Suppressing the Microbunching Instability at ATF using Laser Assisted Bunch Compression

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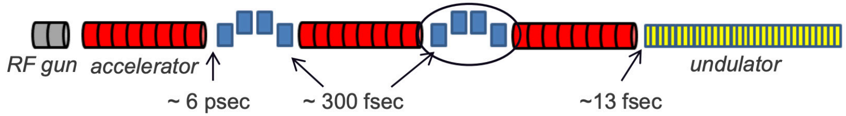
Introduction

1. Novel architecture: eSASE and LABC can shorten the length of the LINAC.
2. These new architectures can be used to suppress the microbunching instability.
3. Proposed experiment to test this concept at ATF.
4. ELEGANT simulations of the experiment.

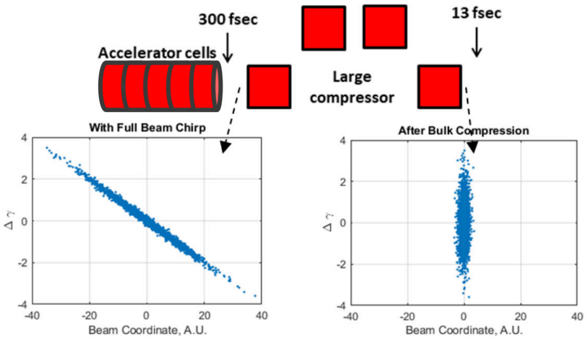
Novel Accelerator Architecture

Our proposed alternative XFEL architecture may have a major impact on the performance and energy reach of existing and proposed XFELs

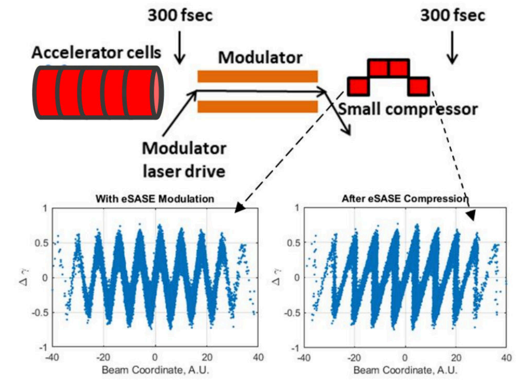
We would replace the second bunch compressor in a conventional design



Compression of the entire bunch to the ~ 3 kA needed for lasing causes other problems – undulator resistive wall wake, microbunch instability, CSR enhancement



with a modulator/buncher that keeps an overall longer bunch



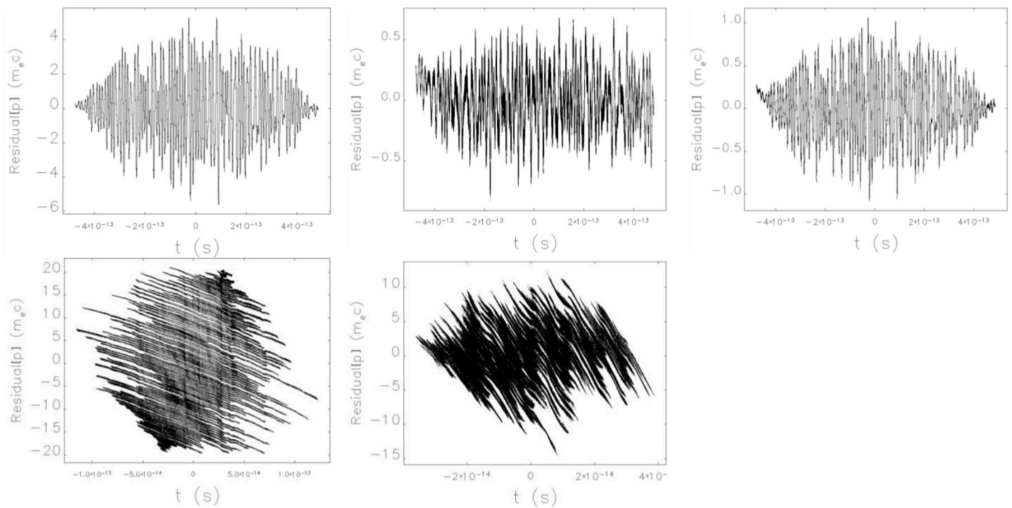
The other problems are reduced (or eliminated)with this new architecture

Problem Being Solved

eSASE architecture eliminates the MicroBunch Instability (MBI) which is recognized as the key limitation of existing XFELs

before BC2

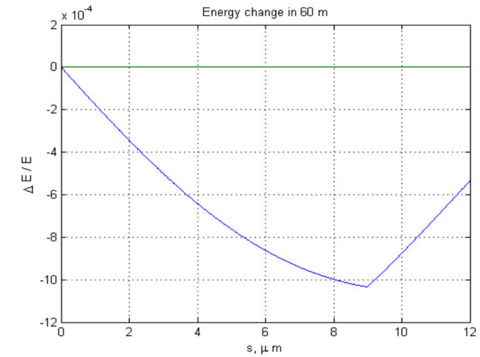
after BC2

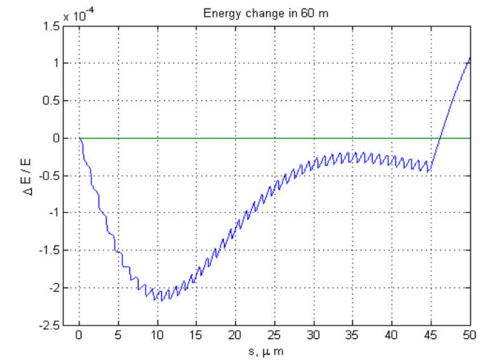


Cold beam | Laser-heated beam | eSASE beam

(these simulations are for 450:1 total compression ratio)

A microbunched beam eliminates the MBI growth mechanism



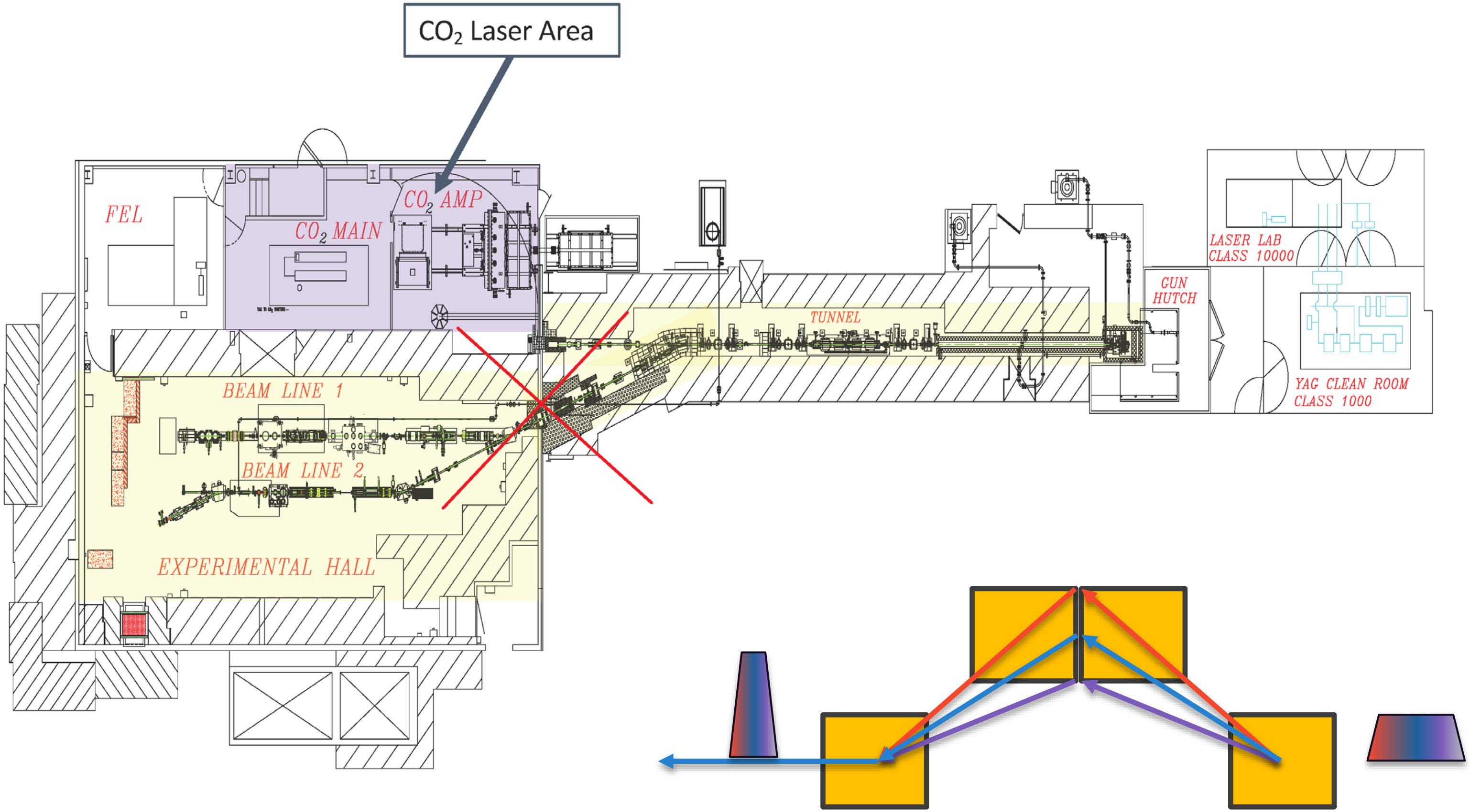


The magnitude of the URWW is also reduced by a factor of ~ 5, making it a non-issue

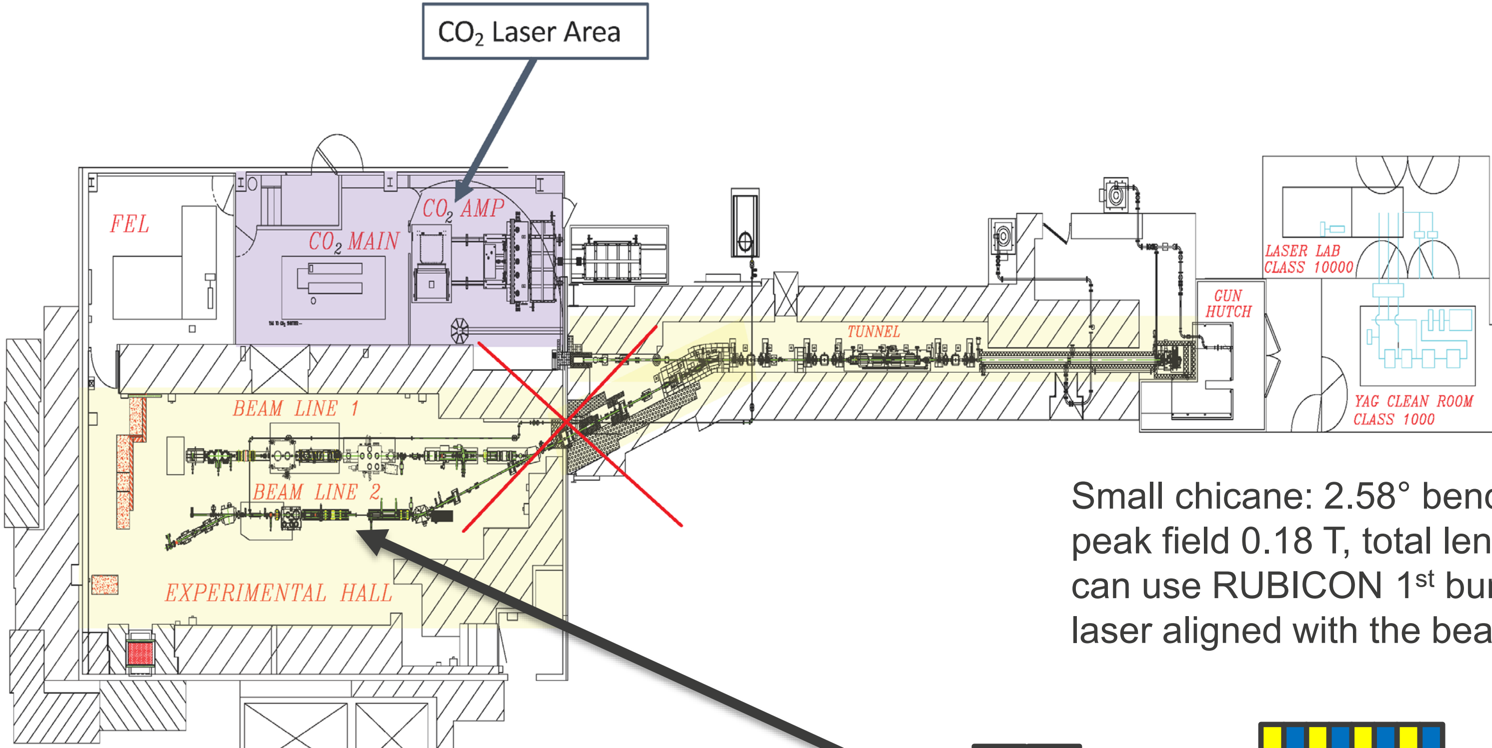
Experiment will take place at ATF

- ATF is a good location for our demonstration experiment.
- Has required beam magnetics: chicanes and undulators.
- Also has CO_2 laser that can be used to modulate the beam.

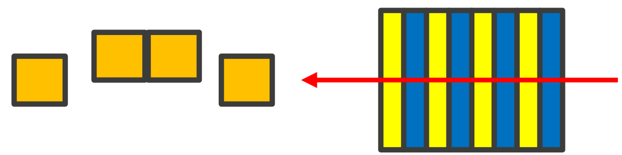
Experiment 1: Bulk Compression



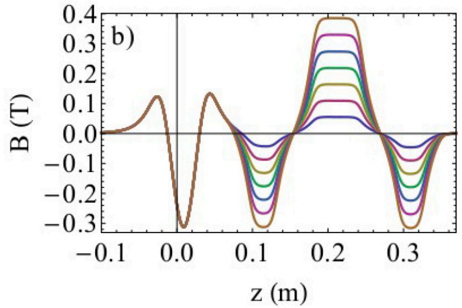
Experiment #2: Laser Assisted Bunch Compression



Small chicane: 2.58° bending angle, peak field 0.18 T, total length 30 cm. We can use RUBICON 1st buncher. CO2 laser aligned with the beam.

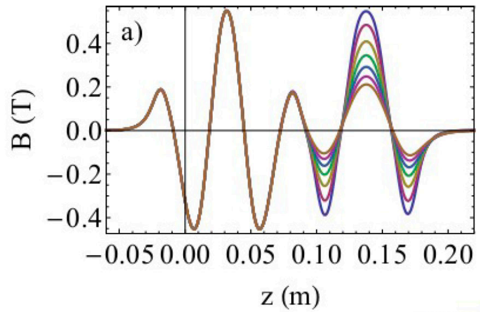


Available equipment: Bunchers and Modulators



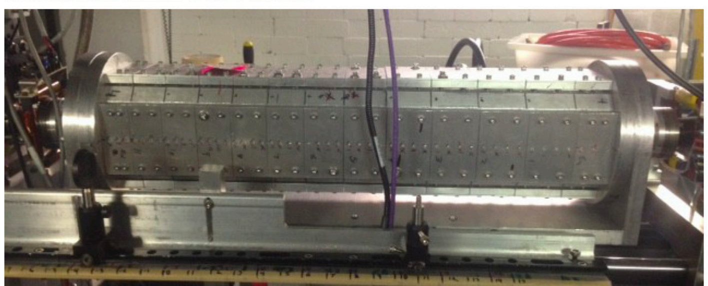
<u>1st buncher</u>

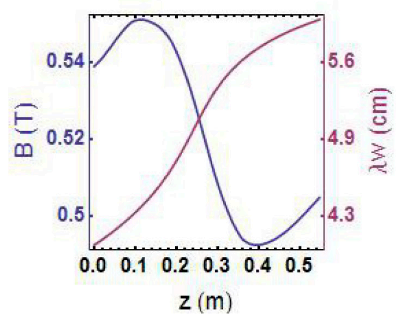
- 7 cm - half period – planar undulator
- electro-magnetic chicane
    - R56 0-900 um



<u>2nd buncher</u>

- 5 cm - 1 period – planar undulator
- variable gap permanent magnet chicane
    - R56 40-90 um



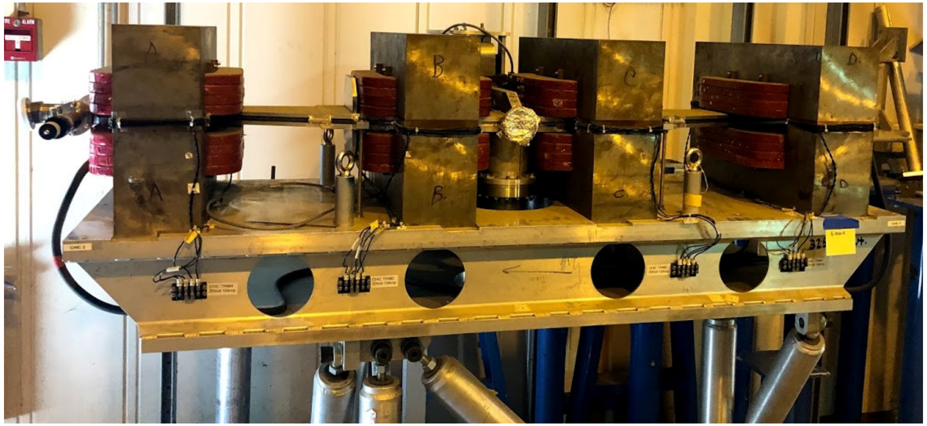


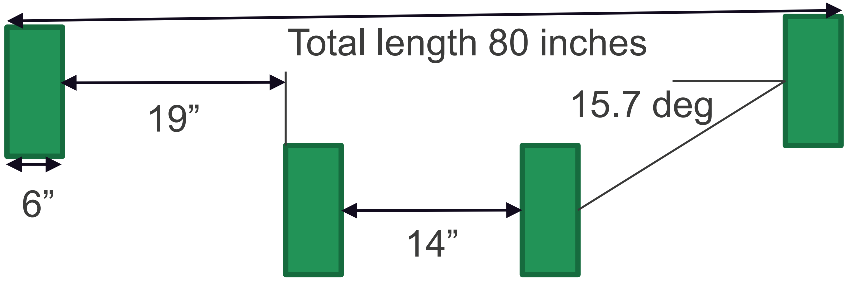
<u>Rubicon undulator</u>

- 4-6 cm period – 11 period - helical undulator
- gap tapered
- resonant phase: -π/4
- resonant energy: 52- 82 MeV

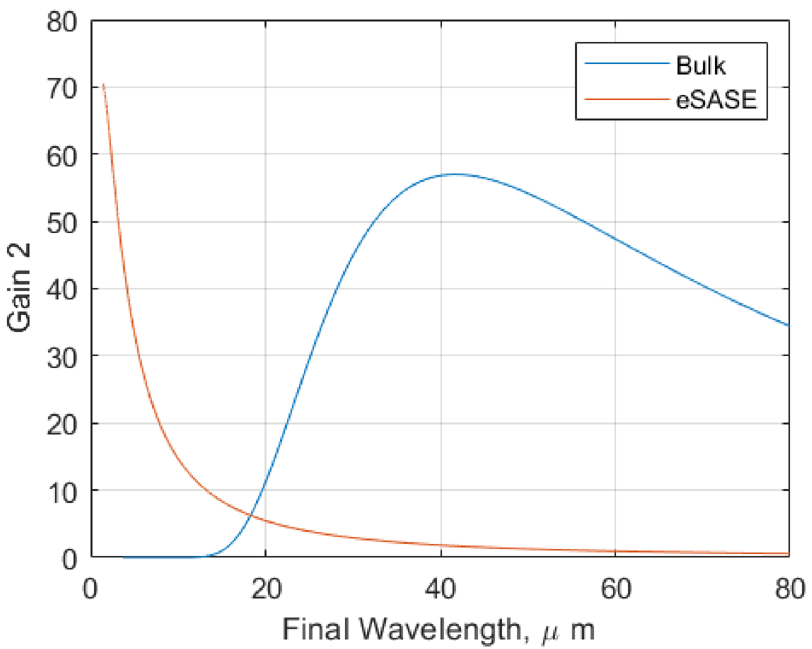
Available Equipment: Bunchers

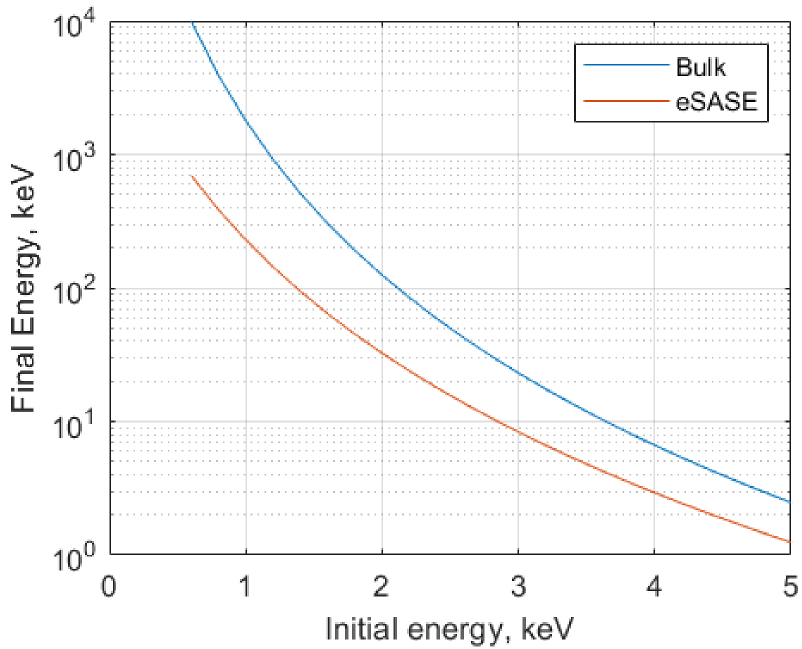
- ATF has a large chicane, which is 1.5 m long and could be used instead of fabricating a new one:





Prediction for ATF Experiment

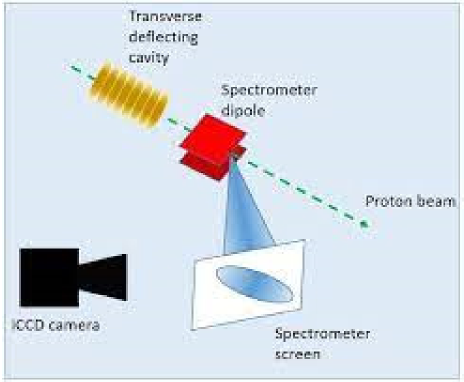


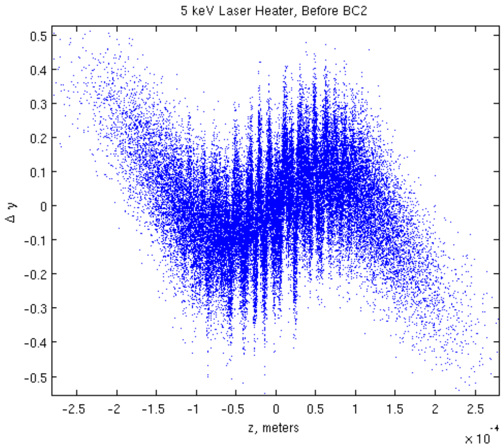


- Laser assisted bunch compression has significantly lower gain and energy spread from the microbunching instability.
- We planned to measure this using x-band deflecting cavity at ATF, which could measure down to 10 um.

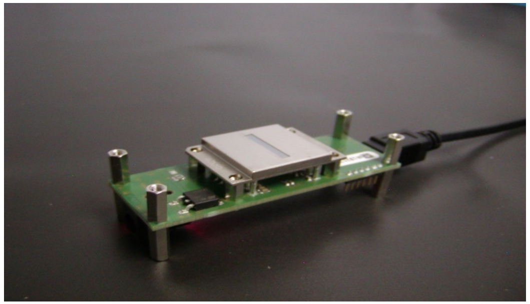
TCAV was Ideal Diagnostic

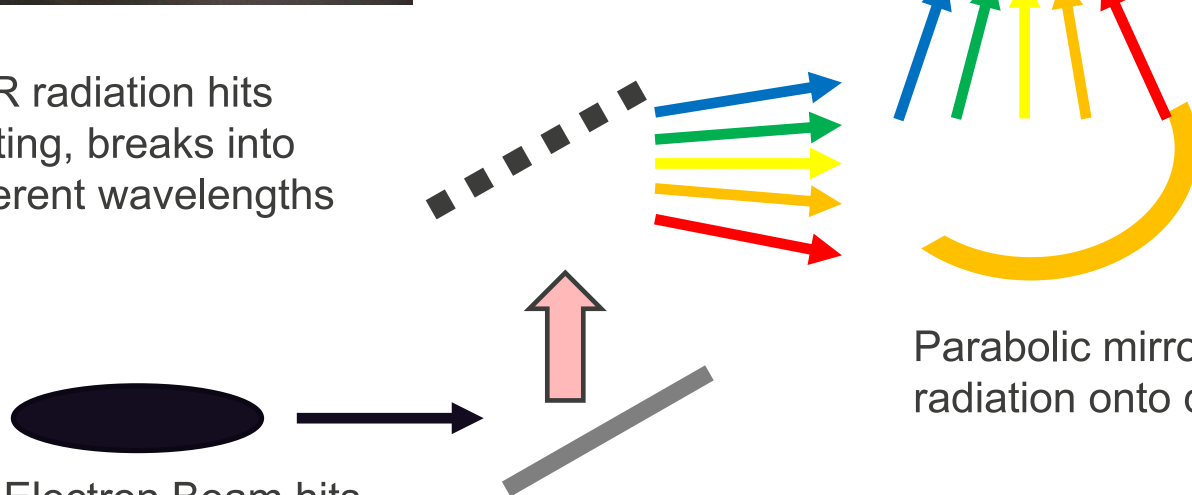
- Transverse deflecting cavity (Tcav) is used to measure the longitudinal phase space of the electron beam.
- This is an ideal diagnostic because it allows us to measure for the microbunching instability and the distribution after eSASE.
- Unfortunately, the klystron that drives the Tcav at ATF has broken. We explored options for helping to repair it, but none of these options worked out in the end.



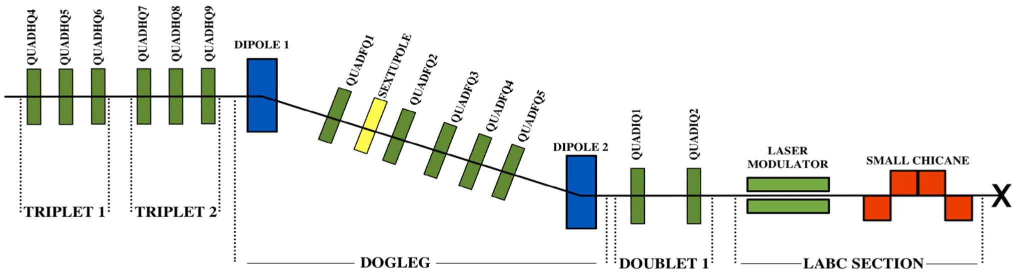


Alternate Diagnostic for Experiment

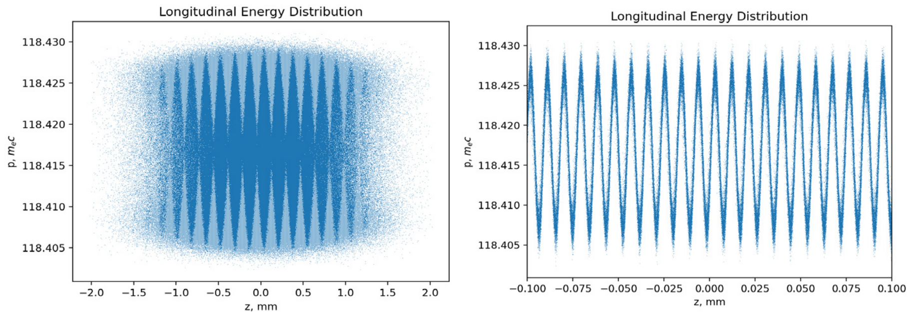




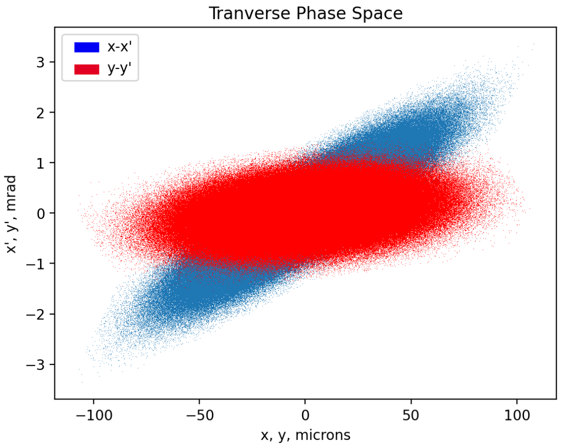
ELEGANT model – low energy spread



Drawing of the ATF beamline section that we modeled in ELEGANT. The bunch is injected, accelerated to ~60 MeV, and compressed by a factor of X before it enters Triplet 1. The bunch then propagates toward the right through the beamline.

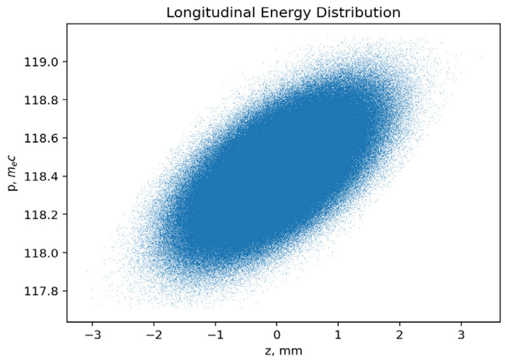


Longitudinal energy distribution of the modulated bunch (left) and zoomed in view of the same bunch (right).

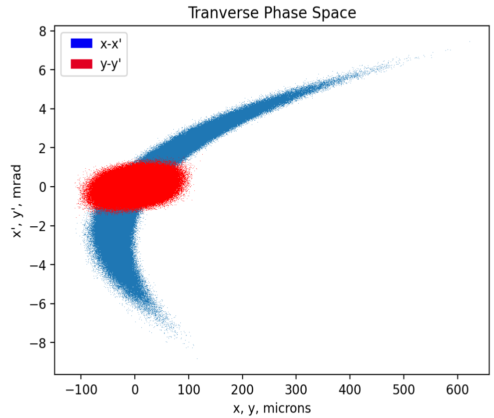


Transverse phase space of the bunch at the entrance of the laser modulator. The bunch has an rms size of about 25 microns in both x and y and 0.7 mrad in x' and 0.3 mrad in the y'-coordinate.

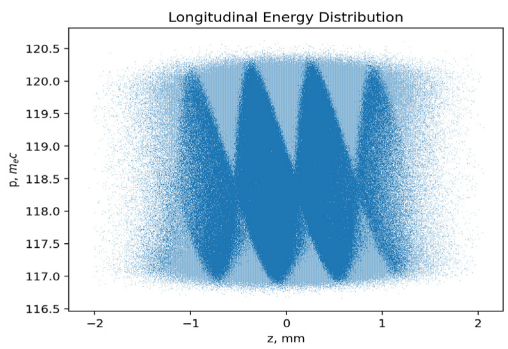
ELEGANT model – high energy spread

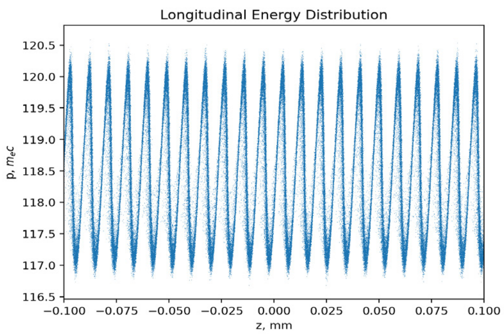


Longitudinal energy distribution of the higher energy spread bunch prior to entering the laser modulator. The bunch develops a chirp-like slope.



Transverse phase space of the higher energy spread bunch with the old matching optics setup. The odd boomerang shape and large spread in x' is cause for concern.





Longitudinal energy distribution of the higher energy spread bunch after exiting the laser modulator. The full bunch is shown on the left and a zoomed in picture on the right.

Conclusion

- We have an experimental plan to verify the prediction that eSASE and LABC can be used to suppress the microbunching instability.
- This test is planned at ATF.
- Testing was delayed due to lack of the TCAV diagnostic.
- We have a plan for an alternate diagnostic.
- Submitted an LDRD proposal to do this experiment, but the proposal was not funded.