DWA as a radiation source

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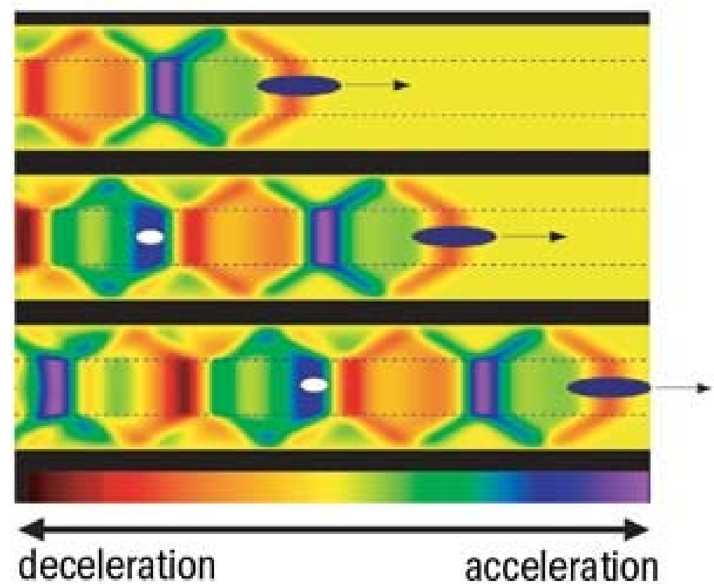
Motivation

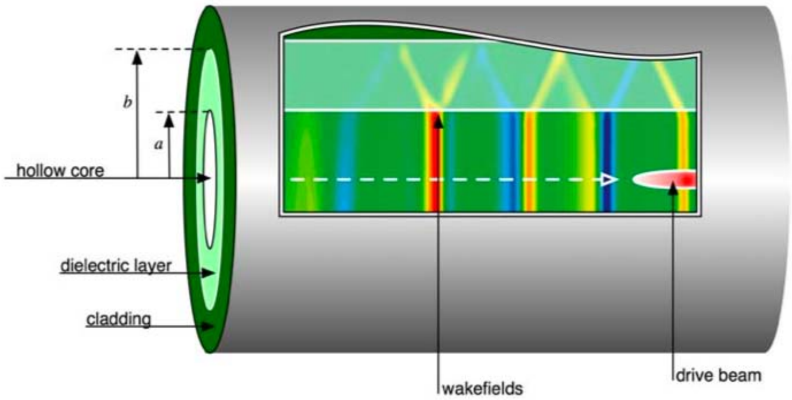
- High gradient DWA applications
  - HEP
  - Radiation Source
  - Advanced accelerator for future FEL
    - ~GV/m fields reduce size of machine
    - Larger scales (THz), relax emittance, higher charge beams
- Relevant Issues in DWA research
  - Determine achievable field gradients
  - High energy gain in acceleration
  - Transformer ratio enhancement
  - Resonant excitation of structure
  - Dielectric/metal heating issues
  - Cladding composition, thickness
  - Periodic structure development
  - Novel materials, meta-materials
  - Alternate geometries (slab)
  - Transverse modes and beam-breakup



$$E \sim \frac{N_b}{\sigma_z^2}$$

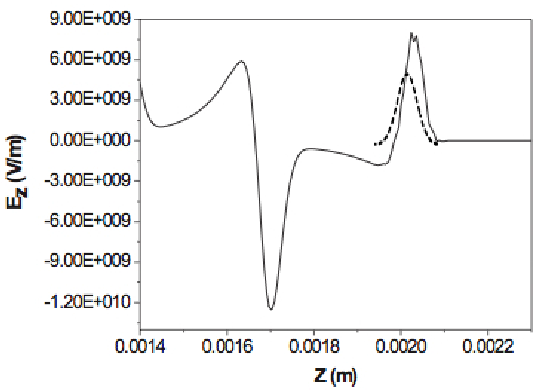
Accelerating gradient scales with high charge, short beams

Dielectric Wakefield Accelerator



- Electron bunch (β ≈ 1) drives wake in cylindrical dielectric structure
  - Dependent on structure properties
  - Generally multi-mode excitation
- Wakefields accelerate trailing bunch

- Design Parameters $a, b \quad \sigma_z \quad \varepsilon$



Ez on-axis, OOPIC

- Peak decelerating field

$$eE_{z,dec} \approx \frac{-4N_b r_e m_e c^2}{a\left[\sqrt{\frac{8\pi}{\varepsilon-1}}\varepsilon\sigma_z + a\right]}$$

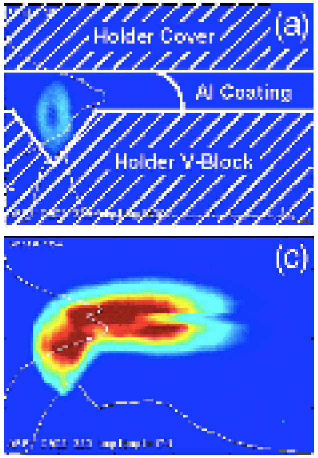
- Transformer ratio (unshaped beam)

$$R = \frac{E_{z,acc}}{E_{z,dec}} \leq 2$$

Previous experimental work

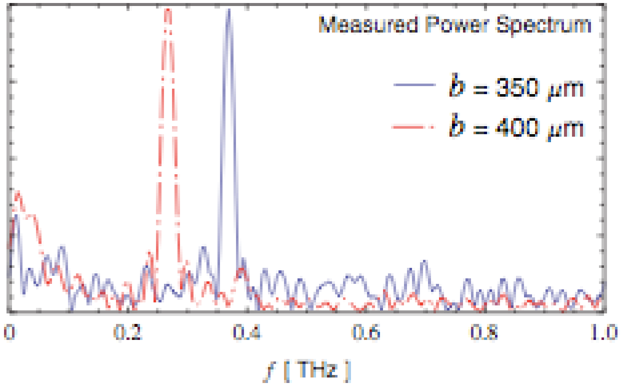
- SLAC FFTB
  - Study breakdown limits
  - Q~3nC, E=28.5GeV, σ_z~20µm
  - SiO_2, a=100,200µm, b=325µm, L=1cm
  - Beam can excite fields up to 13GV/m
- UCLA Neptune
  - CCR as a tunable THz source
  - Q~200pC, E=14MeV, σ_z~200µm,
  - PMQs to focus down to σ_r~80µm
  - Varied outer radius (b=350µm,400µm),L=1cm
  - ~10µJ of THz, narrowband
- UCLA experience in…
  - Short focal length PMQ
  - Preparation and fabrication of DWA structures,
  - Mounting, alignment of structures
  - Collection and measurement of emitted CCR

SLAC FFTB 2008



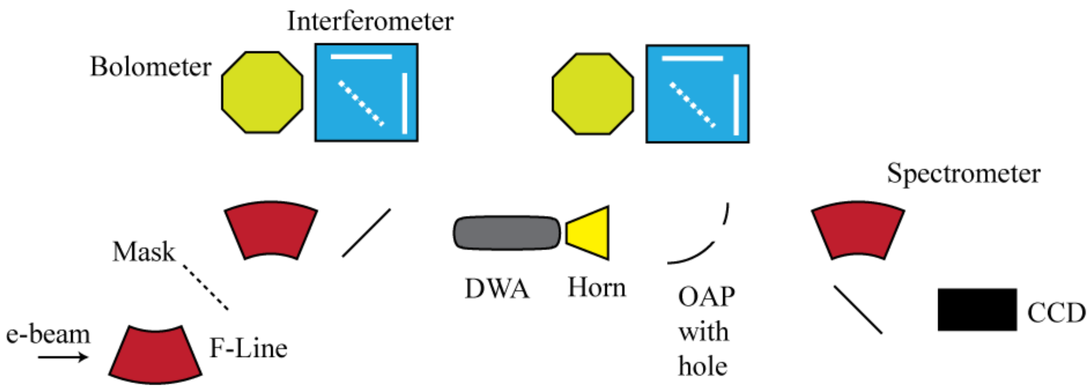
M. Thompson, et al., PRL 100, 214801 (2008)

UCLA Neptune 2009



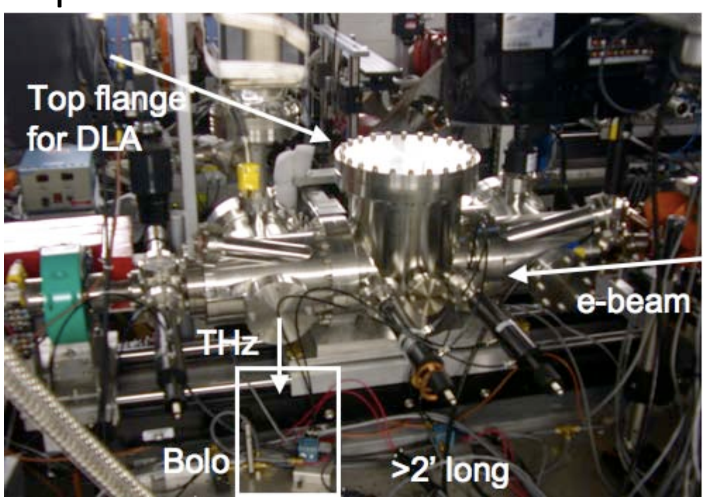
A. Cook, et al., PRL 103, 095003 (2009)

Experiment description at ATF

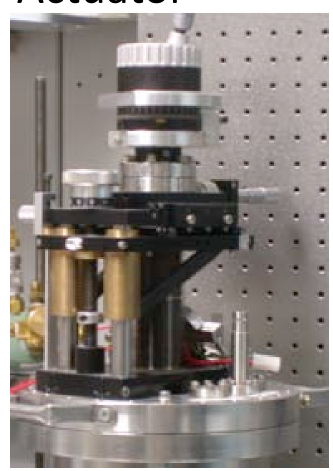


- Pulse train generated in F-line with mask
- Phase feedback loop (0.5deg)
- CTR measurement of multipulse bunch spacing
- DWA mount and alignment in old plasma chamber
- CCR measurement
- Hole in OAP allows simultaneous energy spectrum measurement

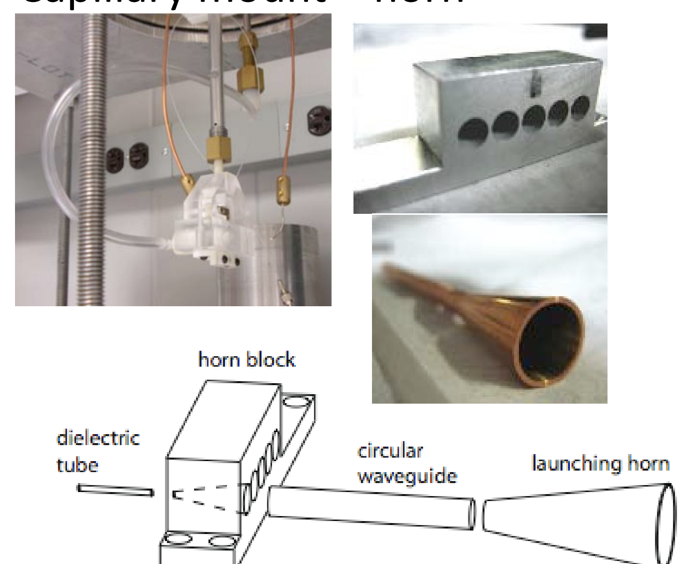
Top view



Actuator



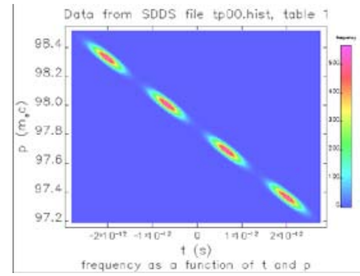
Capillary mount + horn



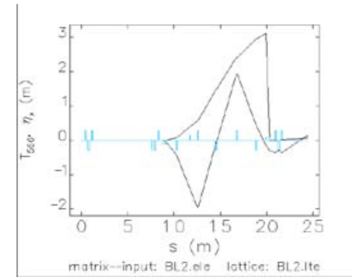
Sextupole studies – May 2010

- Goal: Mitigate nonlinear dispersion to generate uniform bunch spacing
- Experience from VISA FEL
  - Exploited second order dispersion for high current
  - Saturation at 800nm
- Elegant simulations
  - Generate bunch train externally
  - Not including full start-to-end
  - Include CSR effects
- Beam Chirp
  - Energy spread <1%
  - Tail has higher energy
- CTR autocorrelation
  - Width of FT spectrum correlates to uniformity of bunch spacing

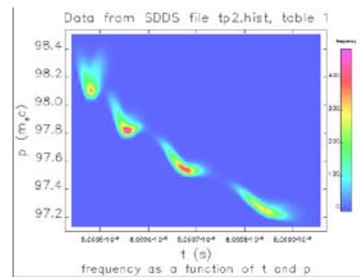
Initial longitudinal phase space



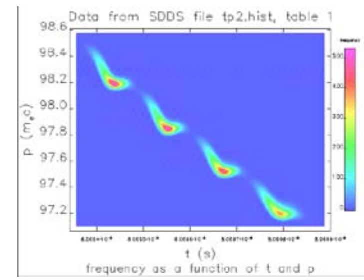
Dispersion with sextupole



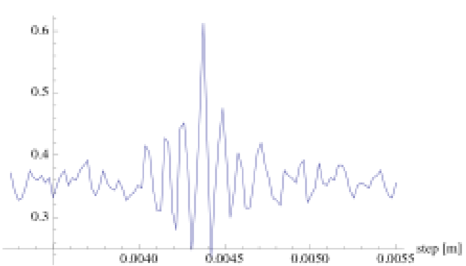
Final phase space – no sextupoles



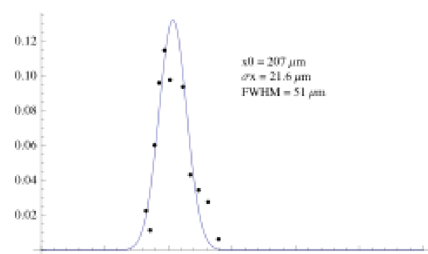
Final phase space –sextupoles

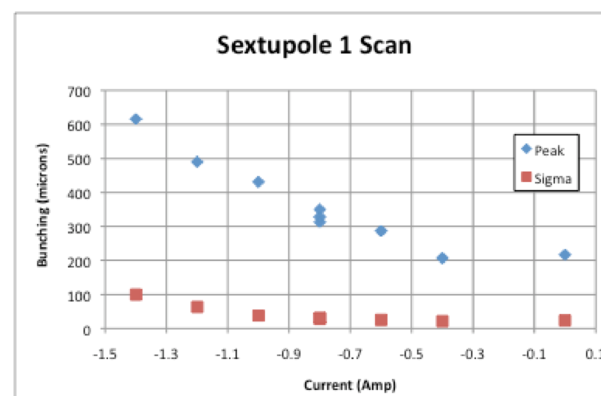


CTR interferogram



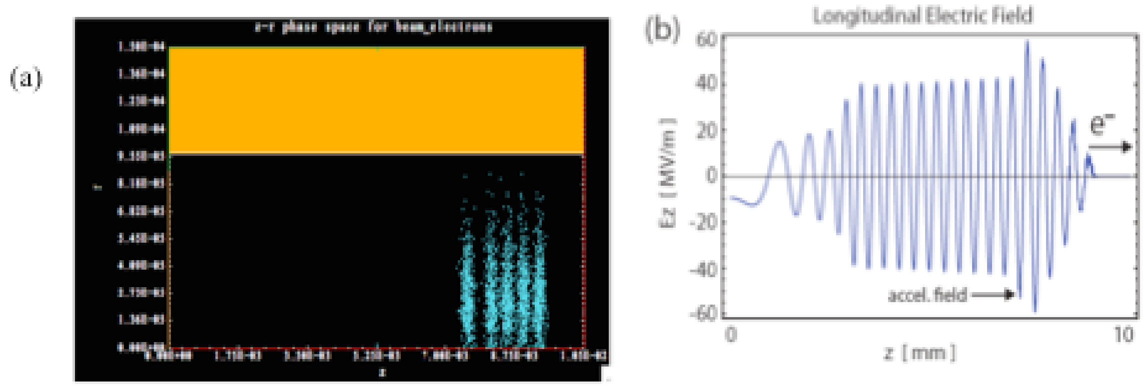
Fourier transform





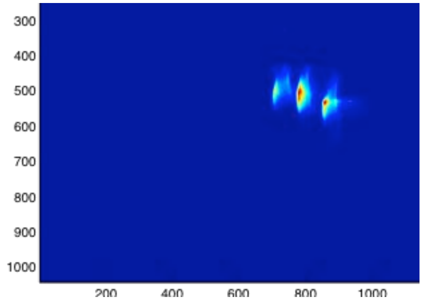
CCR studies – June2010

- Parameters
  - SiO2
  - Al coated (vapor deposition)
  - a=100µm, b=150µm
- Fundamental excitation
  - Bunch spacing set to ~500µm
  - 490µm fundamental
  - 3 bunches + witness
  - Wrong chirp
- Attempted to observe acceleration simultaneously
  - Used “wrong” side of chirp (low energy at tail)
  - Figures inconclusive

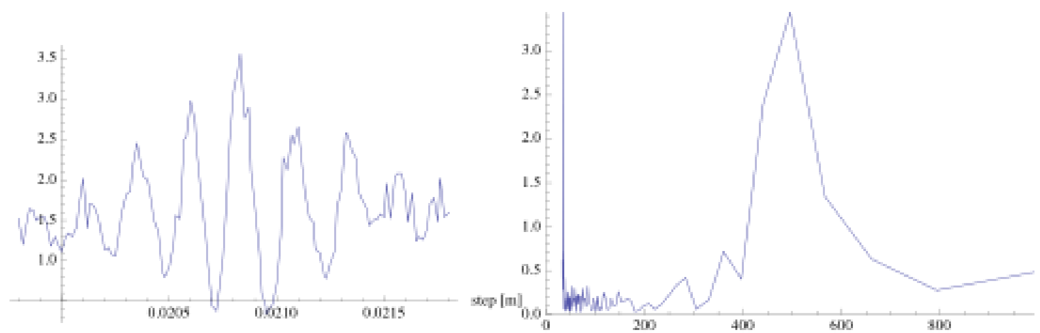


OOPIC simulations for multibunch + witness beam

Peak field = 55MV/m



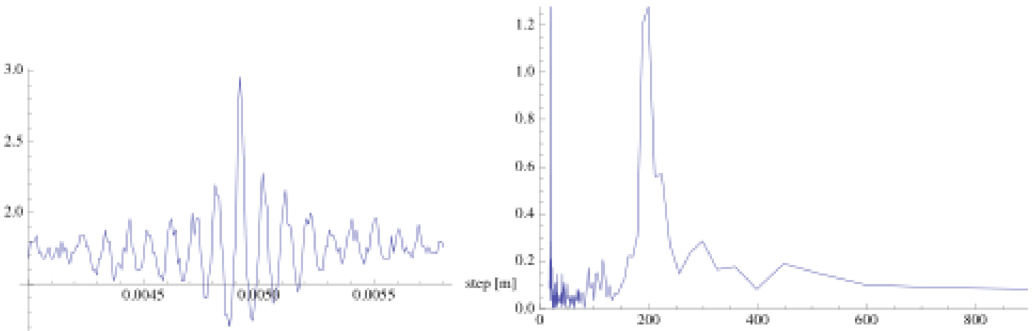
Spectrometer image (3 bunches)



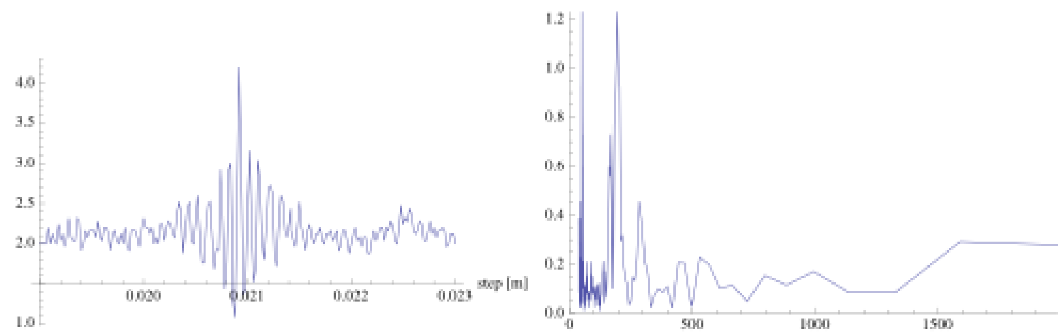
CCR interferogram and spectrum (peak ~500µm)

CCR harmonic – Aug2010

- Bunch spacing tuned to harmonic
  - Spectral peak ~200µm
  - 3 or 4 bunches
  - Selective excitation of harmonic
- Deflecting mode
  - 300µm peak
  - Misalignment in beam trajectory through tube
  - Confirmed in simulations
- Beam phase stability
  - Feedback loop
  - ~0.5deg target



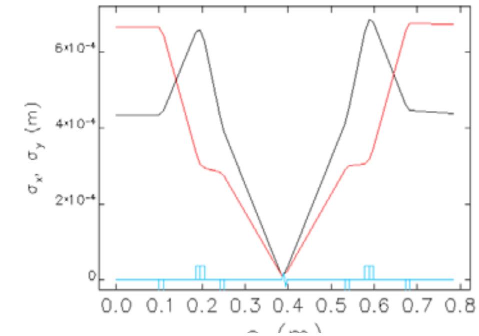
CTR interferogram and FT (bunch spacing ~200µm)

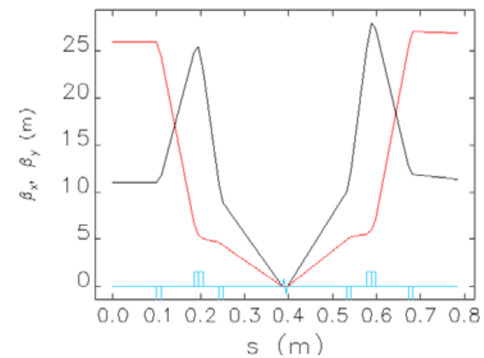


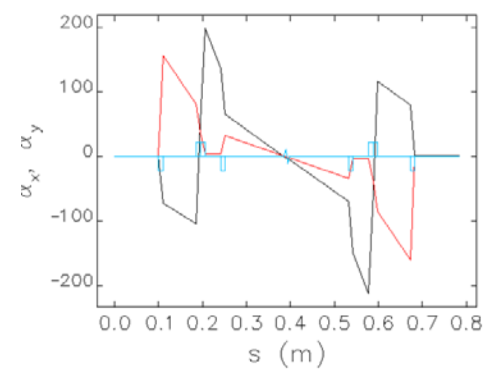
CCR interferogram and spectrum (peak~200µm)

Follow-on measurements at BNL ATF (2010-11)

- Use “new” DWA tubes
  - a=50µm, b=100µm, L=1cm
  - SiO2 and CVD Diamond
  - Euclid Tech Labs (A. Kanaryekin)
  - Al-coated at UCLA
  - Accel. fields >100MV/m
- Small beam spot size (~10µm) – Elegant Studies
  - need PMQ (125T/m)
  - Triplet configuration
  - Symmetric lattice to recollect beam for diagnosis
  - spectrometer
- Fabricate mask for correct bunch spacing and chirp for acceleration demonstration
  - Allow for harmonics studies
- Also study single compressed bunch
  - Low charge (mask selection)
  - High charge (chicane compressor)







Conclusions

- Progress in DWA as radiation source
  - May2010: Sextupole studies
  - June2010: Fundamental excitation
  - Aug2010: Harmonic excitation, deflection mode observation
- Leverage off recent results
  - Use smaller tubes
    - a=50µm, diamond (Euclid Tech)
  - Employ PMQ focusing
  - Observe acceleration
  - Continue to build experience in
    - Fabrication, mounting DWA
    - Radiation collection, transport
- ATF is unique because it offers…
  - Pulse trains
  - Compressed beams
  - CR diagnostics in place (interferometers, bolometers)

Acknowledgements

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