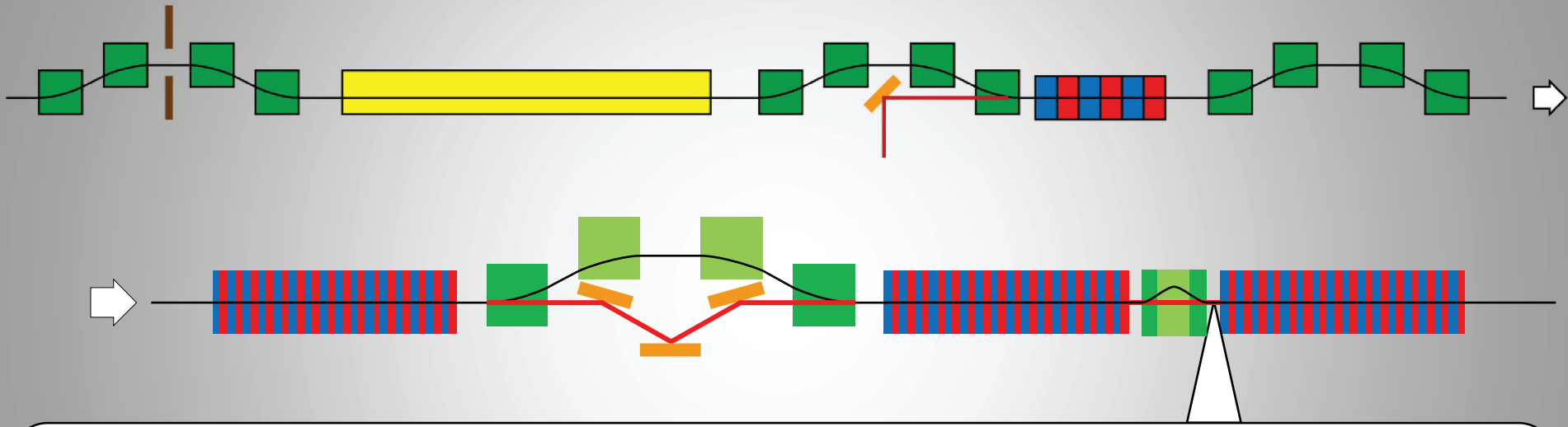

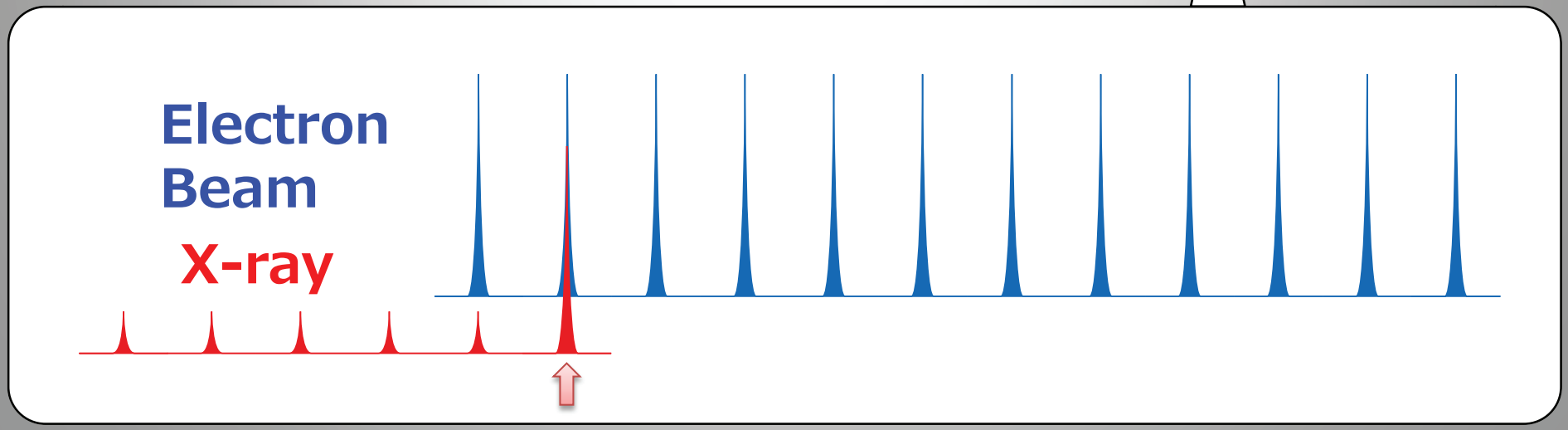

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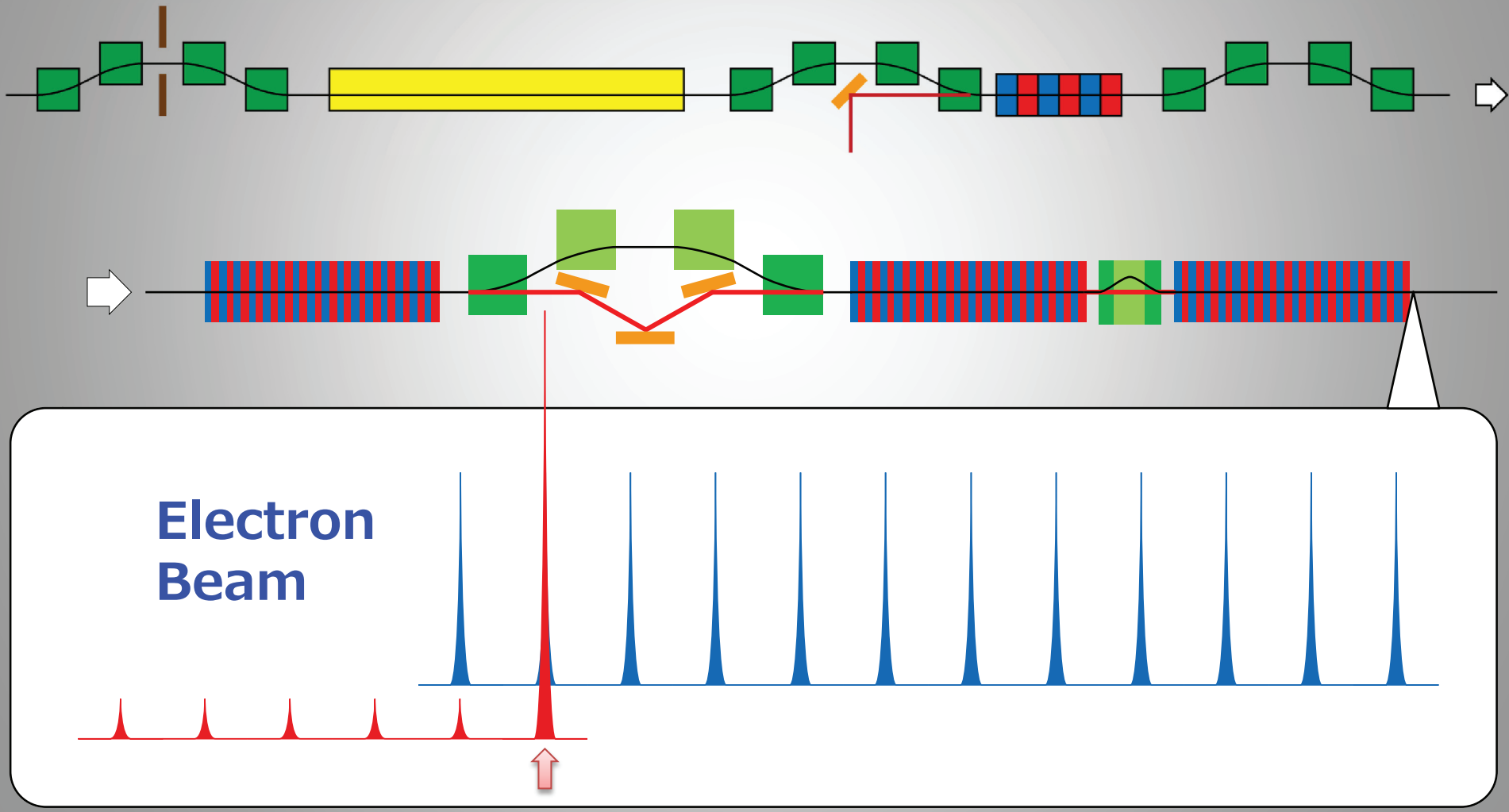


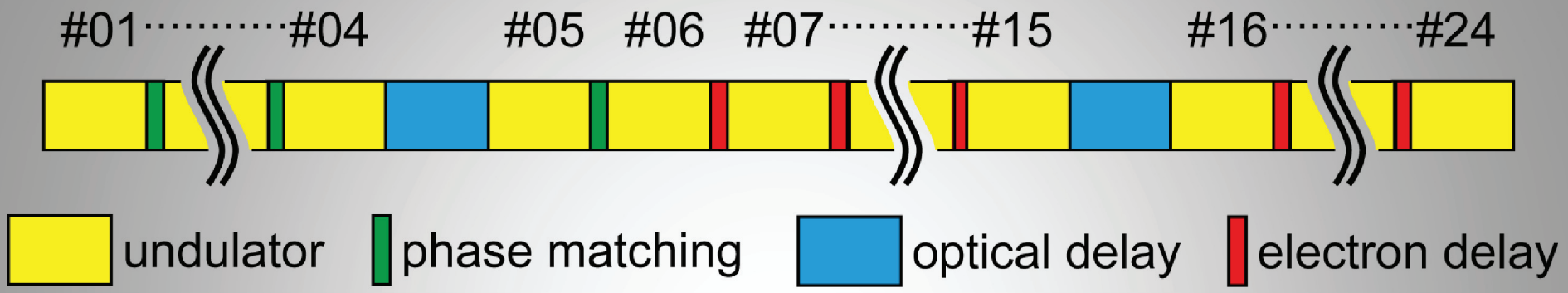
Example

- Performance of the proposed scheme when applied to SACLA facility

Relevant parameters assumed in the calculation

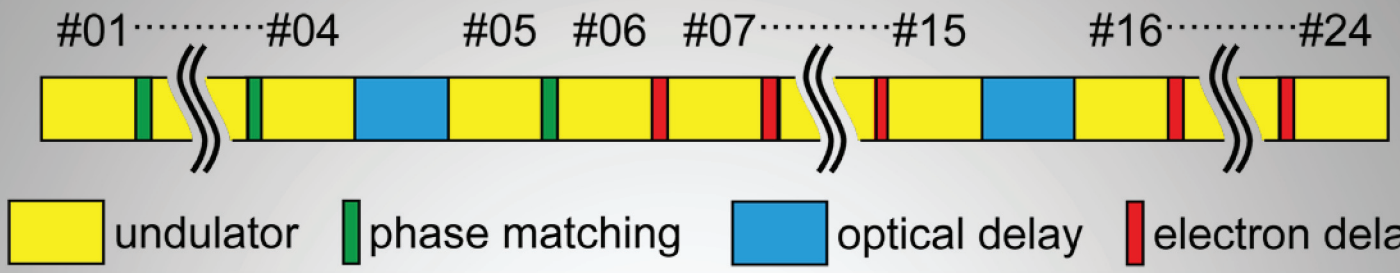
Electron Beam		**Undulator**	
Electron Energy	8 GeV	Period	18 mm
Slice Emittance	0.7 μm	Length/Segment	5 m
Energy Spread	10^{-4}	K Value	2.18
Peak Current	3.5 kA	**SASE Radiation**	
Bunch Length	*40 fsec (FWHM)	Photon Energy	10 keV
Bunch Charge	*0.15 nC	Sat. Power	~ 20 GW
*needs to be improved, under discussion		Pulse Length	~ 20 fsec

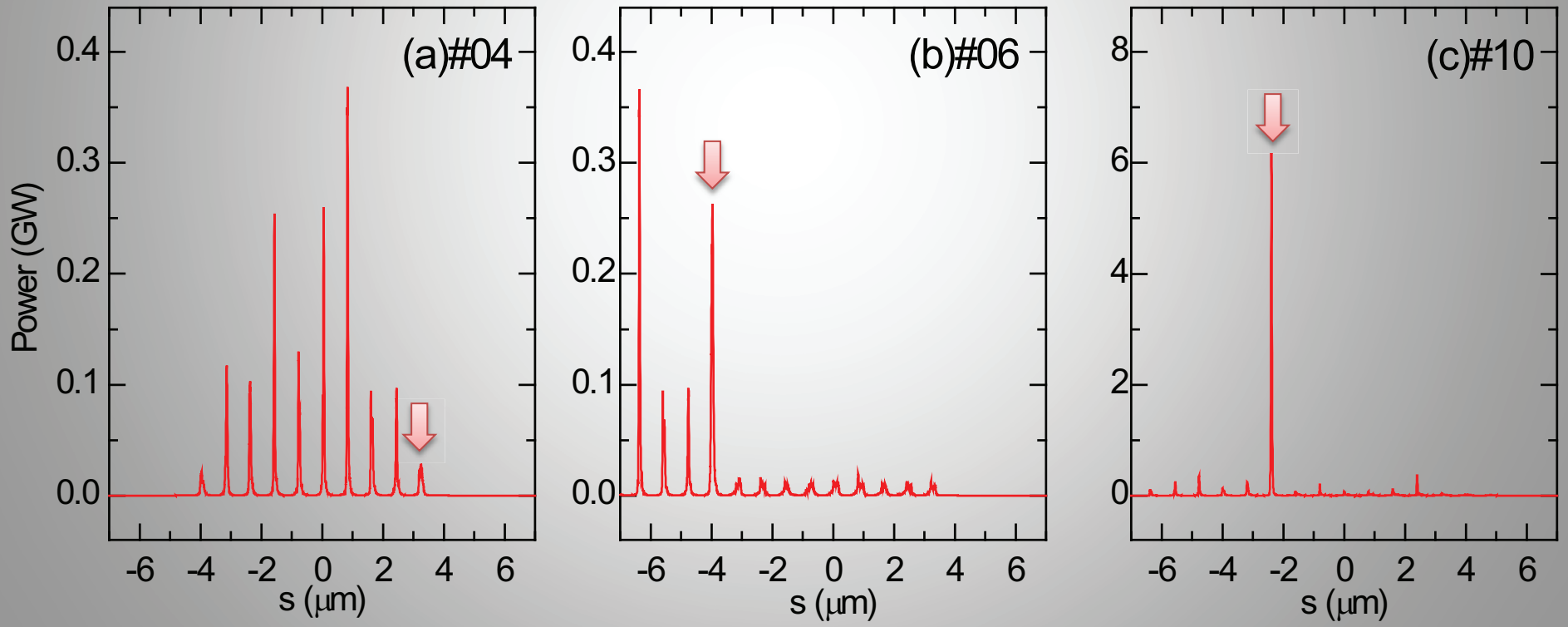
Layout of Undulator Section



- In SACLA BL3, 26 segments of undulators can be installed in total.
- Among them, two optical-delay chicanes are assumed to be installed, resulting in 24 segments.

Evolution of Radiation Pulse





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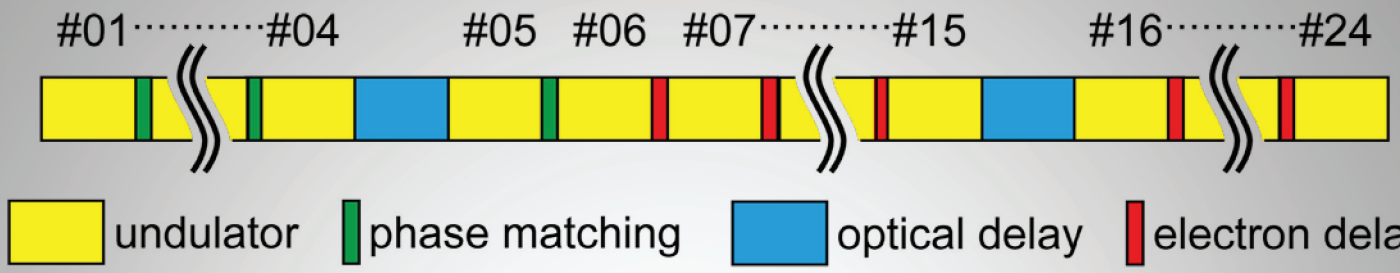
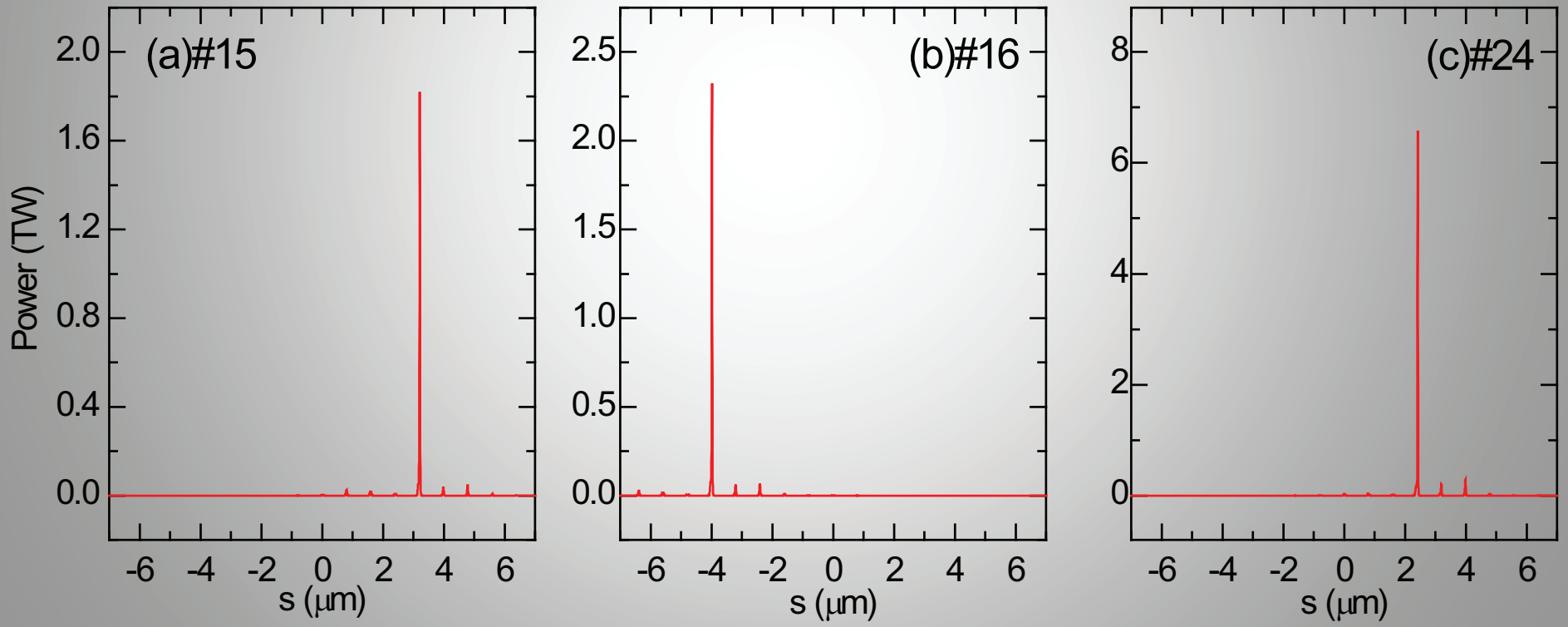
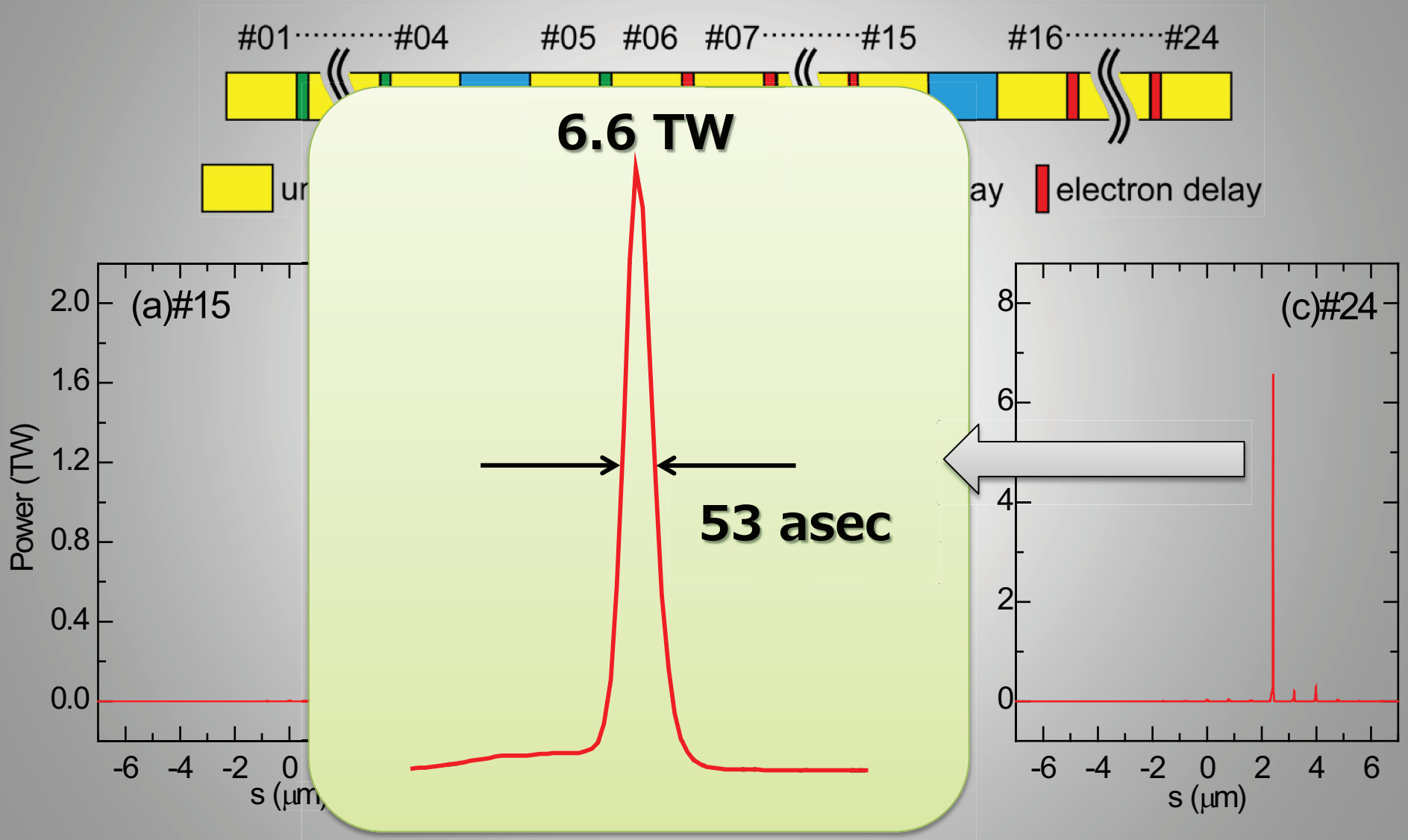
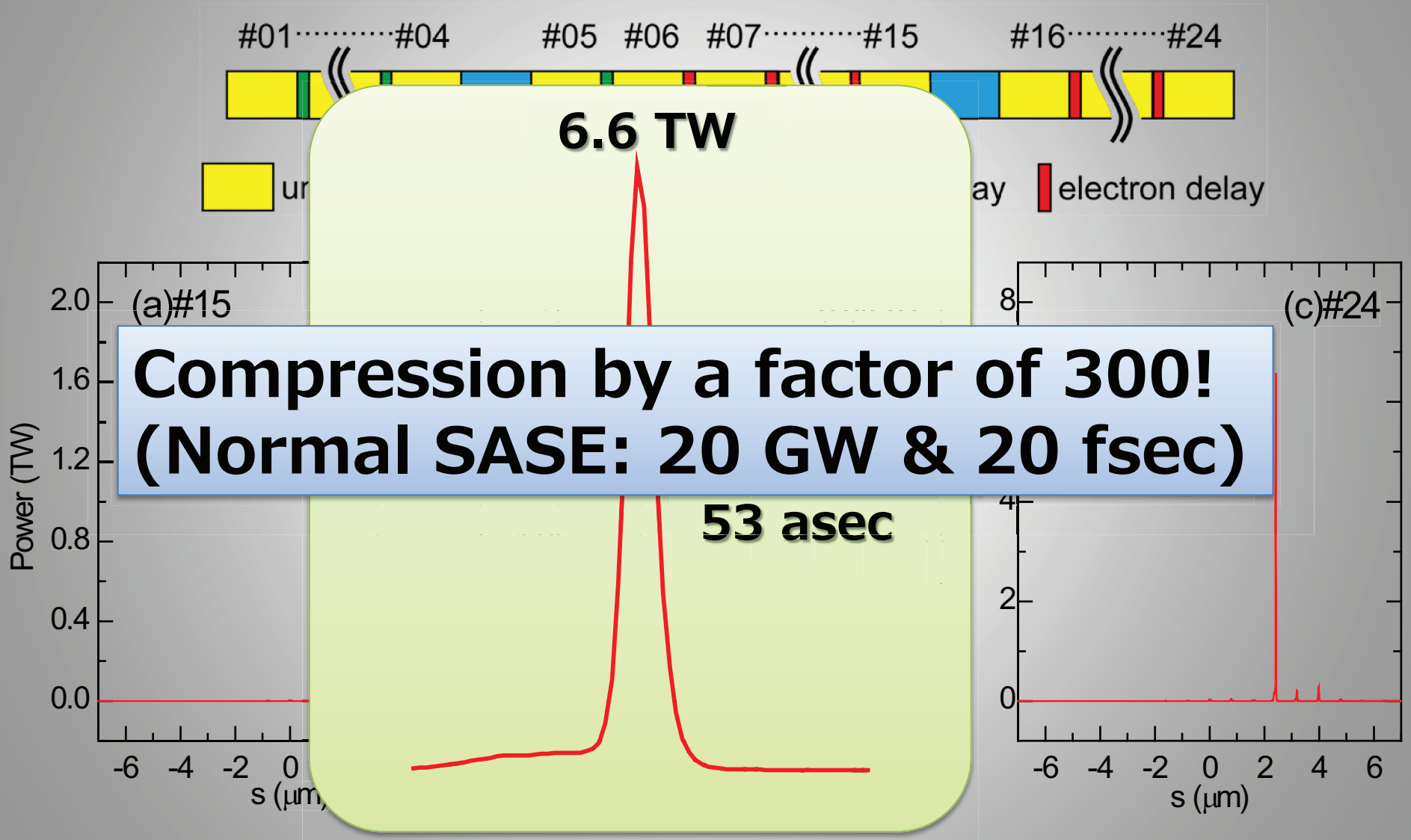




Evolution of Radiation Pulse



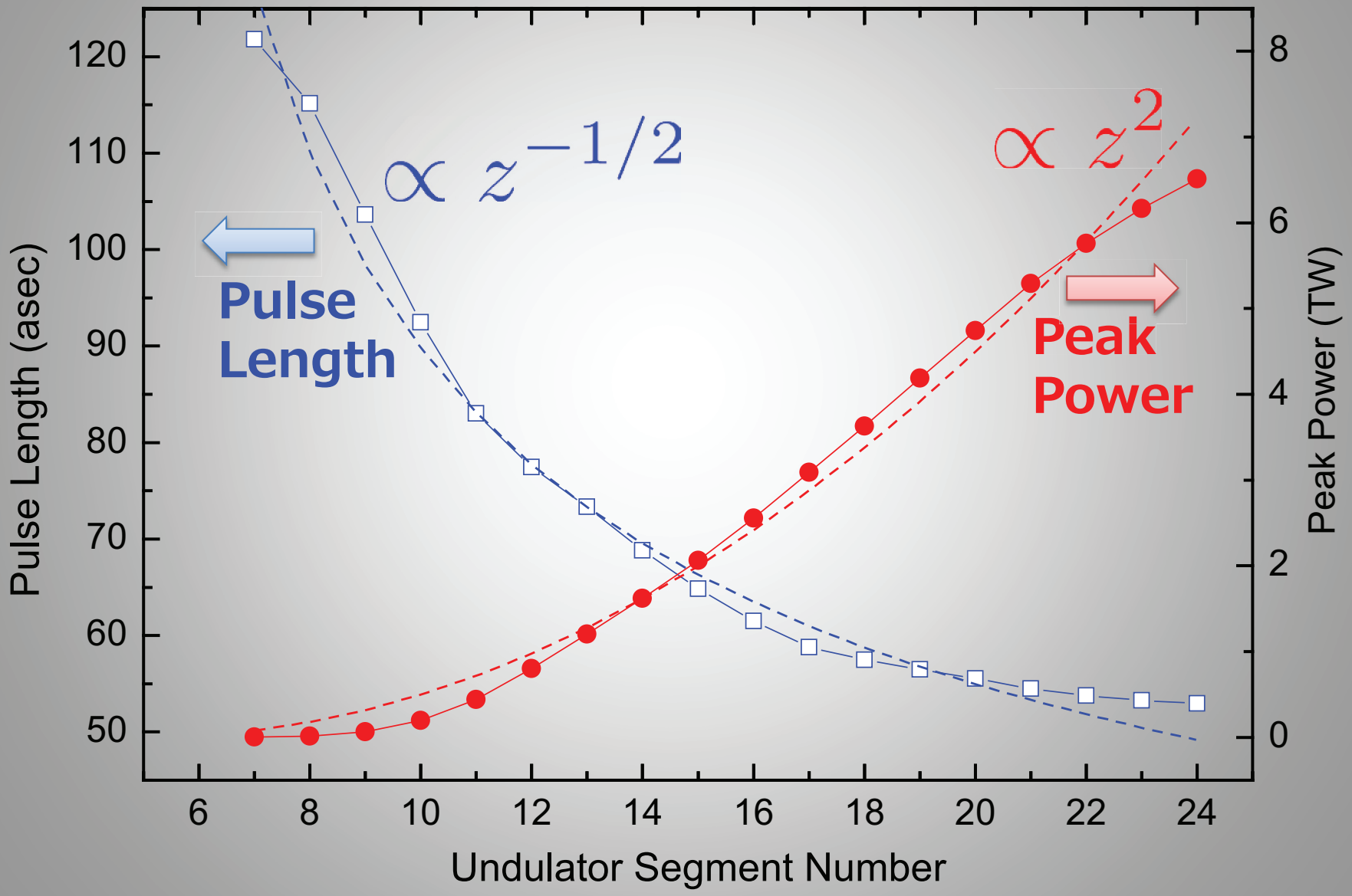
Evolution of Radiation Pulse



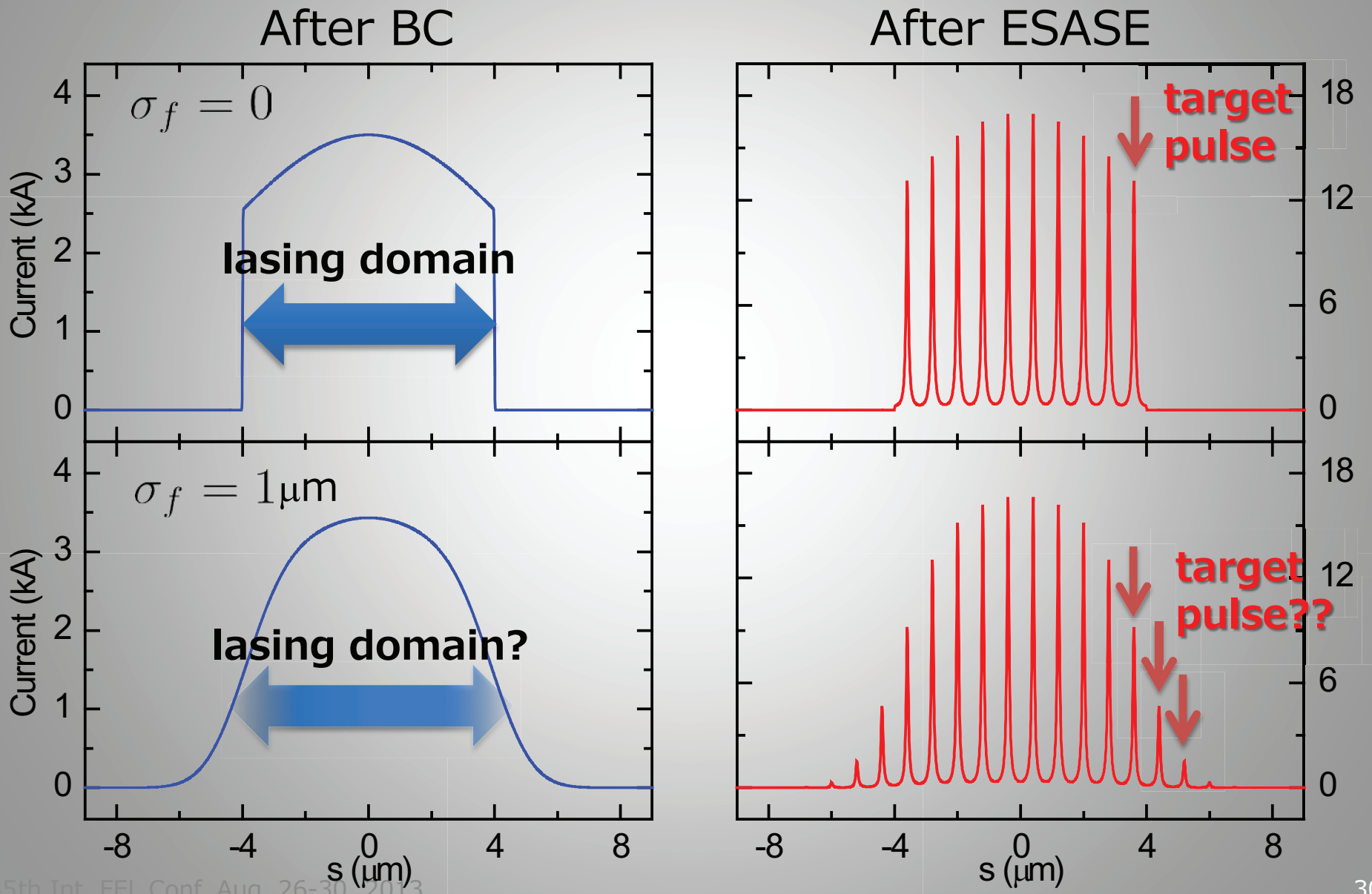
Compression by a factor of 300!
(Normal SASE: 20 GW & 20 fsec)

53 asec

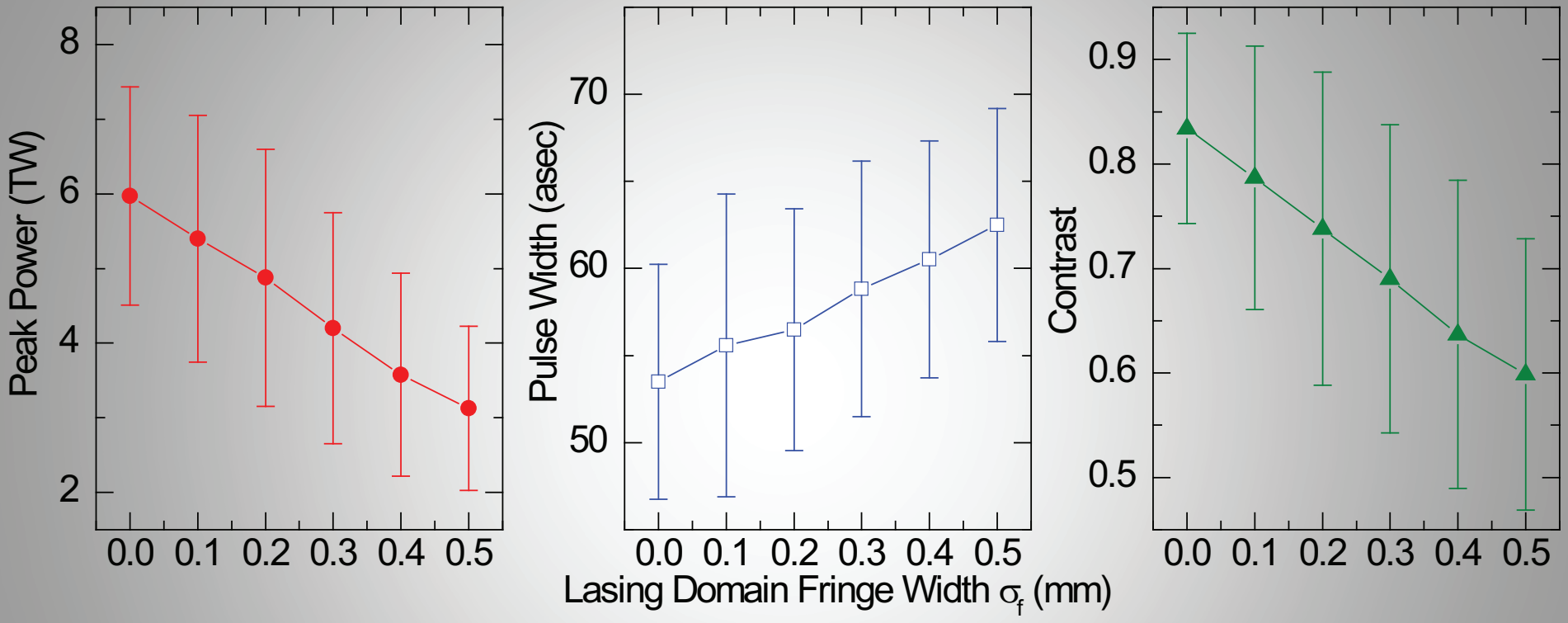
Power Growth & Pulse Shortening



Effect of the “Fringe Width”



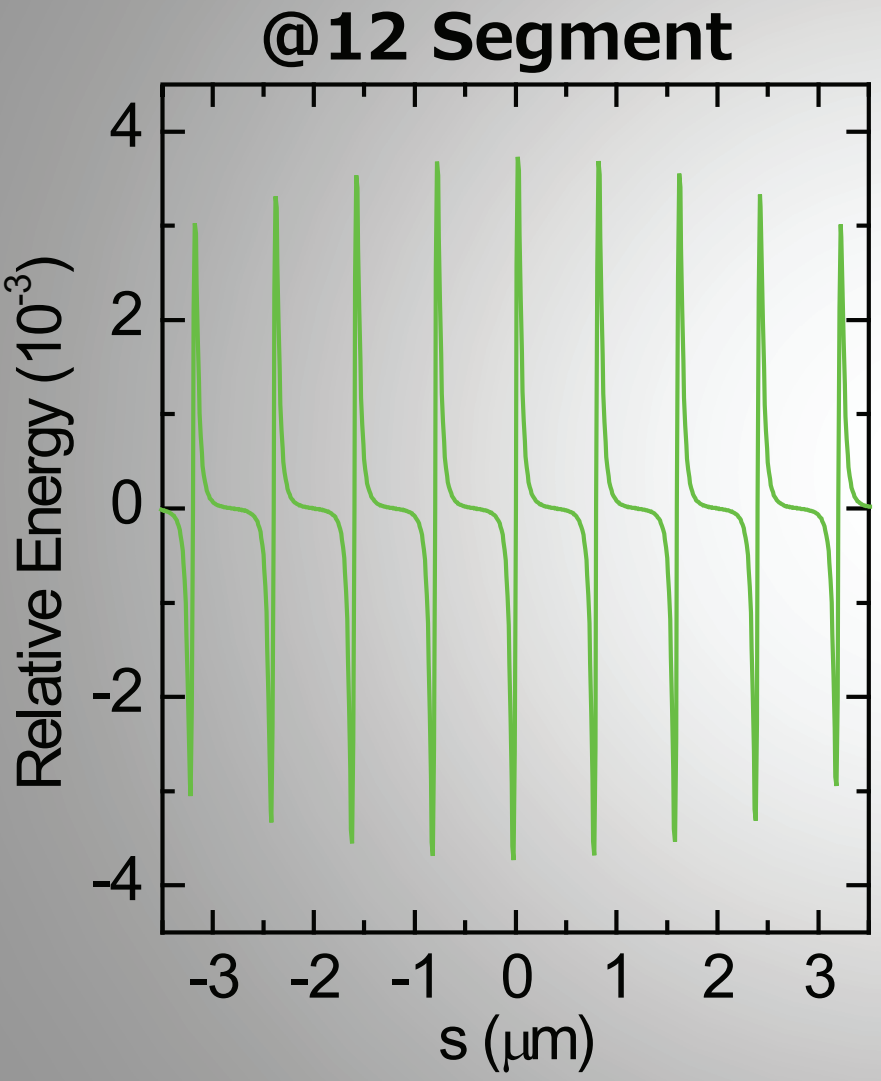
Numerical Study

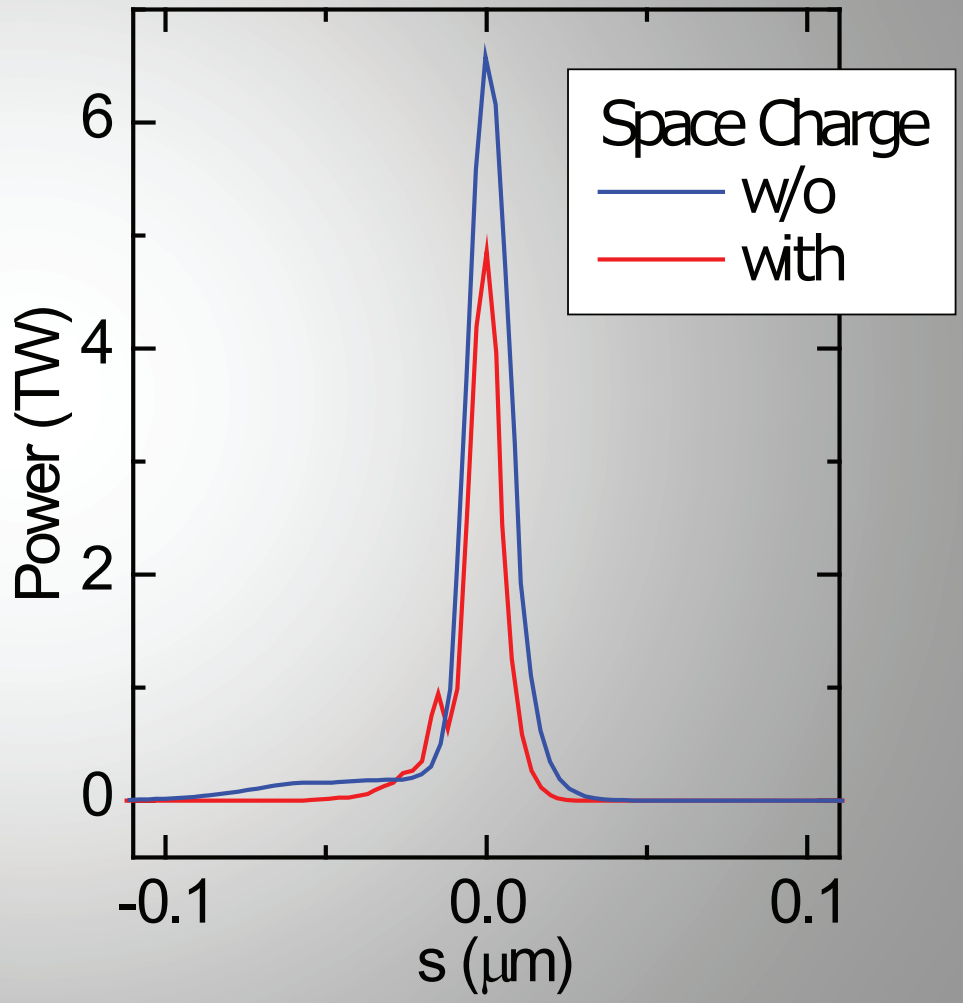


- Estimate the impact of σ_f with simulations.
- Δt of 1.3 fsec is feasible with the slotted foil scheme [1], corresponding to σ_f of 0.17 μm

[1] P. Emma et al., proc. FEL2004

Space Charge Effects (preliminary)





Toward Realization

- Optimization of beam parameters
  - @Bunch compressor (twiss, R_{56}, ⋯)
  - @ESASE section (λ_E, location, ⋯)
- Hardware development
  - Optical-delay chicane (mirror system)
  - Compact electron-delay chicane (PM)
- Diagnostics (ultra-short pulse)
- Exploration of a better solution
  - Elimination of satellite peaks
  - Others ideas?

Thank you for your attention!