Compressor and Chicane Radiation Studies at the ATF

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ATF Users Meeting
April 4-6, 2007
BNL, Long Island, NY

Collaboration

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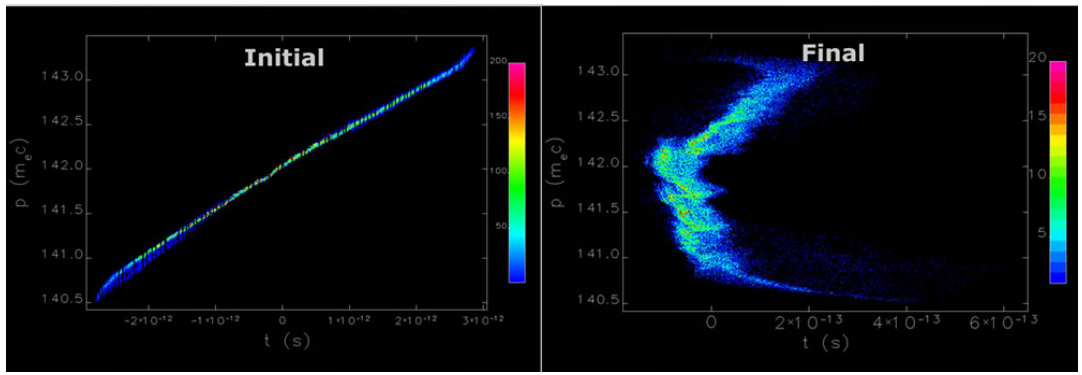
Outline

- Motivation
- Technical Specifications and layout
- CTR
- CER (Edge Radiation)
  - Theory
  - Results
  - Analysis (Simulations)
- Outlook
  - Upgrades
  - Silencer

Motivation

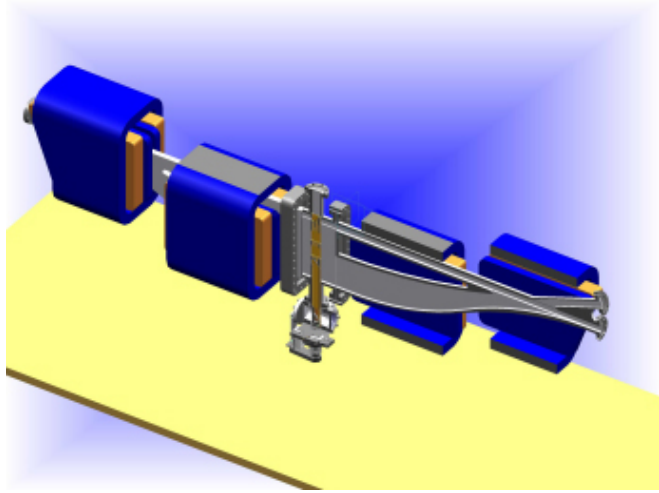
- Generation of compressed sub-micron beams
  - Study radiative effects (CSR, CER) emitted from short beams
  - Continue UCLA Neptune compressor physics studies in acceleration field dominated regime (space charge -> coherent radiation)
  - May greatly impact performance of future compressors and FELs (e.g. microbunching instability)
  - Use CER as non-destructive bunch length monitor



Parmela-Elegant simulation longitudinal phase space of beam, with compression from 50A to 1.5 kA.

Chicane Compressor

- Designed and Constructed at UCLA
  - Modeled with Amperes
  - Engineering, safety concerns addressed by ATF
- Installed and operational at ATF
  - Add to ATF core capabilities
    - SASE FEL, wake field studies
- Field = 0.2 T ; Bend Radius = 1.2m
- Extensive Simulation work
  - TREDI, Field-Eye, Parmela, Elegant, Quindi
  - Compress from 350 μm – 30 μm
- Study basic beam physics
  - X-ray FEL, linear collider, etc.
    - bunch diagnostic, phase space degradation

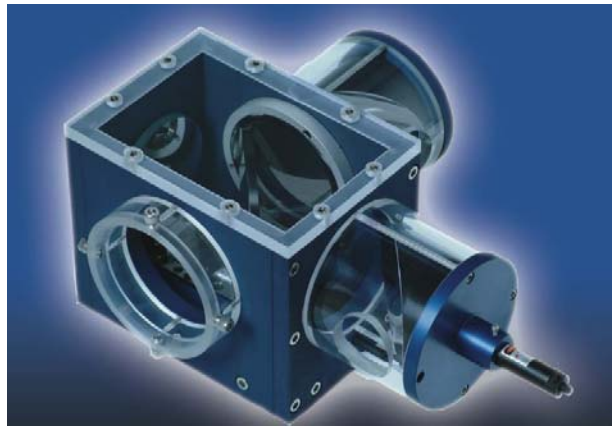


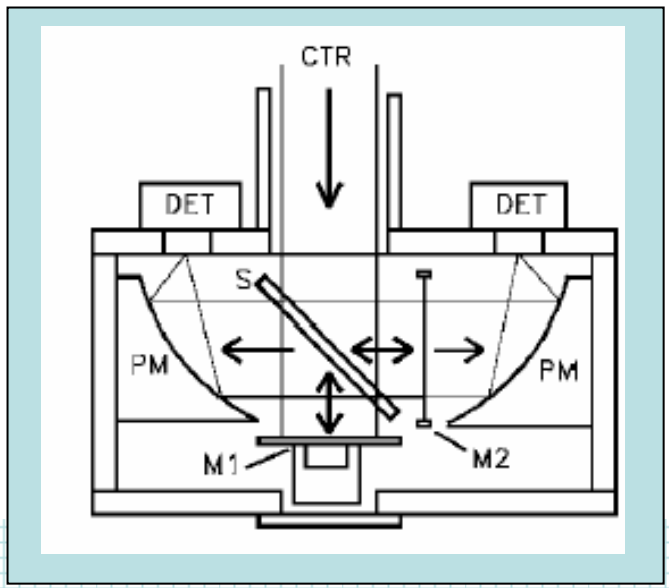
Compressor Radiation Studies

- CTR autocorrelation
  - Bunch length
  - Bifurcation
- CER (Coherent Edge Radiation)
  - Polarization
  - Far field distribution
  - Spectrum
  - Analysis
- Start-to-end Simulations
  - Parmela
  - ELEGANT
  - QUINDI
  - Field-Eye

CTR Measurement

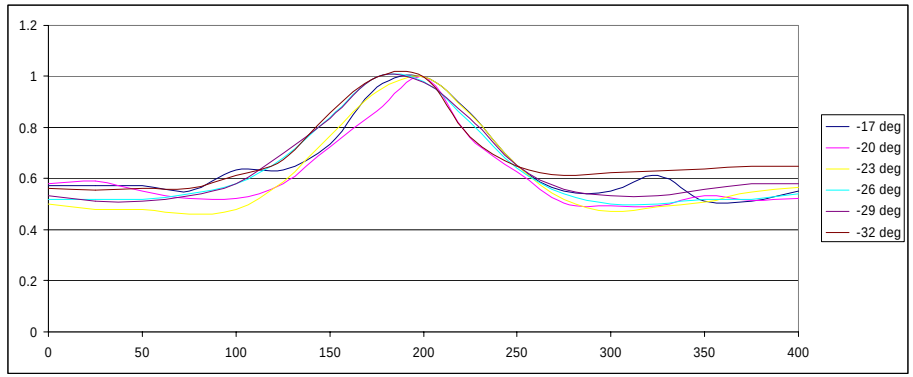
- Michelson Interferometer
  - Commercial Product
  - Compact Footprint
  - Convenient Alignment
  - Range : 15 μm – 1.5 mm (rms)
- Observe CTR from insertable foil
  - Golay Cell detectors
  - Autocorrelation
- UCLA time-domain methods (fitting) and data acquisition
  - Kramers-Kronig analysis



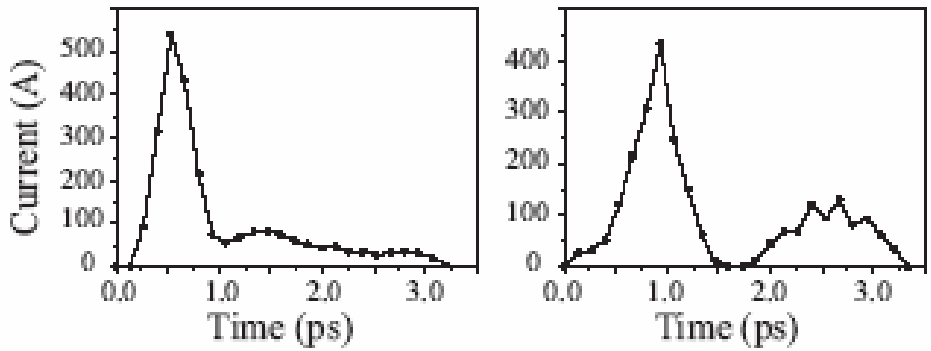


CTR Analysis

- Autocorrelation Analysis (asymmetric bunch)
  - Form factor
  - Kramers-Kronig
  - Phase Reconstruction
  - Longitudinal Dist.
- For optimum compression
  - well defined peak > 500A
  - 370 fs (FWHM)
  - 150 fs rms (~45 microns)



Sample of raw Autocorrelation trace



Longitudinal Distribution for compressed (left), and over-compressed (right) cases.

Momentum Spread

- Observation of bifurcation
  - Momentum spectrum
    - Strong breakup of momentum distribution at phase of full compression
    - Currently being studied with QUINDI code

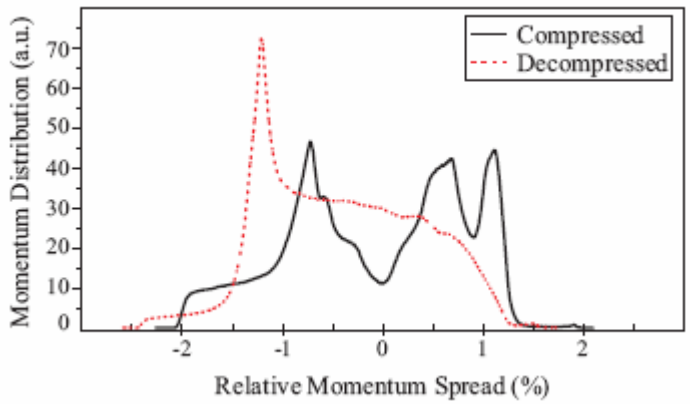
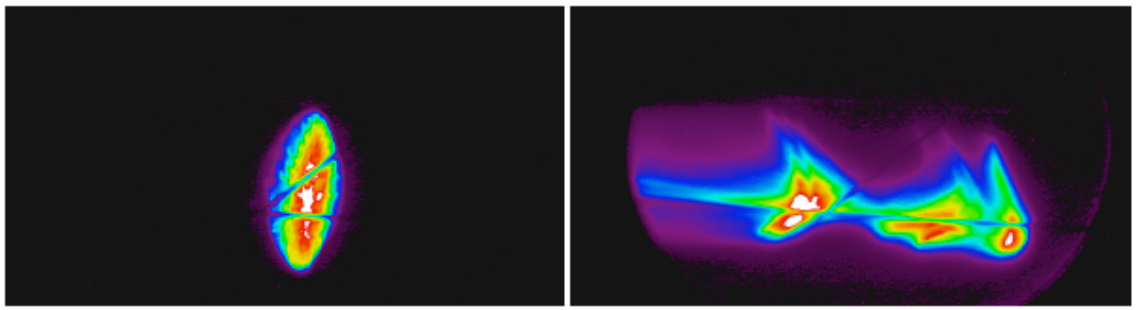


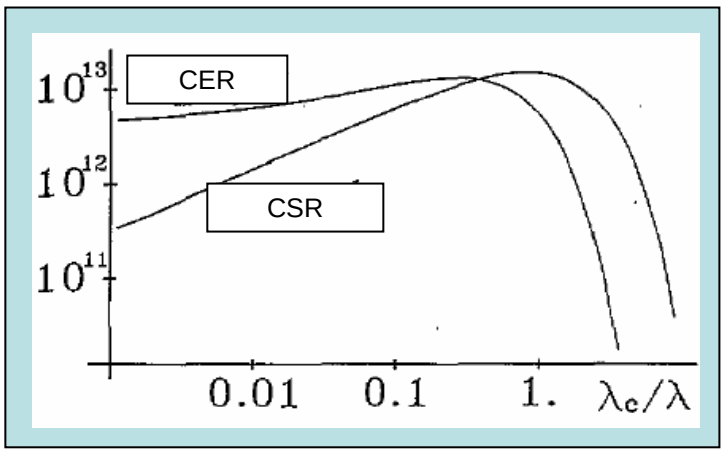
Image of beam in spectrometer (horizontal is bend plane).



Min. energy spread and no compression - 9 deg fwd of crest (left); Max. compression -19 deg fwd of crest (right).

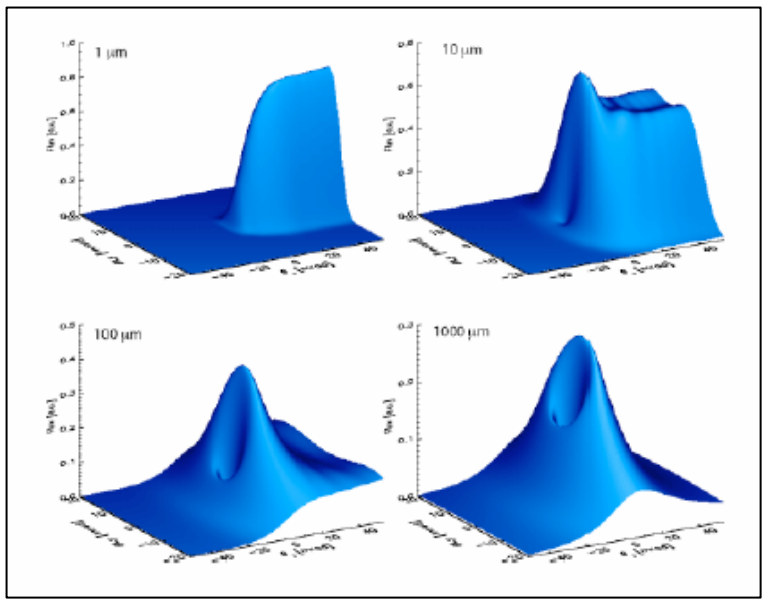
CER Overview

- Comparison to CSR
  - Not well distinguished from CSR at short wavelengths
  - Like CTR at long wavelengths
  - Radial polarization



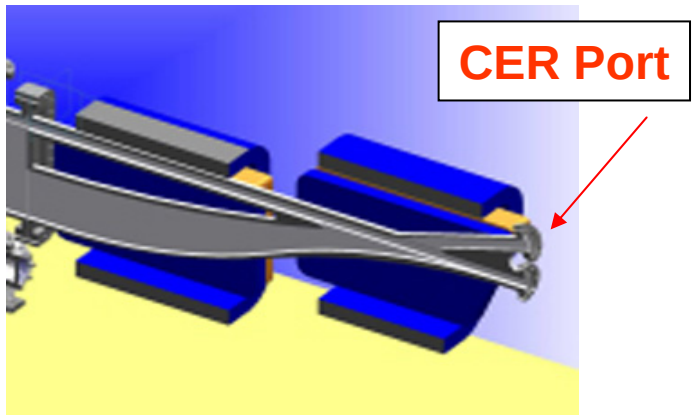
Chubard, Smolyakov, J. Optics 24 (1993) 117

- CER calculations
  - Modeling with:
    - Semi-analytical
    - Field-Eye, Quindi



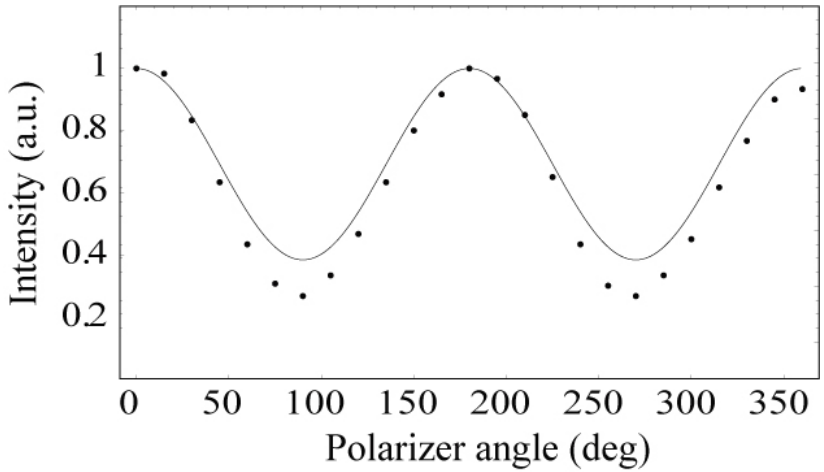
CER Measurement

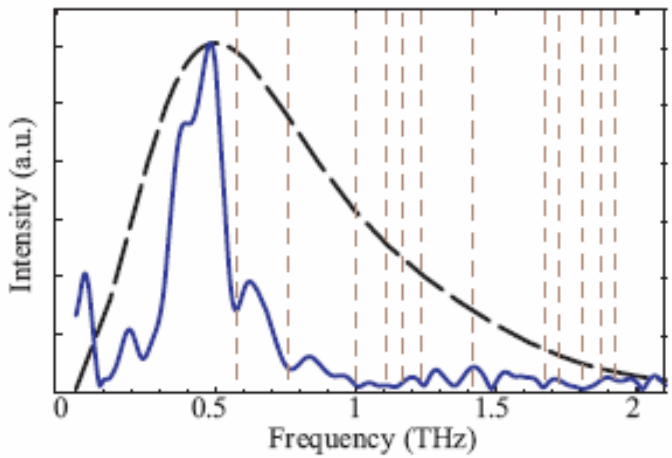
- 7m transport
  - CER port → detector
  - picarin lens
  - collecting mirror
  - aligned with HeNe
- Si LHe cooled bolometer
  - IR labs
  - filter wheel
- Iris scans
  - FF angular dist.
- Polarizer
- Interferometer



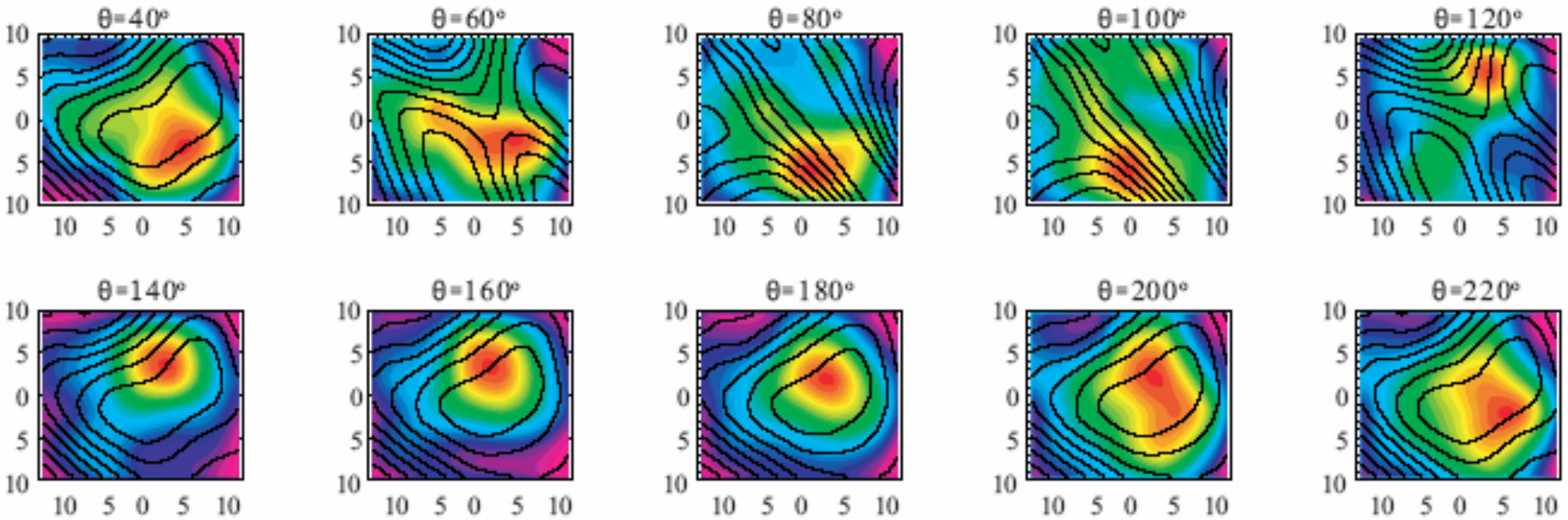
Chicane Radiation Results

- Polarization
  - sigma and pi polarizations
    - radial polarization
    - CER + CSR
- THz spectrum
  - data (solid blue curve)
  - QUINDI simulations (dashed black curve)
  - water absorption lines (vertical red lines)
    - water lines correspond to troughs in data





Results (cont.)



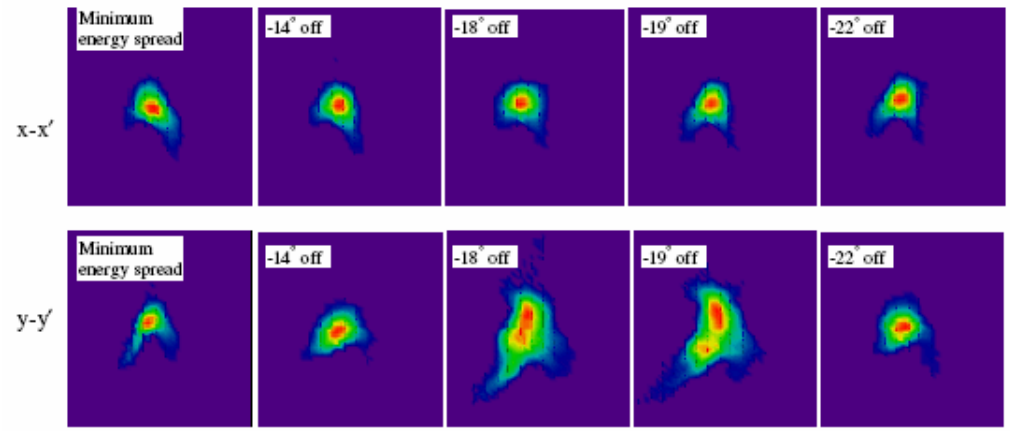
- Far-field intensity distributions
  - as a function of polarizer angle
  - horizontal and vertical axis (mm)

Upgrades

- THz transport
  - window (z-cut quartz)
    - coming soon
  - enclosure flushing (or evacuating)
  - polished picarin lens
    - remote control stage
  - spectrometer (gratings)

Transverse Effects

- Tomography
  - Quadrupole scanning tomography developed at ATF
    - reconstruction from projections
    - builds on multi-slit technique for low E beams
- Operating parameters
  - Energy = 60 MeV, Charge = 200 pC
  - Normalized Emit = 2 mm-mrad
- Mild bifurcation observed
  - Space charge forces giving phase space bifurcation are alleviated at this energy



Reconstructed transverse phase space for varying beam parameters (optimal compression at -19 deg)

F. Zhou, et al., Experimental characterization of the transverse phase space of a 60-MeVelectron beam through a compressor chicane, PRSTAB 9, 114201 (2006)

Conclusions

- Chicane installed, commissioned
  - tool for basic beam physics studies
  - characterization of radiation
    - CTR, CSR, CER, etc.
    - tomography techniques employed
- Outlook
  - More data on CER
    - Improve transport for THz
    - Continue developing codes (benchmark STE)
  - Compressed beam FEL
    - x-band silencer
  - Halo Monitor
    - Wire-scanner along F-line