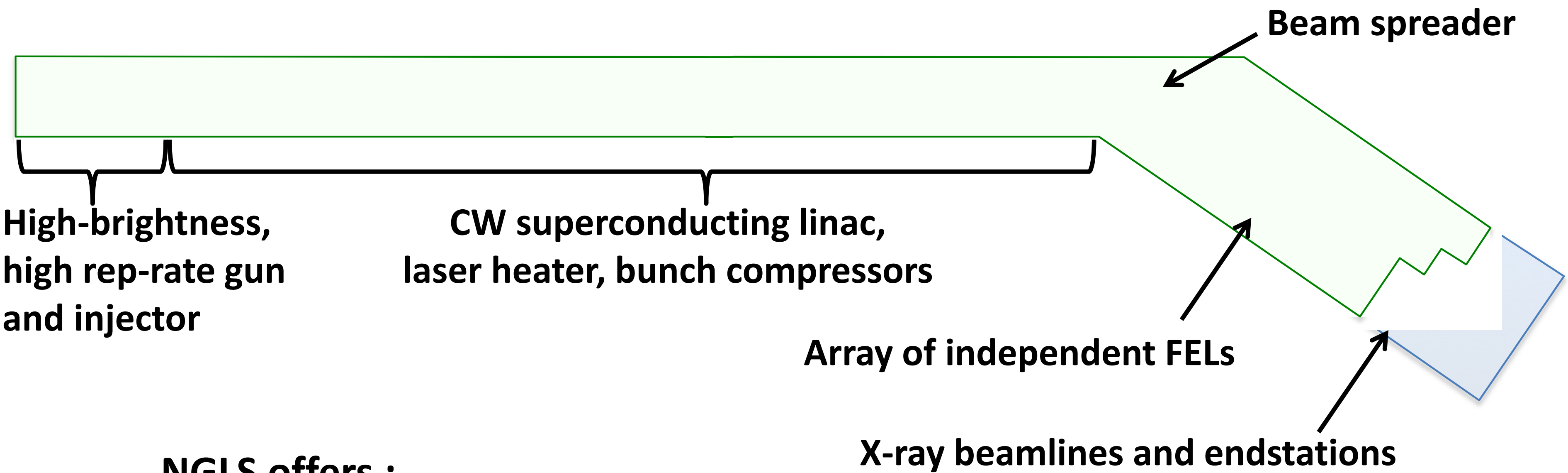
Soft x-ray optical diagnostics, concepts and issues for NGLS

Tony Warwick
(for the NGLS project team)
EuroXFEL user meeting 2013
Satellite workshop on photon beam diagnostics
24 January 2013

BERKELEY LAB
Lawrence Berkeley National Laboratory

NGLS
next generation light source

NGLS approach

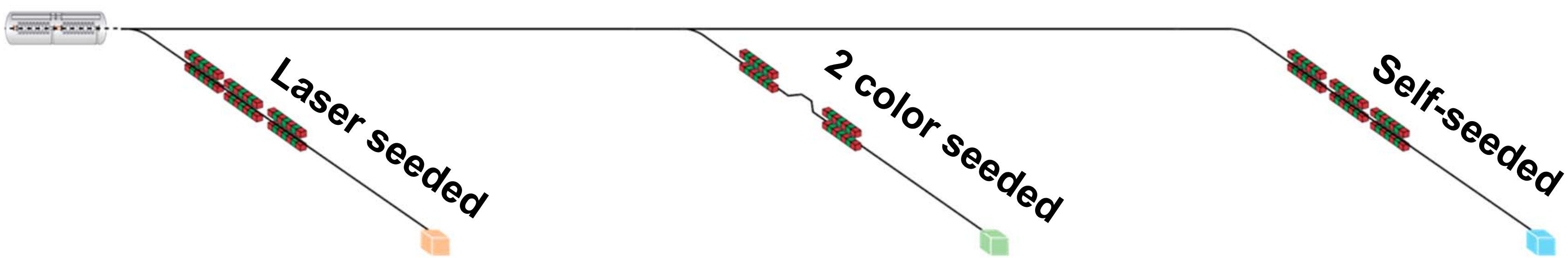


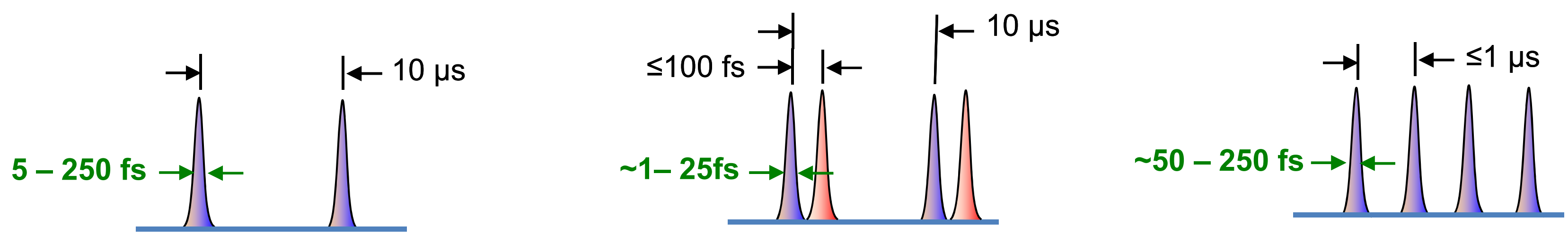
NGLS offers :

- CW pulse train
- More energy per unit bandwidth
- More photons per second
- Shorter pulses
- Controlled trade-off between time and energy resolution

NGLS plans three FELs initially………expands later to nine

Three FEL Strategy **proposed by Paul Emma and LBNL CBP team**



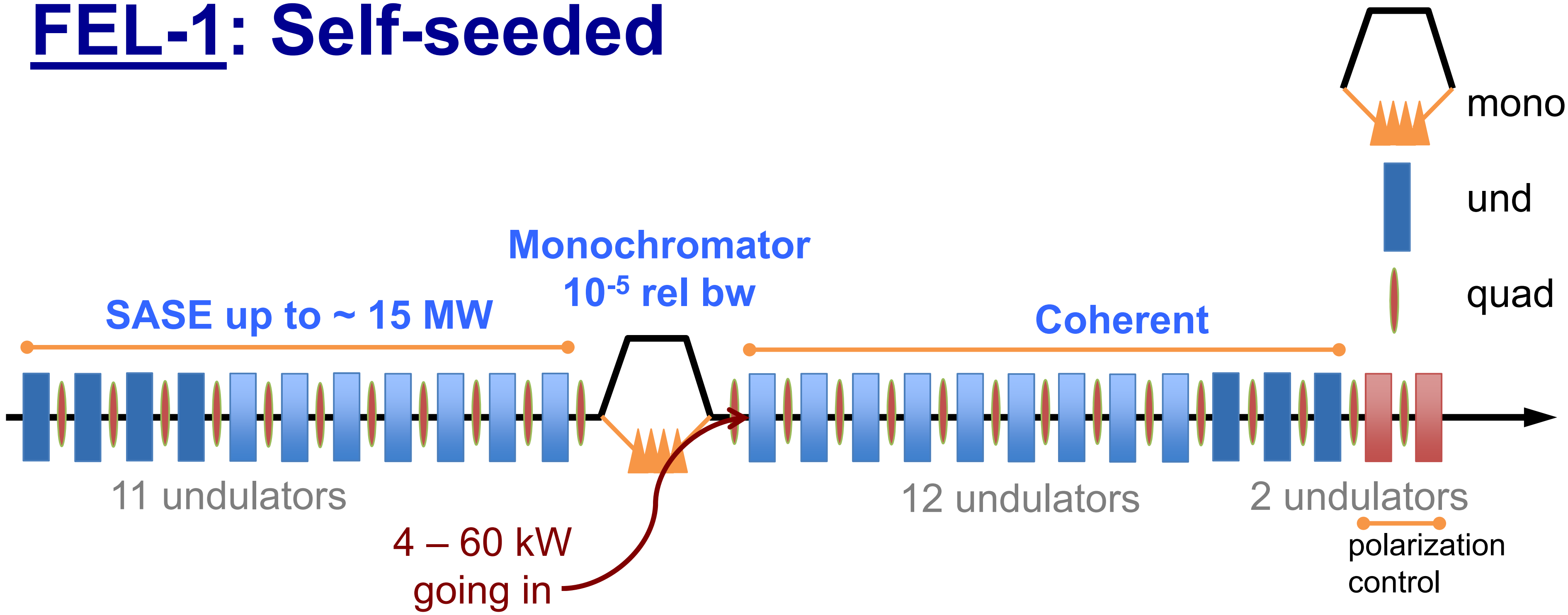


High resolution
Trade-off time/energy resolution
10^{11} – 10^{12} ph/pulse
10^{-3} – 5×10^{-5} bandwidth

Ultra-fast
≤ fs pulse capability
2 color
10^{8} ph/pulse

Highest rep rate
High flux
10^{11} - 10^{12} ph/pulse
100 W

FEL-1: Self-seeded

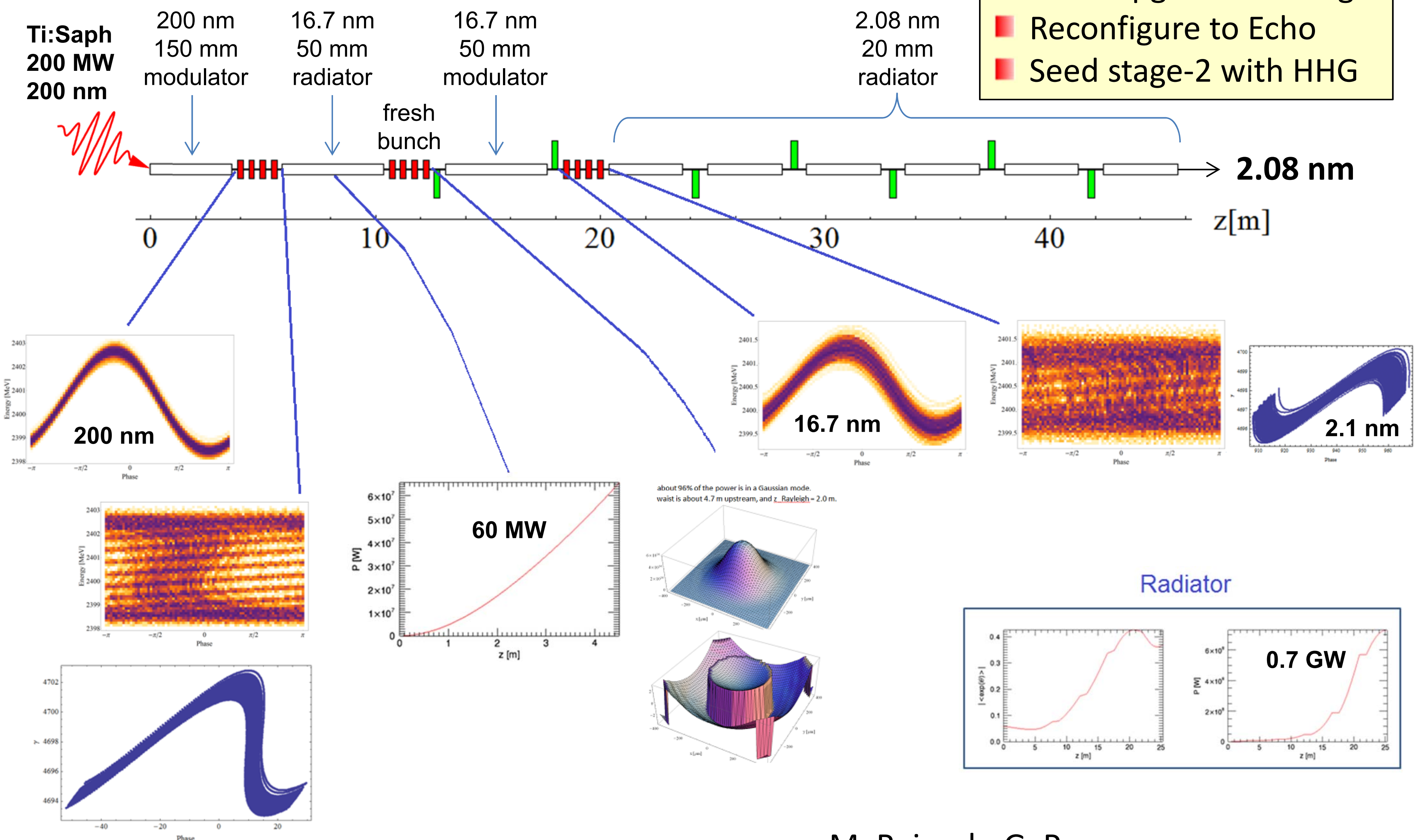


Undulator length 3.3 m (magnetic)
1.1 m gaps
undulators includes contingency for beam quality & undulator errors

- Aggressive bandwidth goal
- Self-seeding monochromator reduces photons by 10^3
  - Factor 100 in reduced BW, factor 10 in losses in monochromator

FEL-2: 2-Stage HGHG (100-600 eV)

- 1-nm upgrade: 3rd stage
- Reconfigure to Echo
- Seed stage-2 with HHG



M. Reinsch, G. Penn

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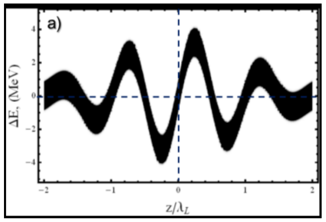
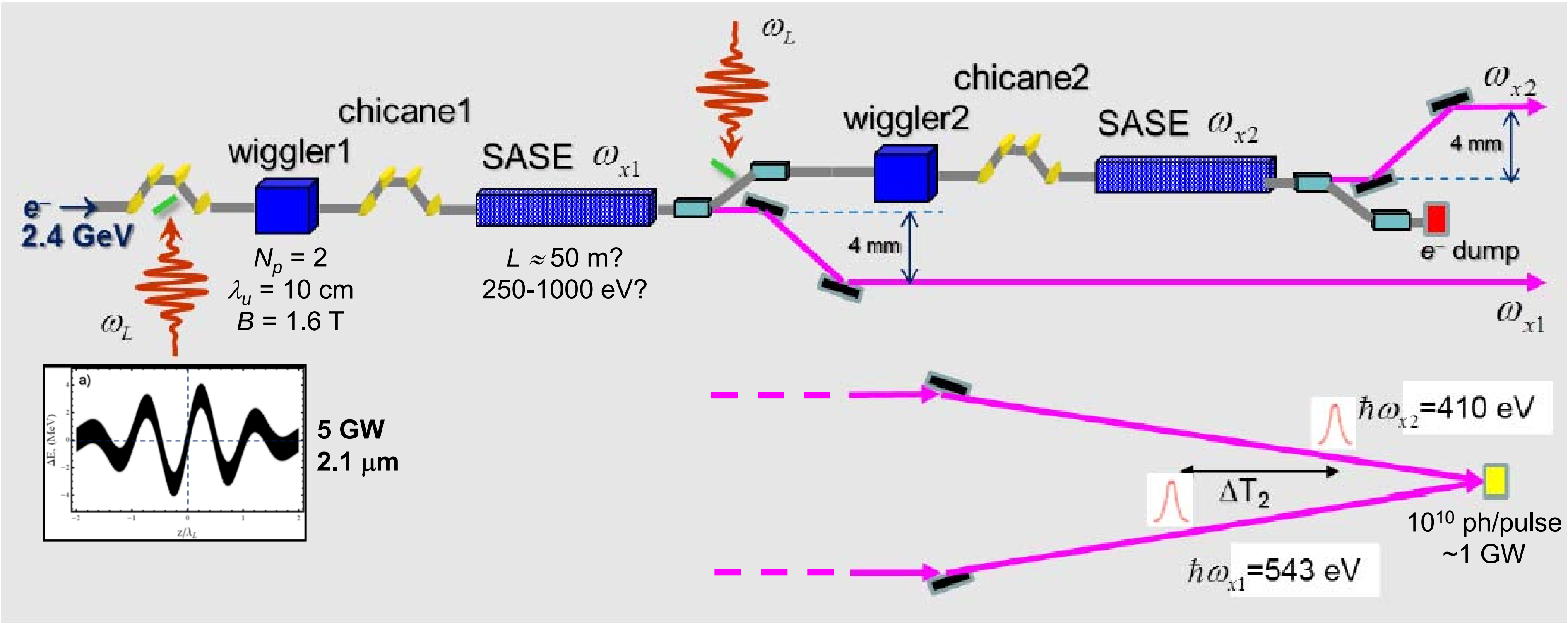
NGLS next generation light source

FEL-3: Chirped SASE 2-Color (250eV-1000 eV?)

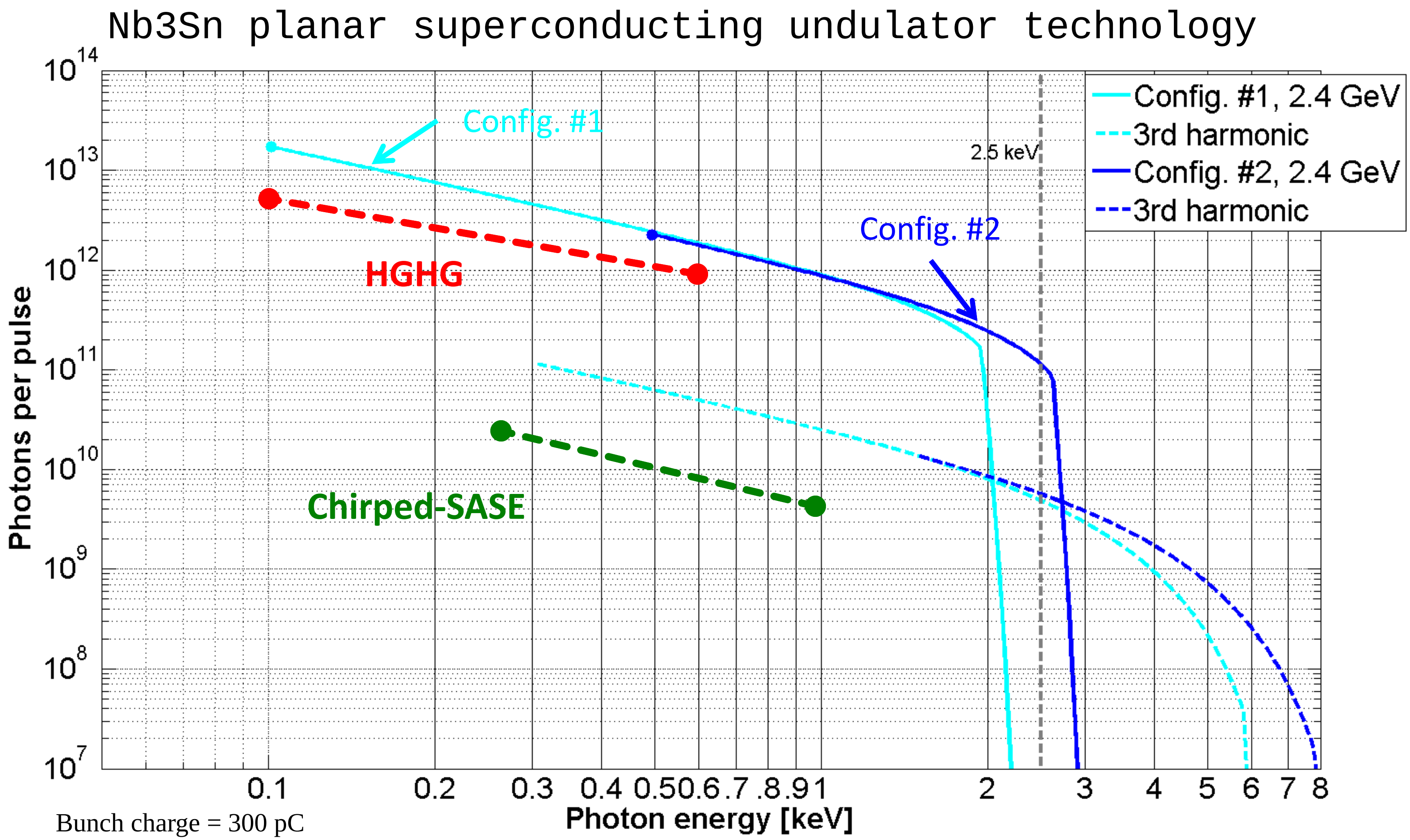
Carrier-envelope-phase-stable 15.7-fs (2-cycle) 70-μJ pulses at 2.1-μm wavelength, or less?



5 GW
2.1 μm



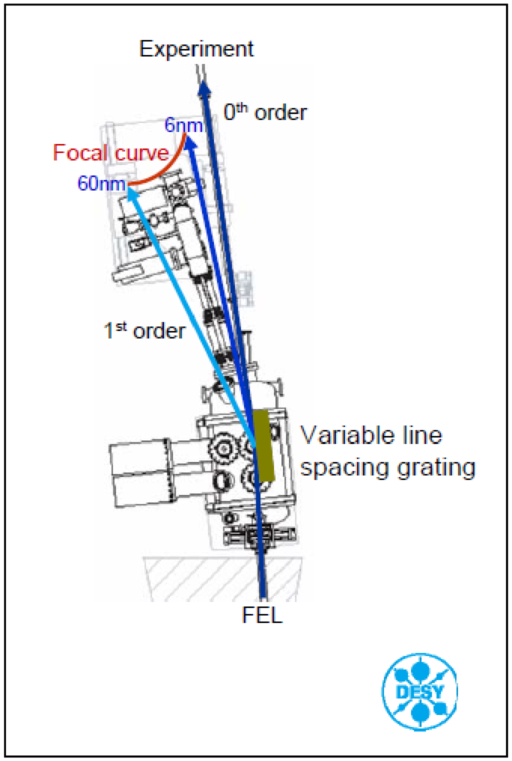
3 concepts: SXRSS + HGHG + Chirped SASE



Bunch charge = 300 pC
Bunch length = 250 fs (100 fs in HGHG)
$ß_u$ = 15 m
min._gap = 7.5 mm
Current = 600 A
Emittance (norm.) = 0.6 micron
Energy spread = 100 keV

Do we need spectral diagnostics?.........

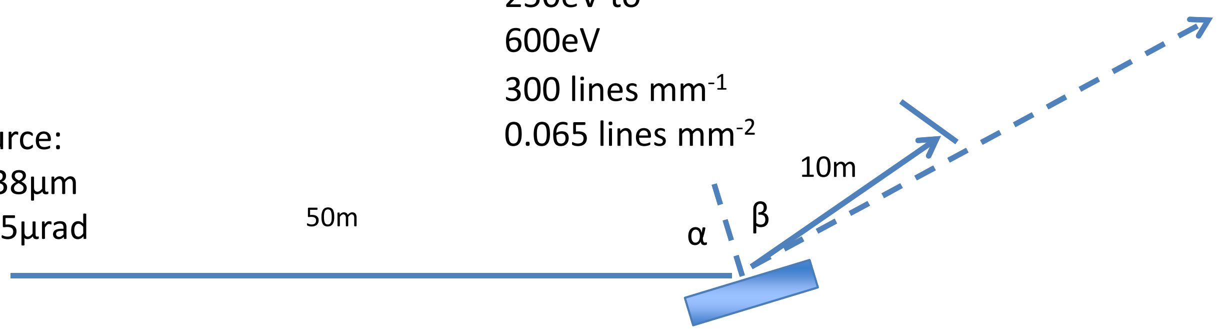
FLASH and FERMI have diagnostic grating spectrometers on experiment floor that pass zero order to experiment

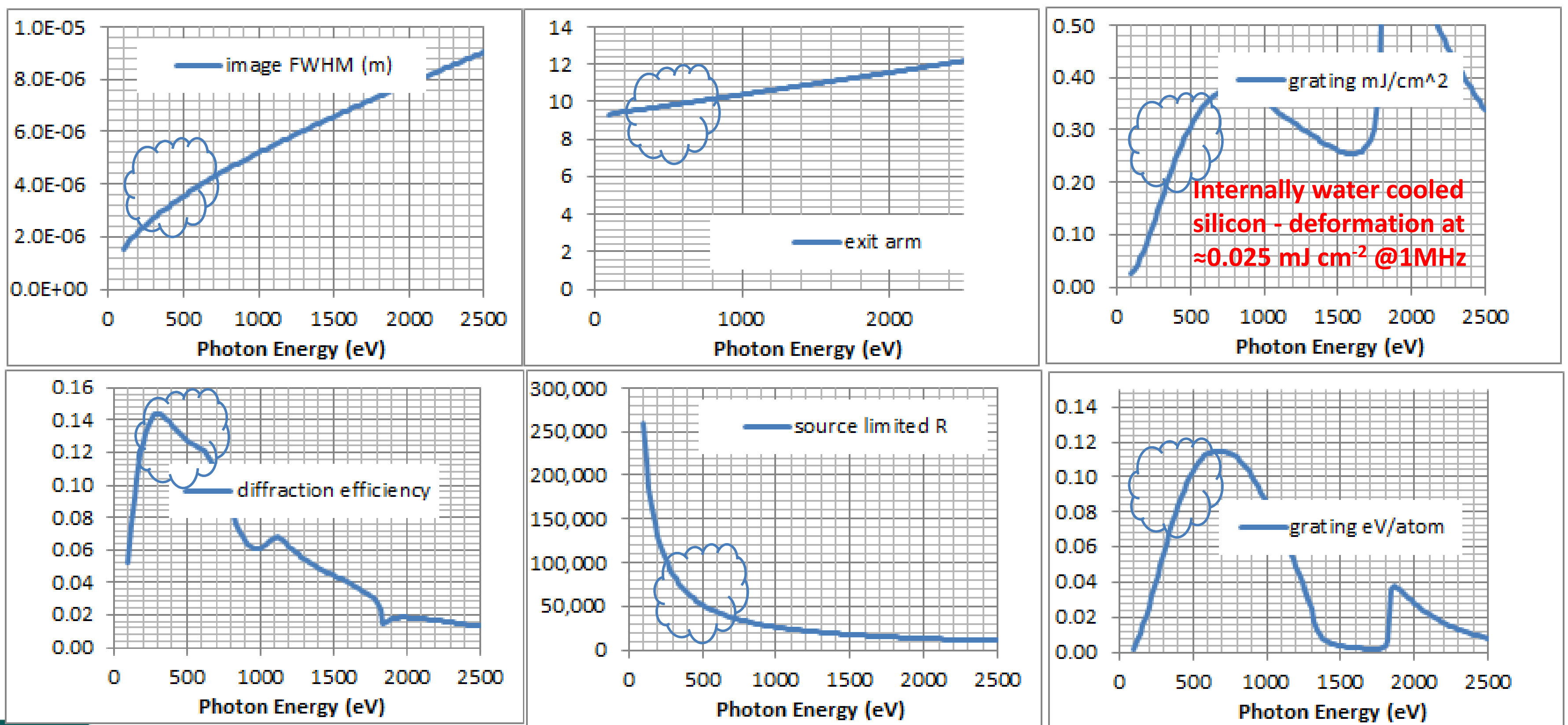


Diagnostic spectrometer

250eV to
600eV
300 lines mm^{-1}
0.065 lines mm^{-2}

source:
σ=38μm
σ'=5μrad





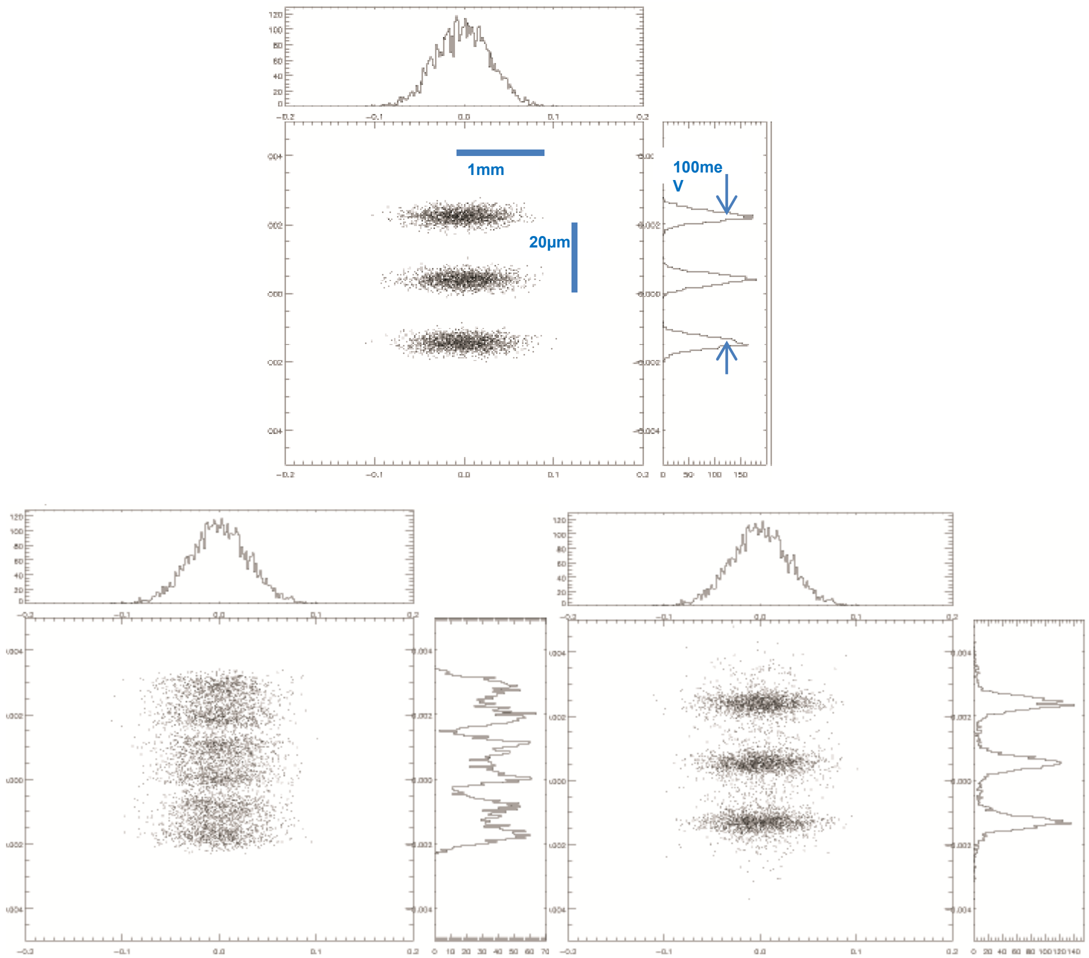
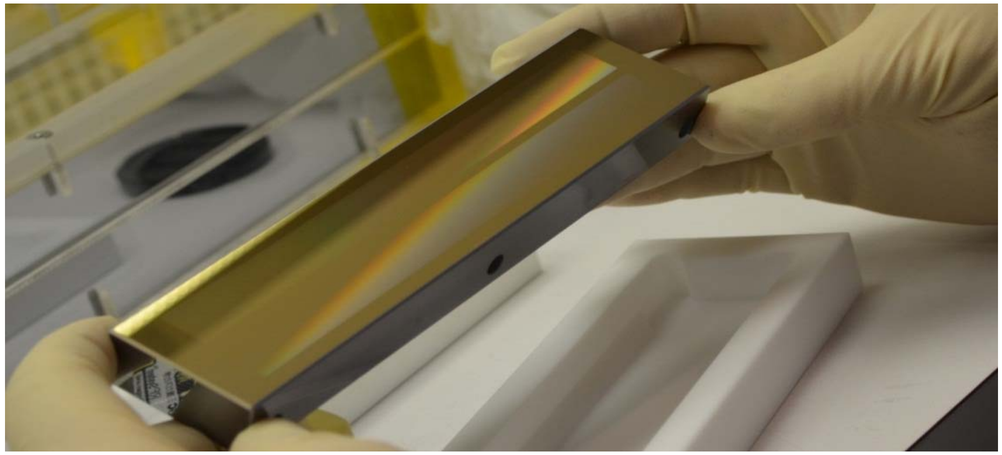
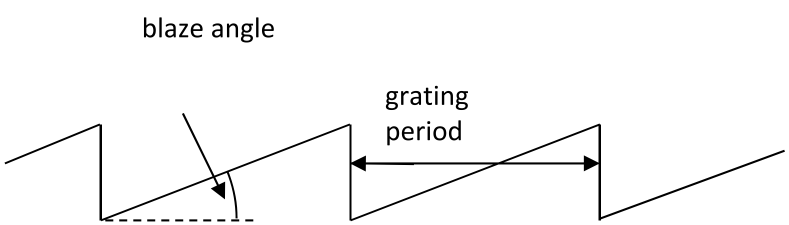


Figure 8. Ray trace of operation at 500eV showing the image on the focal plane scintillator i) with no heat, ii) with thermal load corresponding to 100kHz operation and an internally water cooled silicon grating and iii) the same, with the focal plane shifted downstream 58mm to recover the focus as far as possible. Beyond this is the possibility of a cryogenic silicon grating with negligible thermal deformation.

Gratings should be long with blazed groove profile, and blaze angles shallow…





stripe	groove density (lines/mm)	blaze angle	coating
G101a	100±0.2%	0.2±0.02°	Gold
G101b	100±0.2%	0.4±0.04°	Gold
G102a	300±0.2%	0.4±0.04°	Gold
G102b	300±0.2%	0.3±0.03°	Rhodium

- Spectral diagnostic is certainly required to measure performance.

- But is this measurement required shot-by-shot as part of the data stream?

- *Answer: please, no.*

Do we need timing diagnostics?

Spectral encoding of x-ray/optical relative delay

Mina R. Bionta, H. T. Lemke, J. P. Cryan, J. M. Glownia, C. Bostedt, M. Cammarata, J.-C. Castagna, Y. Ding, D. M. Fritz, A. R. Fry, J. Krzywinski, M. Messerschmidt, S. Schorb, M. L. Swiggers, and R. N. Coffee

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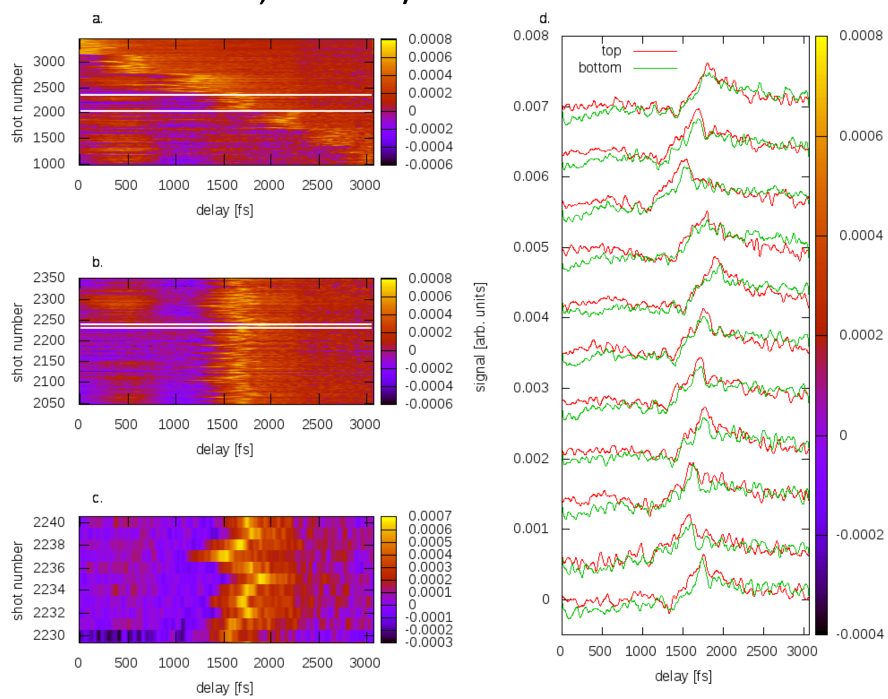
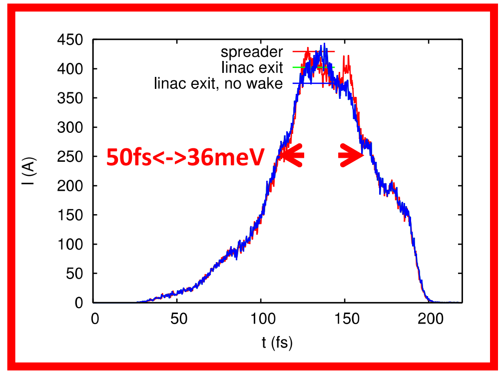
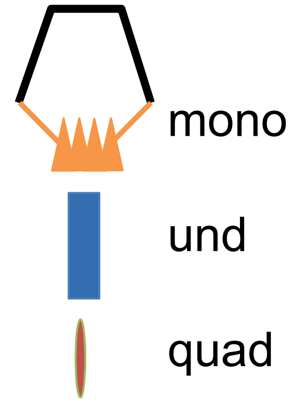
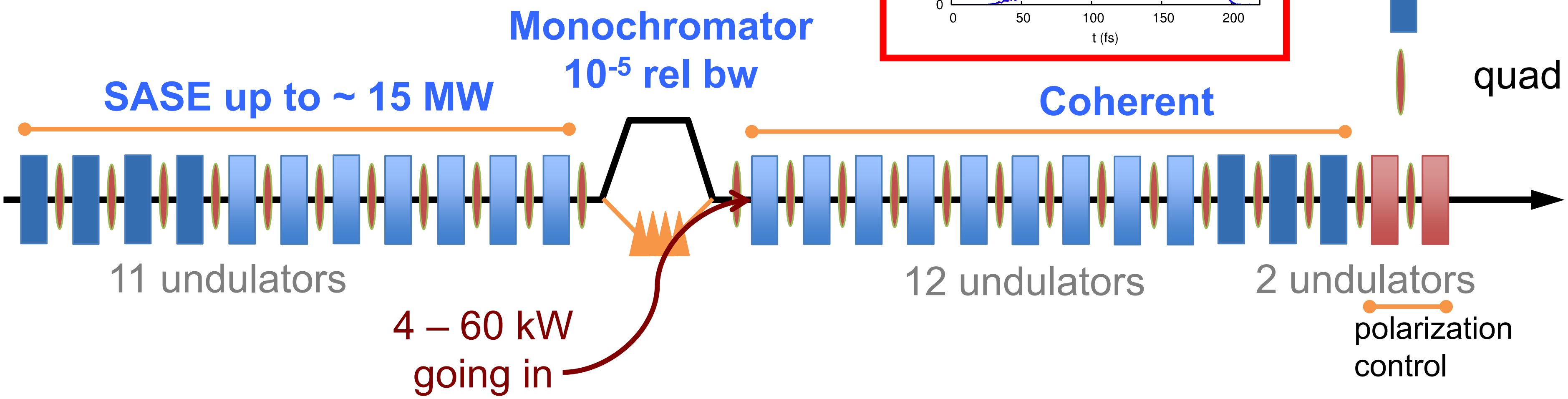


Panel (a) shows the transmitted single-shot spectra, stacked so that the abscissa and ordinate correspond to the spectrum and shot-number respectively. The delay between the xrays and the laser was scanned in 500 fs steps, twice the full width at half maximum (FWHM) natural jitter of the FEL [8]. Panels (b) and (c) incrementally zoom as indicted by the white lines in previous panels. Panel (d) shows lineouts of panel (c) shots, but for both of the correlated signal traces, top = t1 and bottom = t2.

FEL-1: Self-seeded







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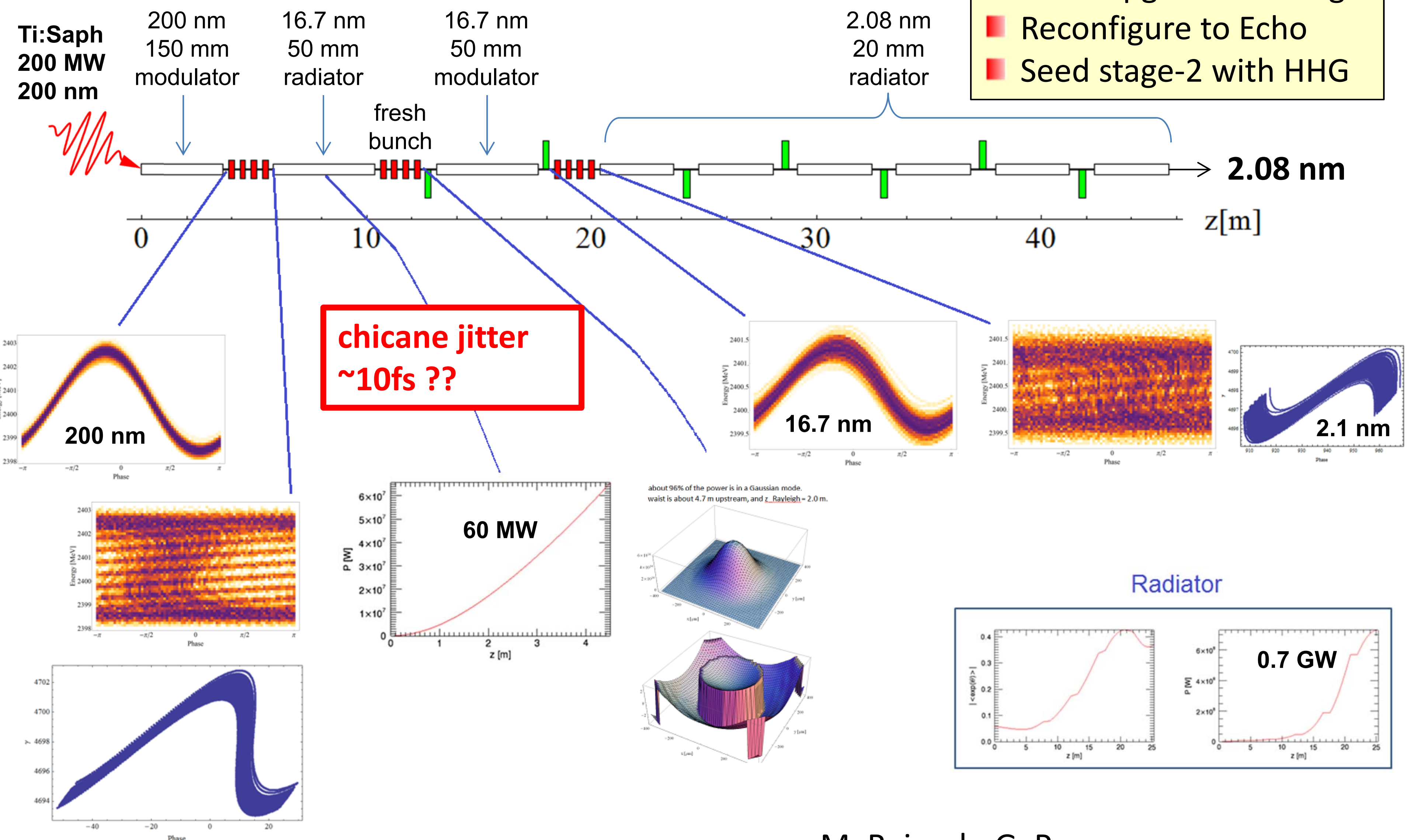

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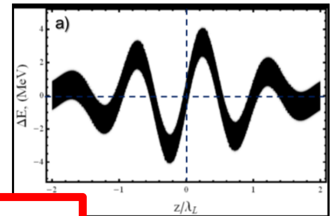

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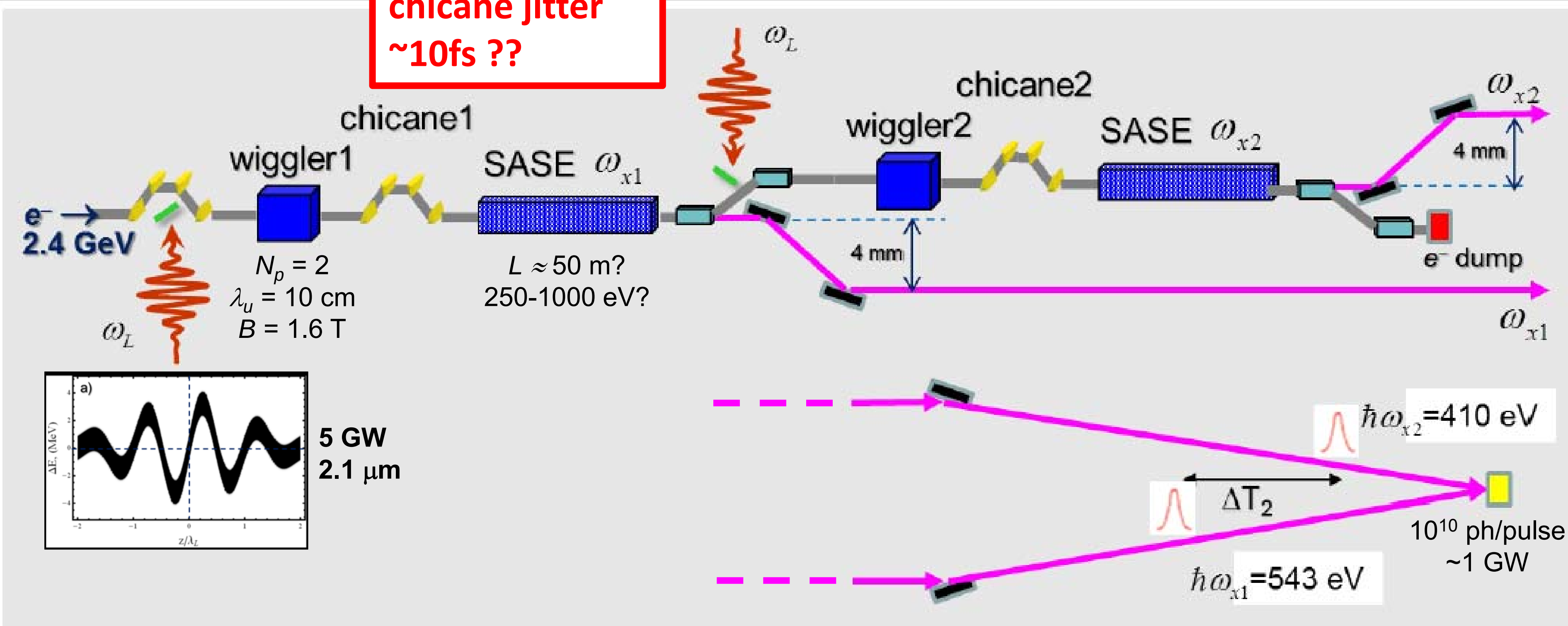
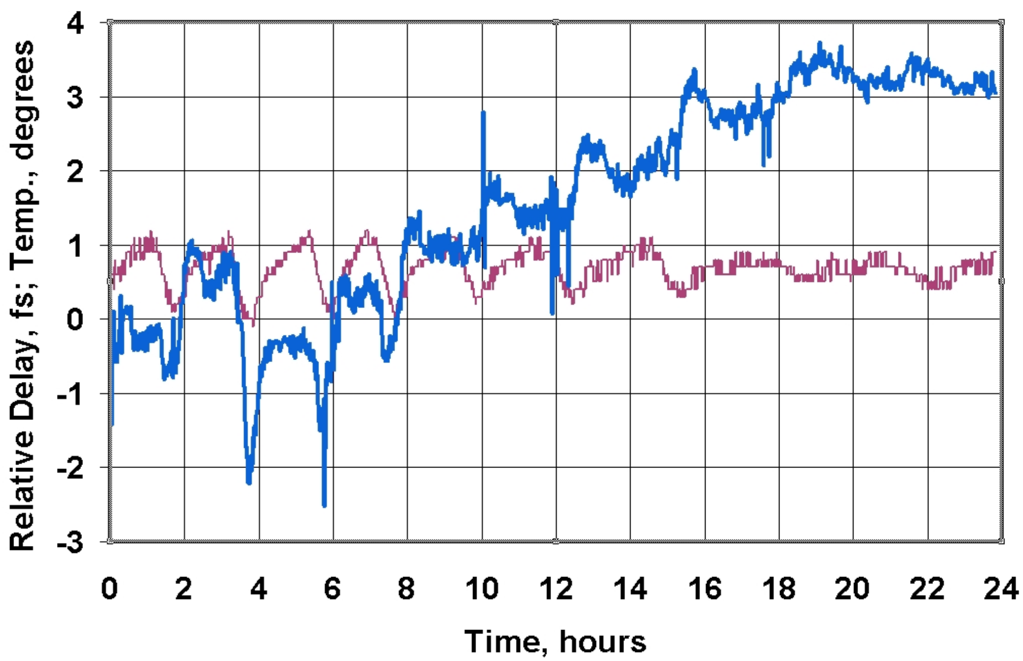


Synchronizing Lasers Over Fiber by Transmitting Continuous Waves

R. B. Wilcox and J. W. Staples
Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley CA 94720
Phone: 510-495-2704, FAX: 510-486-7981, E-mail: rbwilcox@lbl.gov

Abstract: We have developed an interferometric method of delivering optical phase information over kilometers of fiber with sub-10fs long term stability. This enables temporal synchronization of pulsed lasers by transmission of CW signals.



Relative phase delay stability between 2km and 2m stabilized fibers in femtoseconds (blue) and room temperature variation in degrees (red).

Being optimistic…..

Self seeding may be synchronized to **~50fs**, depending on electron bunch length.
No better than SASE, except the bandwidth is controlled and may be narrow (>50meV).

Laser seeding synchronization could be as good as **~10fs.**

- Cross-correlation diagnostic is required to measure (and confirm) this performance.
- But is this measurement required shot-by-shot as part of the data stream?
- *Answer….depends on the performance*

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