Potential Implementation of a Dogleg Bunch Compressor with Linearization Optics in Argonne Wakefield Accelerator Facility

National Synchrotron Radiation Research Center (NSRRC)

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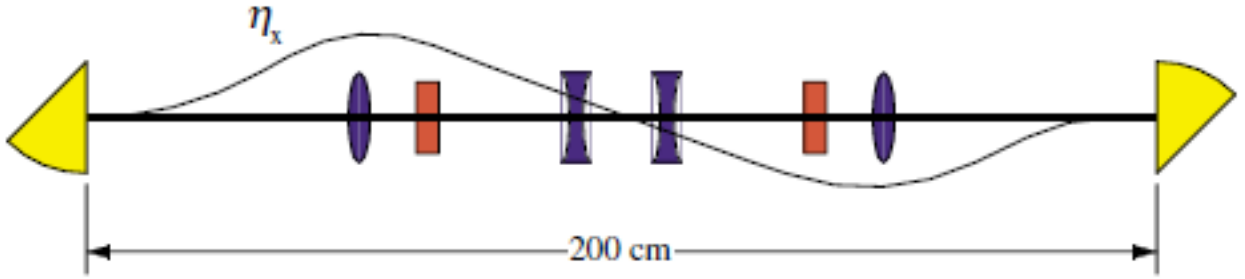
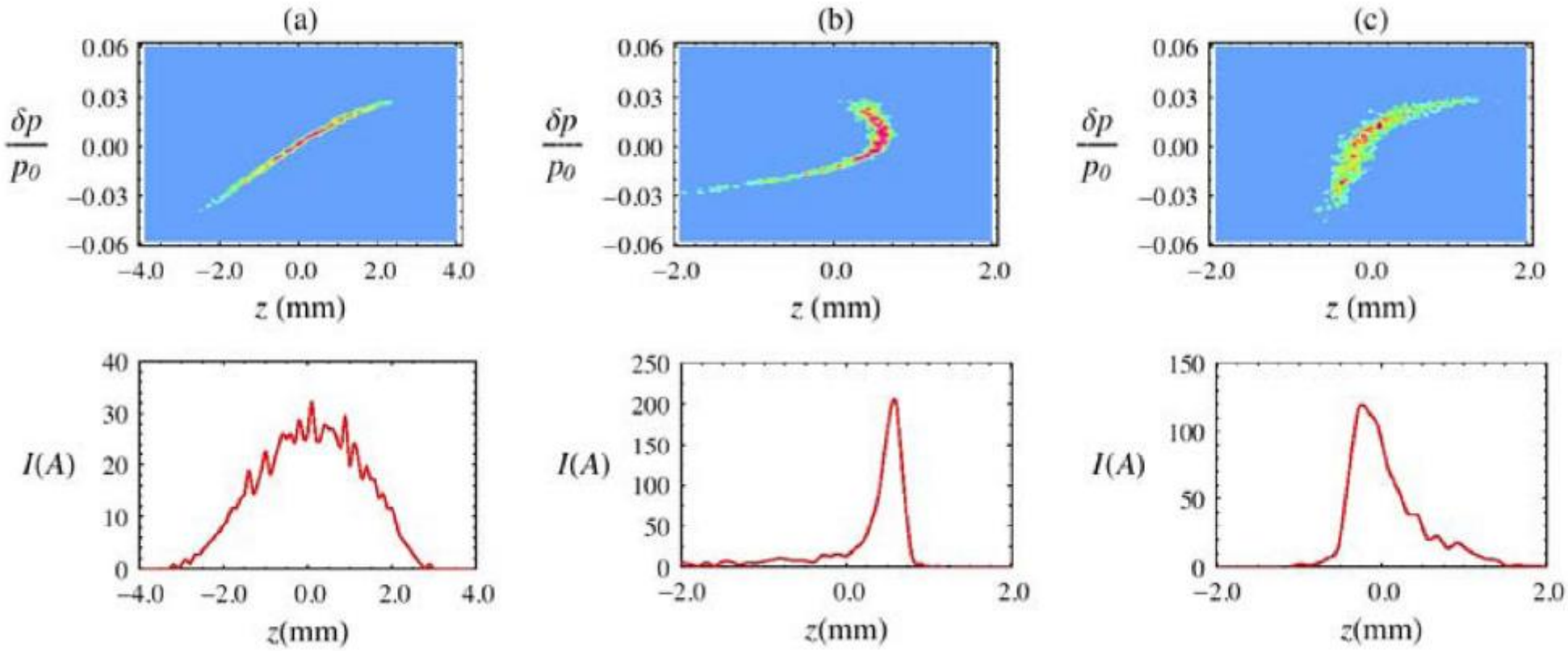
Dogleg section : UCLA example for PWFA

Cartoon picture of dogleg section at UCLA



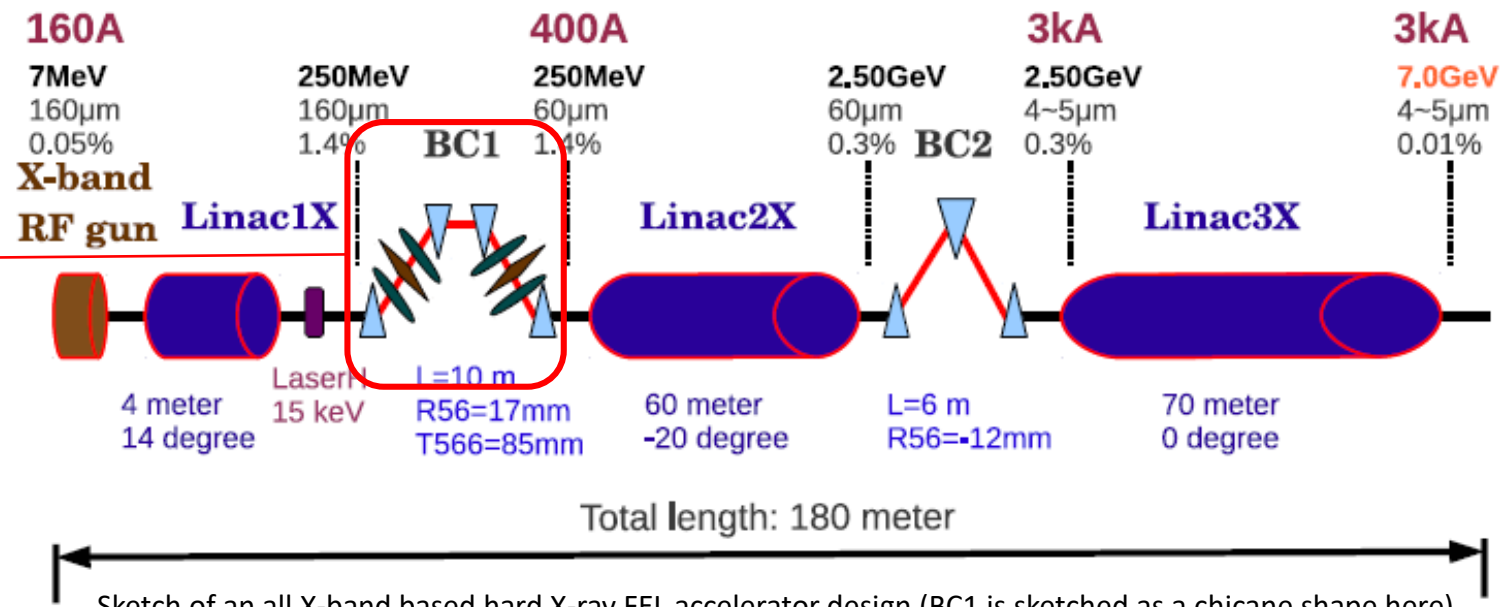


Plot of phase space simulation results from Elegant (a) the beam at the entrance of the dogleg compressor, and the same beam at the end (b) without sextupole correction and (c) with sextupole correction.

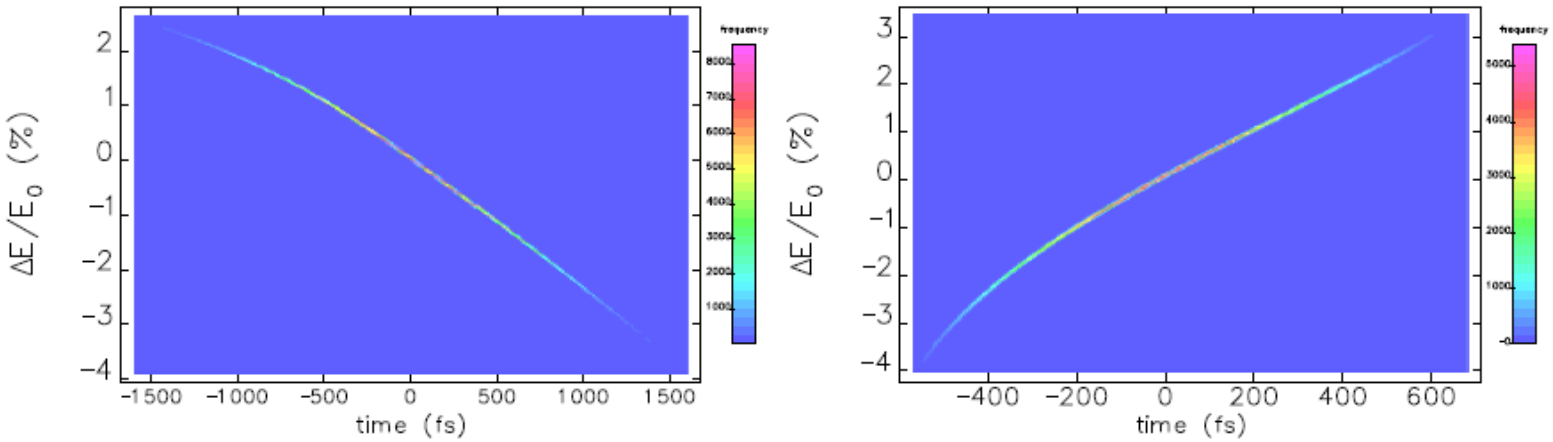
R. J. England et al., Phys Rev ST Accel Beams (2005) 8:012801. doi:10.1103/PhysRevSTAB.8.012801

Dogleg compressor : SLAC example

replace rf linearizer and chicane by a dogleg compressor



Sketch of an all X-band based hard X-ray FEL accelerator design (BC1 is sketched as a chicane shape here).



Plot of phase space simulation results from Elegant

Beam manipulation& linearization

Yipeng Sun et al., Phys Rev ST Accel Beams (2014) 17:110703. DOI: 10.1103/PhysRevSTAB.17.110703

NSRRC THz Free Electron Laser Test Facility

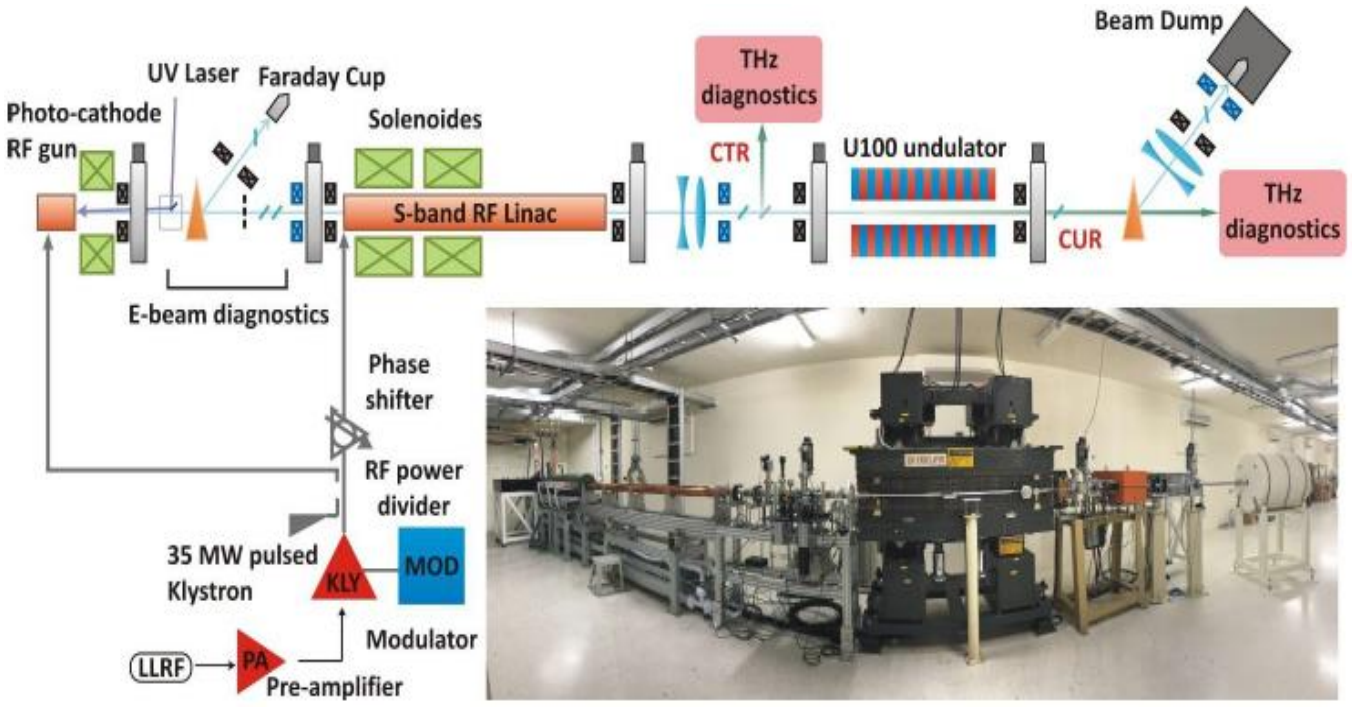
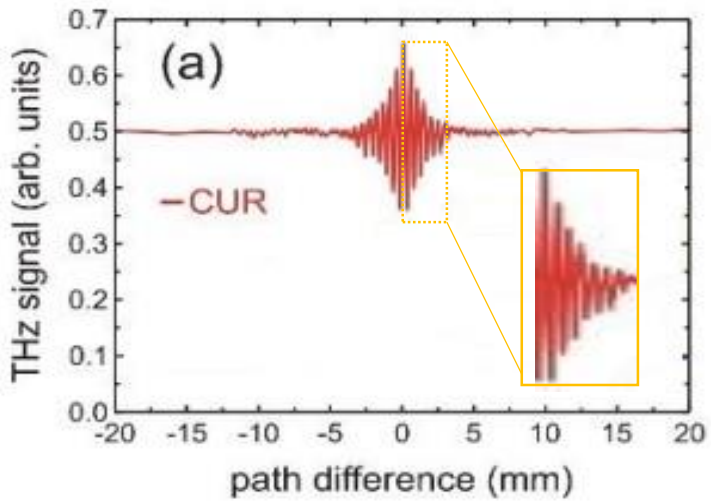


Figure 1: Layout and photo of the NSRRC photo-injector and coherent THz sources.



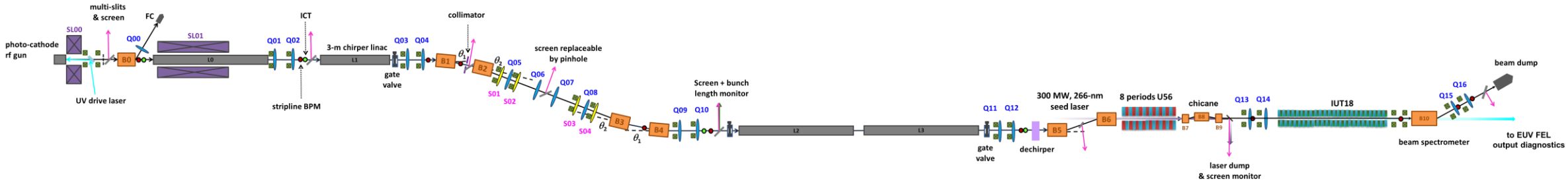
Measured interferograms for CUR source

- We have built up a tunable narrow-band THz coherent undulator radiation source in our test facility

parameters	CUR	CTR
Electron energy(MeV)	17.7	
Total charge(pC)	280	210
Bunch length(fs)	490	
Repetition rate(Hz)	10	
Undulator parameter K	4.6	--
THz Pulse energy (μJ)	26.4	6.7
central frequency(THz)	0.62	--
bandwidth	15%	--
THz peak power	530kW	9.4MW

Performance of THz source

Layout of the Proposed EUV FEL Facility at NSRRC

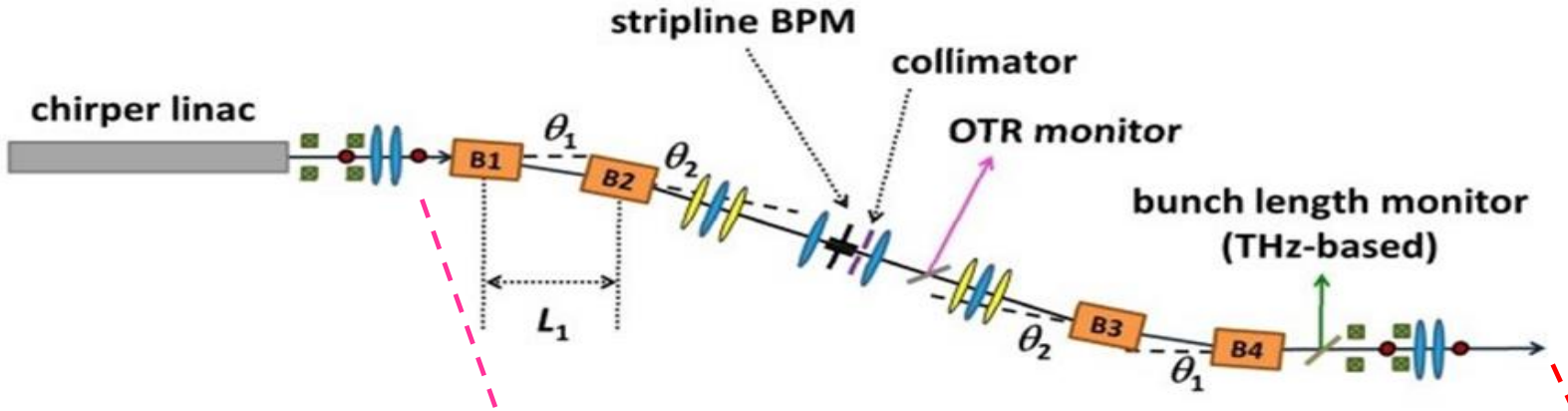


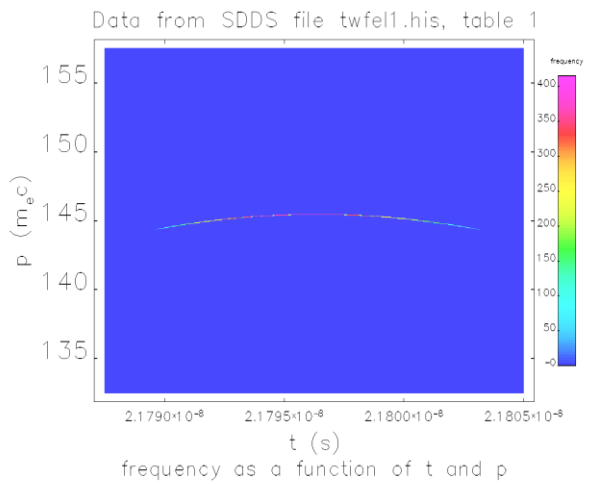
NSRRC photoinjector system

5.2-m rf linac structure

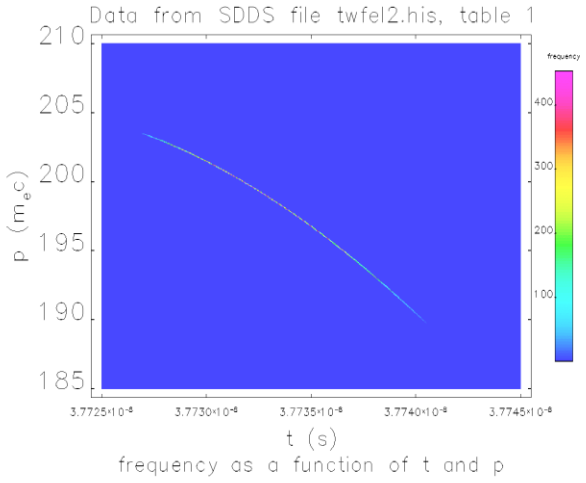
in-vacuum undulator

Dogleg Bunch Compressor

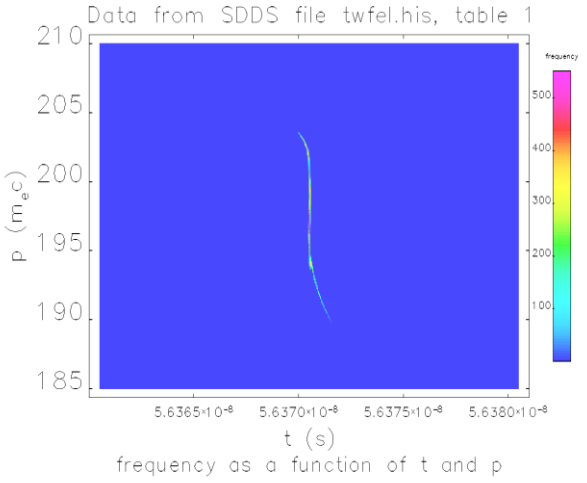




Injected beam



Chirped beam

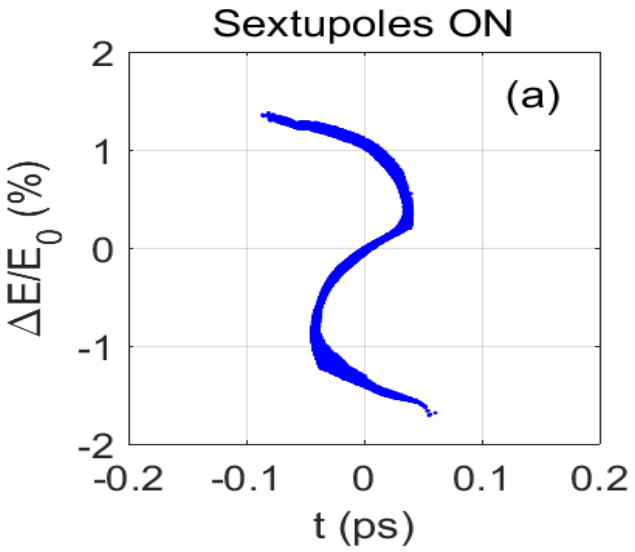


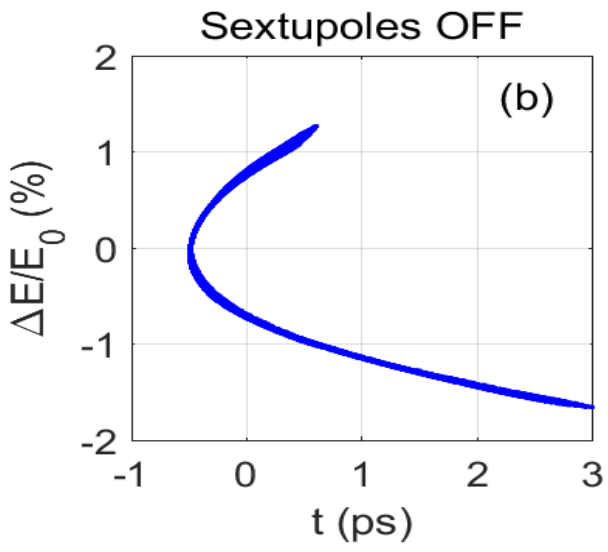
Compressed beam

W.K. Lau et al., “Design of a Dogleg Bunch Compressor with Tunable First-Order Longitudinal Dispersion”, Proceedings of FEL2017, TUP031(2017).

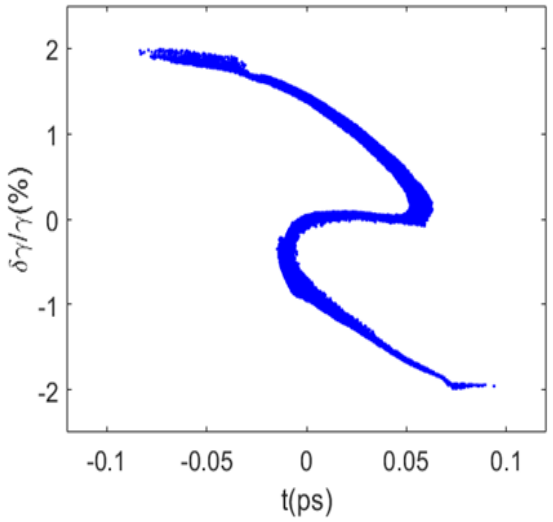
Distribution of drive beam in longitudinal phase space

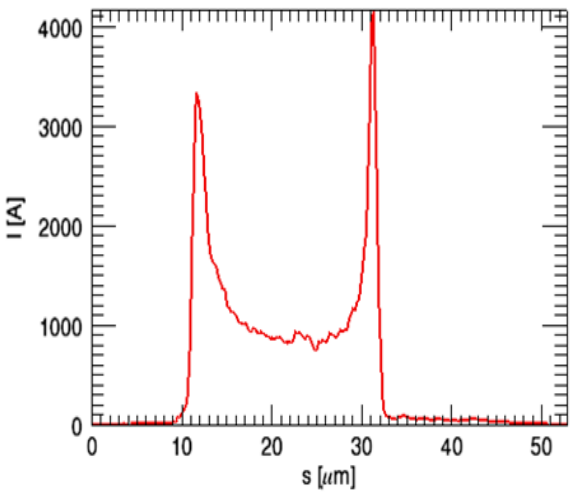
Compressed beam (with residual energy chirp)





Compressed beam is dechirped by a corrugated pipe dechirper





Beam current profile

AWA CAPABILITIES - CURRENT

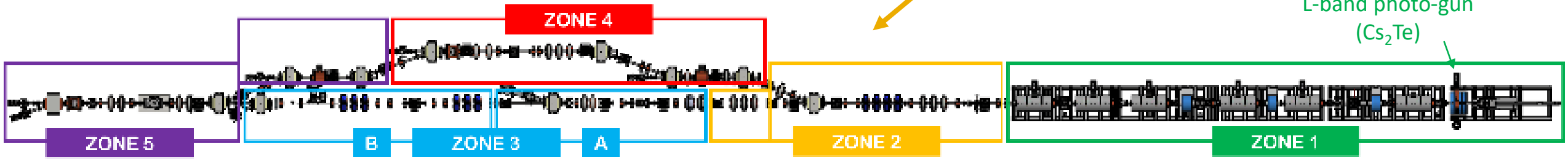
Laser Shaping
(α-BBO, multi-splitter, MLA, SLM, etc)

6D PHASE SPACE MANIPULATION BEAMLINES

Double emittance exchange beamline

Flat beam transformer

L-band photo-gun
(Cs_2Te)



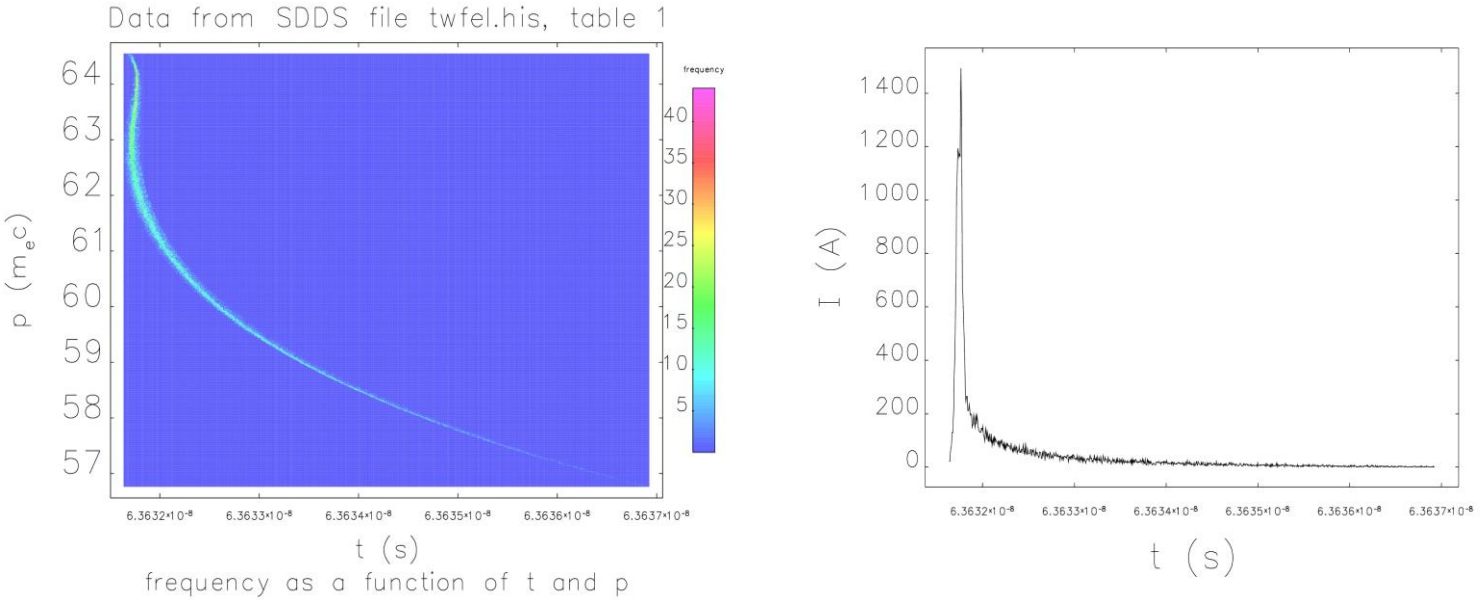
Single bunch parameters	Value
Charge [nC]	0.1 – 100
Energy [MeV]	6 – 63
Rep. rate [Hz]	0.5 – 10
Bunch length [mm]	0.1 - 3
Transverse emittance [μm]	0.5 - 240

*Available energy and rep. rate are not continuous.
*The range showing all range. Actual range depends on charge level.

Special operations	Value	
Bunch train	Modulation freq. [GHz]	$1.3 – 10^3$
	Charger per bunch [nC]	<70
Longitudinal shaping	Shape	Arbitrary
	Charge [nC]	<5
Flat beam	Charge [nC]	<5
	Emittance ratio	<150
Transverse shaping	Available type	1. Dot-array 2. Hollow

Courtesy of Dr. John Power

Case Study of NSRRC photoinjector operated at 30MeV

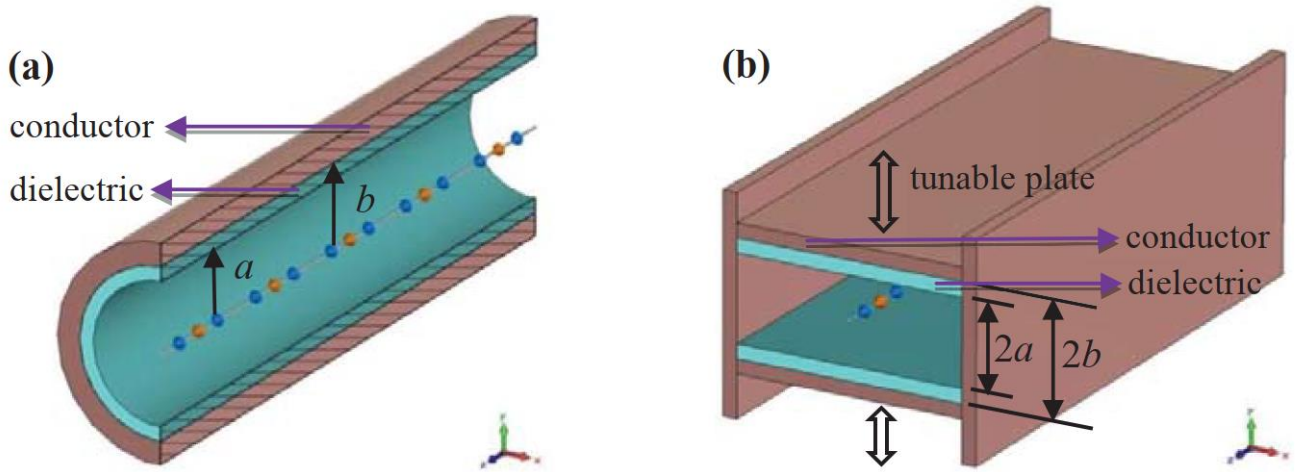


Distribution of electrons in longitudinal phase space before and after bunch compression as calculated by ELEGANT for optimal bunch compression.

- A ~140 fsec bunch of 250 pC charge can be obtained at 30 MeV beam energy after bunch compression.

NSRRC Photoinjector Beam Parameters	
Beam Energy [MeV]	32.3
Bunch Charge [pC]	250
Beam Size [mm]	0.65
Bunch Length [mm]	1.16 (3.9 ps RMS)
Projected Energy Spread [keV]	162
Projected Beam Emittance [π mm-mrad]	0.9
Sliced Energy Spread [keV]	< 30 (-1 < z < 1 mm)
Sliced Beam Emittance [π mm-mrad]	0.5 – 1.0 (-1 < z < 1 mm)
β [m]	31.0
α	-3.0

Applications : Dielectric Wakefield Acceleration & PWFA



(a) Cylindrical dielectric waveguide and (b) Rectangular dielectric waveguide.

- The ultrashort bunch can be used to drive wakefields in some DLW structure to excite wakefields at sub-THz to THz frequency ranges.
- The optimal current profile for PWFA can be achieved by the appropriate beam manipulation

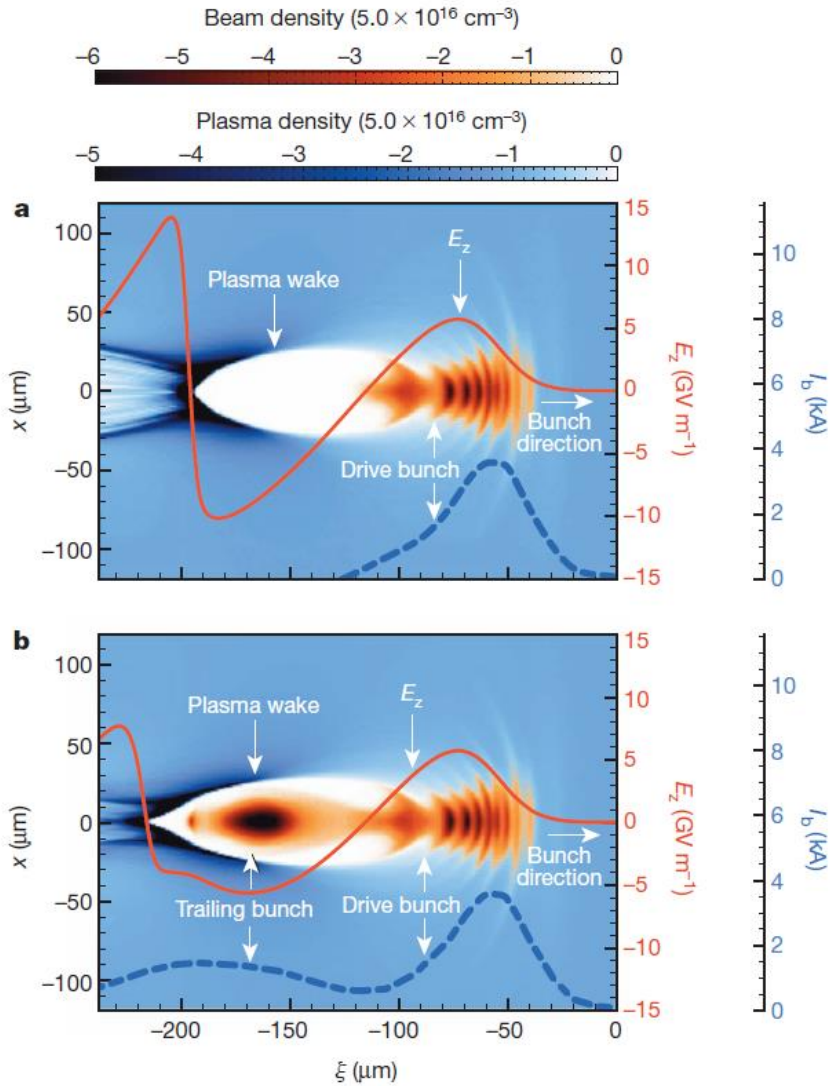


Diagram of PWFA

Litos, M., Adli, E., An, W. et al. High-efficiency acceleration of an electron beam in a plasma wakefield accelerator. Nature 515, 92–95 (2014). https://doi.org/10.1038/nature13882

Summary

Summary

- Instead of using the conventional bunch compressor, we propose to implement a cost effective dogleg beamline equipped with sextupoles for linearization of electron distribution in longitudinal phase space to achieve bunch compression at high compression ratio.
- The chirper linac can be installed in zone 2 and the dogleg can be set up in zone 4
- The ultra-short electron bunch can be utilized in many advanced applications such as DLW acceleration and PWFA

First steps in future plans

- Design of practical magnetic lattice components for AWA
- Feasibility study of bunch compressor can be evaluated using IMPACT simulation

Thanks for your attention