XFEL-O Simulation Methods with the GINGER Code

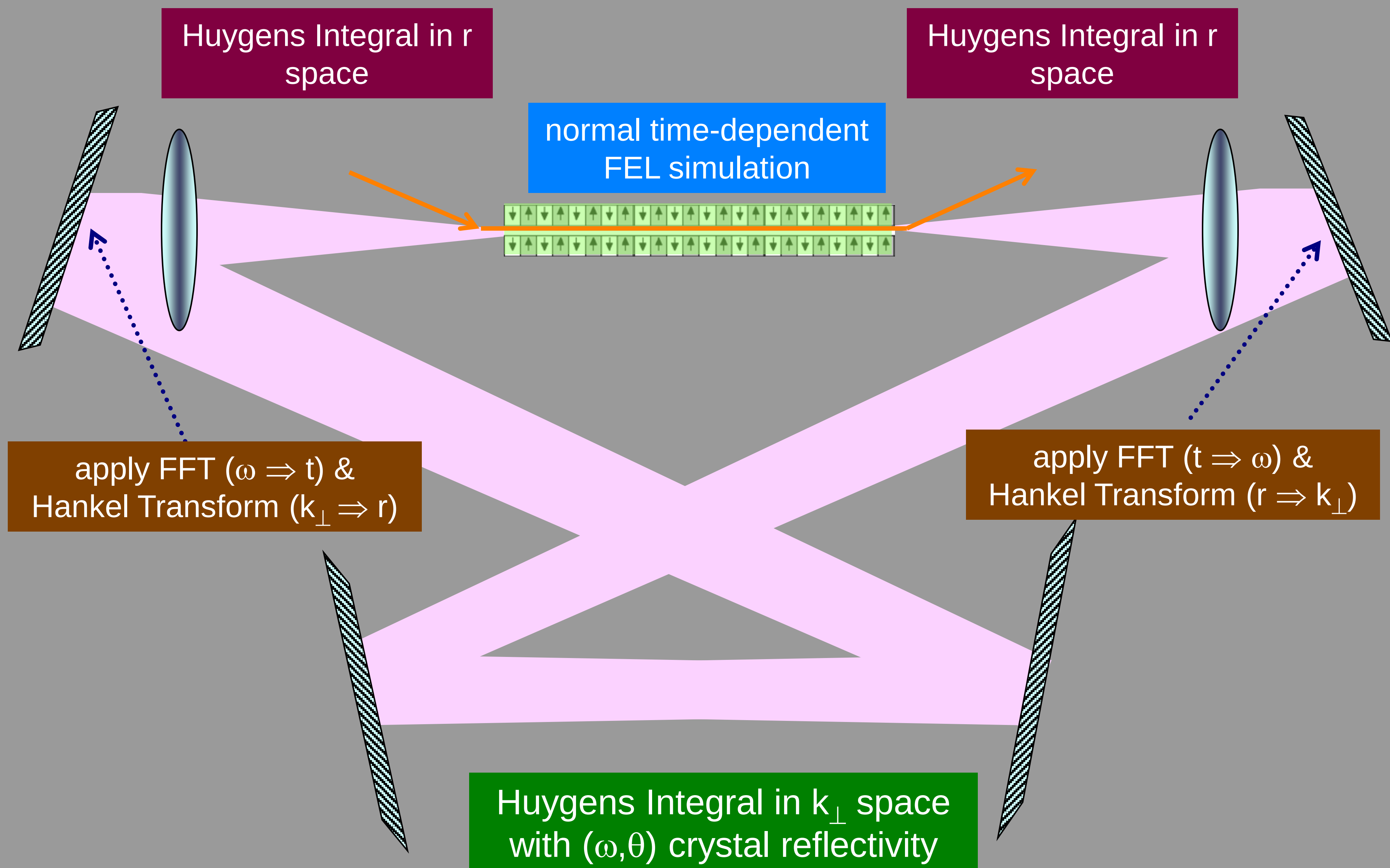
William Fawley
Ryan Lindberg
K-J Kim
Yuri Shyvd'ko

LBNL & ANL

Basic Characteristics of GINGER

- Standard Amplifier/Single-Pass Info:
  - Full 3D particle mover including betatron motion and forces due to external quads and/or dipoles; "fast" wiggle motion averaged with KMR formulation
  - New direct, fully implicit and VERY fast 2D eikonal model (== SVEA) field solver (axisymmetric or "slab" model geometry) ==> diffractive and refractive effects properly included
  - Optional calculation of 3rd and 5th harmonic emission
  - Operates in time domain; slippage applied at discrete intervals in z
  - "Start-to-End" import/export capability for particles/fields
- Oscillator Extensions (1995-2009):
  - direct propagation undulator-mirrors-undulator via Huygens Integral
  - discrete mirror boundaries, holes, curvature
  - Freq.-dependent crystal reflectivity added in 2008 for XFEL-O
  - {Freq. + angle}-dependent crystal reflectivity now being added

Topology for XFEL-O Simulation



Computational Issues

- XFEL-O typically has low gain; numerical propagation losses should be kept to 1% level or smaller
- Huygens Integral in both r and $k_\perp$ space can involve rapidly-oscillating integrands
  - For θ-independent cases, use complex matrix multiply
  - For θ-dependent cases, transform to $k_\perp$ space after mirrors:
    - "Fast" Hankel transforms appear to have their own special "features" (exp. grid, aliasing/ringing)
    - "F-H-A" transform method may be more accurate
    - Brute force transform remains an option (inelegant though…)
  - Many situations (*e.g.*, either high or low Fresnel number) require careful evaluation to ensure sufficient accuracy
- Overall goal to keep CPU time / pass < 1 minute; <10 sec even better for quick "prototyping"

Computational Issues - II

- ω-filtering effect of crystal requires transforming from time to frequency domain (a 1st for GINGER itself…)
  - narrowness of pass-band implies temporal spacing between slices generally ~ slippage distance or greater
  - thus, most e-beam interaction within undulator similar to single-slice simulation (with initial noise different on each pass)
- Crystal reflectivity applied via lookup table input via user-supplied file
  - Simple interpolation in ($k_\perp$, ω)
  - Plan is to allow multiple crystal types
  - Presumed axisymmetry (may not be always true)