Expression of Interest from NIU:

Phase Space Manipulation of High-Brightness Electron Beams and Applications to Novel Light Source and Accelerator Concepts

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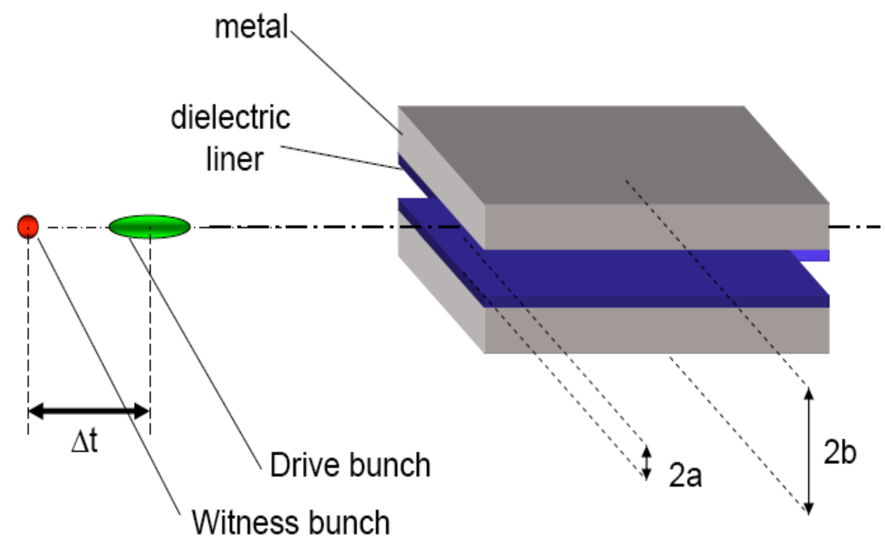
http://www.niu.edu/nicadd/research/beam/

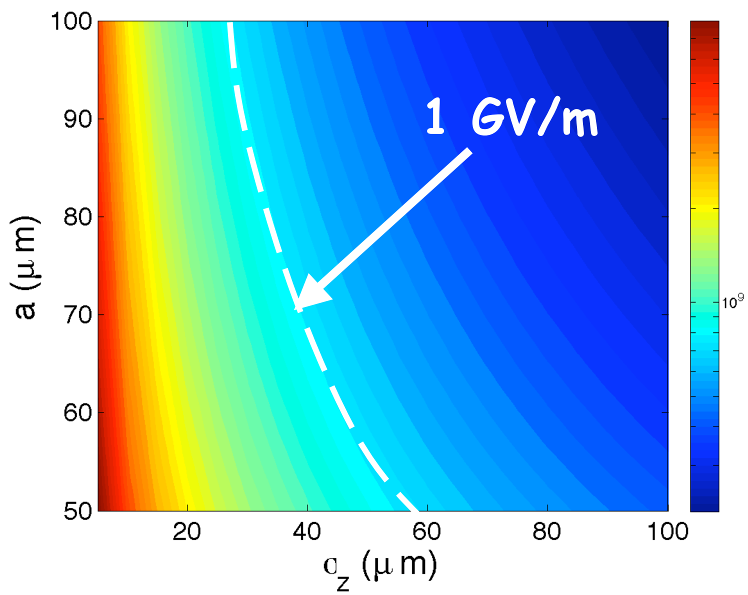
Introduction/Motivations

- FNAL has built significant modeling and experimental expertise in phase space manipulations techniques for electron beams, e.g.
  - Magnetized and flat beams from photoinjector
  - Transverse-to-longitudinal phase space exchange
- One of our goals is to take these schemes a step further and find plausible applications beyond their "academic intricacy"
- Here we discuss two possible applications:
  - Dielectric Wakefield Acceleration (DWFA) in a slab structure possibly using enhanced transformer ratio
  - Image Charge Undulator (ICU).
- We note that to date the final design of the injector is still in process and we hope to include provision for the beamline insertions discussed here.

DWFA in slab structure: overview

- Goals
  - Demonstrate **collinear** acceleration using slab structure
  - Extend AWA work to quasi-optical (THz) regime





- Advantages compared to cylindrical-symmetric structure
  - Better tunability
  - Higher stored energy
  - Mitigation of transverse wakefields

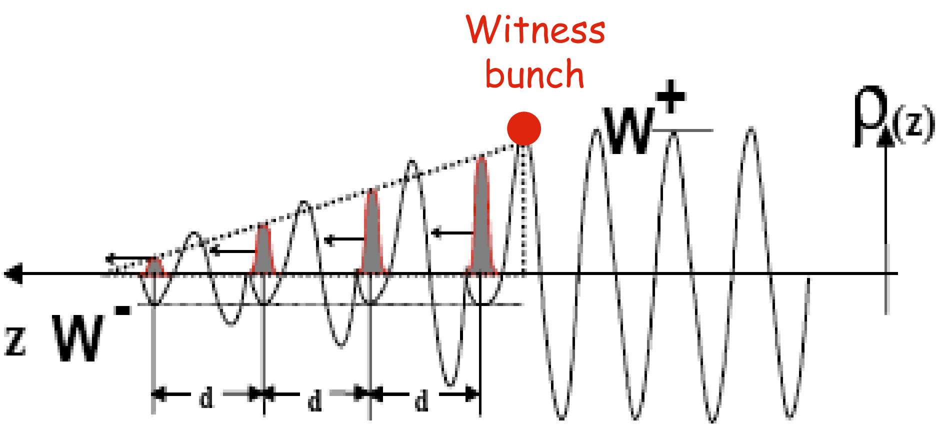
A. Tremaine, et al., PRE **52**, 7204 (1997)
L. Xiao, et al., PRE **62**, 016505 (2001)

DWFA in slab structure: requirements

- High accelerating field possible within damage threshold of the structure [see M. Thompson et al. PRL **100**, 211101 (2008)]
- Require high peak current ⇒ optimized bunch compression
  - Need σ_z< 50 μm bunchlength ⇒ require an elaborate (probably two-stage) bunch compression scheme
- Require small beam (at least in one direction) ⇒ flat beams
  - rms size of σ_y~ 20 μm corresponds to $\varepsilon_{y,n}$<1 μm
- Overall requirement are similar to PWFA (see P. Muggli's talk) to the exception of relaxed requirements to the transverse horizontal size/emittance

DWFA in slab structure: enhanced transformer ratio

- Another exciting development would be to drive the wake with a train of bunch with separation of the order of the "resonant" wavelength



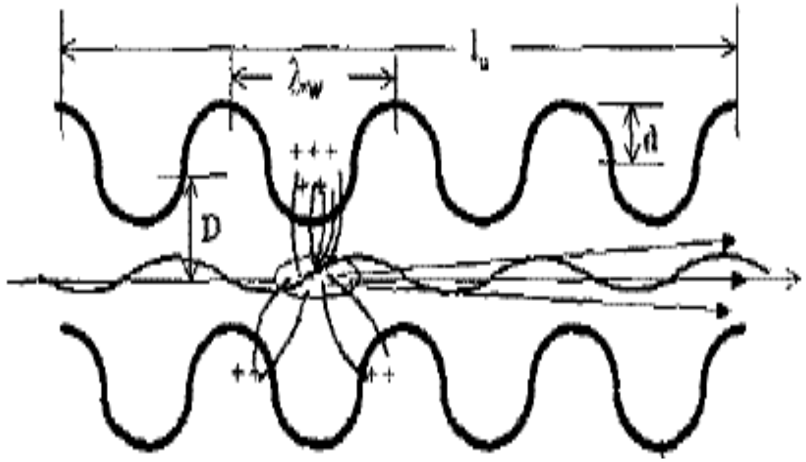
- Would results in an enhanced energy gain for the "witness" bunch

J.G. Power, et al., Proc. PAC01, 114 (2001)
C. Jing, et al., PRL **99**, 133002 (2007)

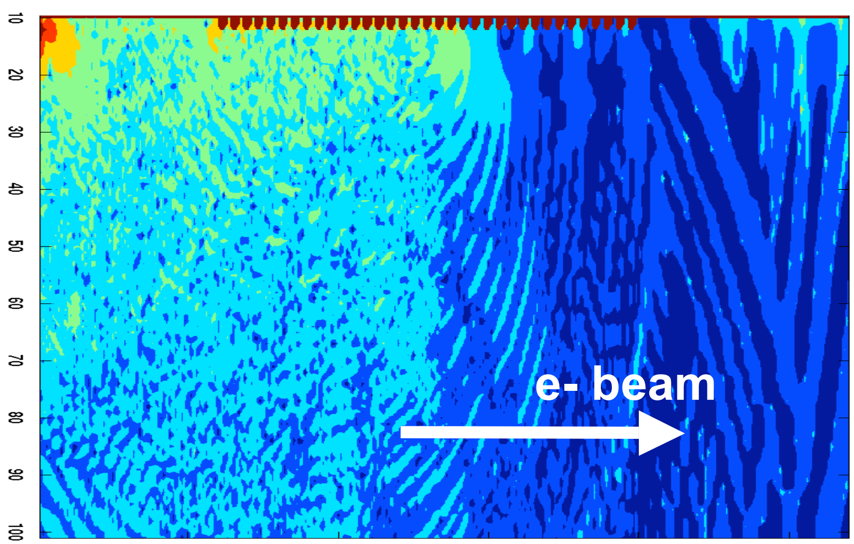
- Production of microbunches could be accomplished with a transverse-to-longitudinal phase space exchange similar to the experiment currently running at A0

Image Charge Undulator

- Undulating motion of an electron bunch as it propagates between a pair of grating provide undulator-type radiation
- Simple estimate: 200MeV, 10 nC flat bunch with sizes $(\sigma_x, \sigma_y, \sigma_z) = (4, 300, 100)$ µm in a ICU with period λ_w =30 µm is equivalent to a magnetostatic undulator with 60 T B-field!
- Proof-of-principle experiment
  - Characterize undulator-type radiation
  - Most probably in the THz regime (except if extremely low emittance achievable, e.g. going to low charge)



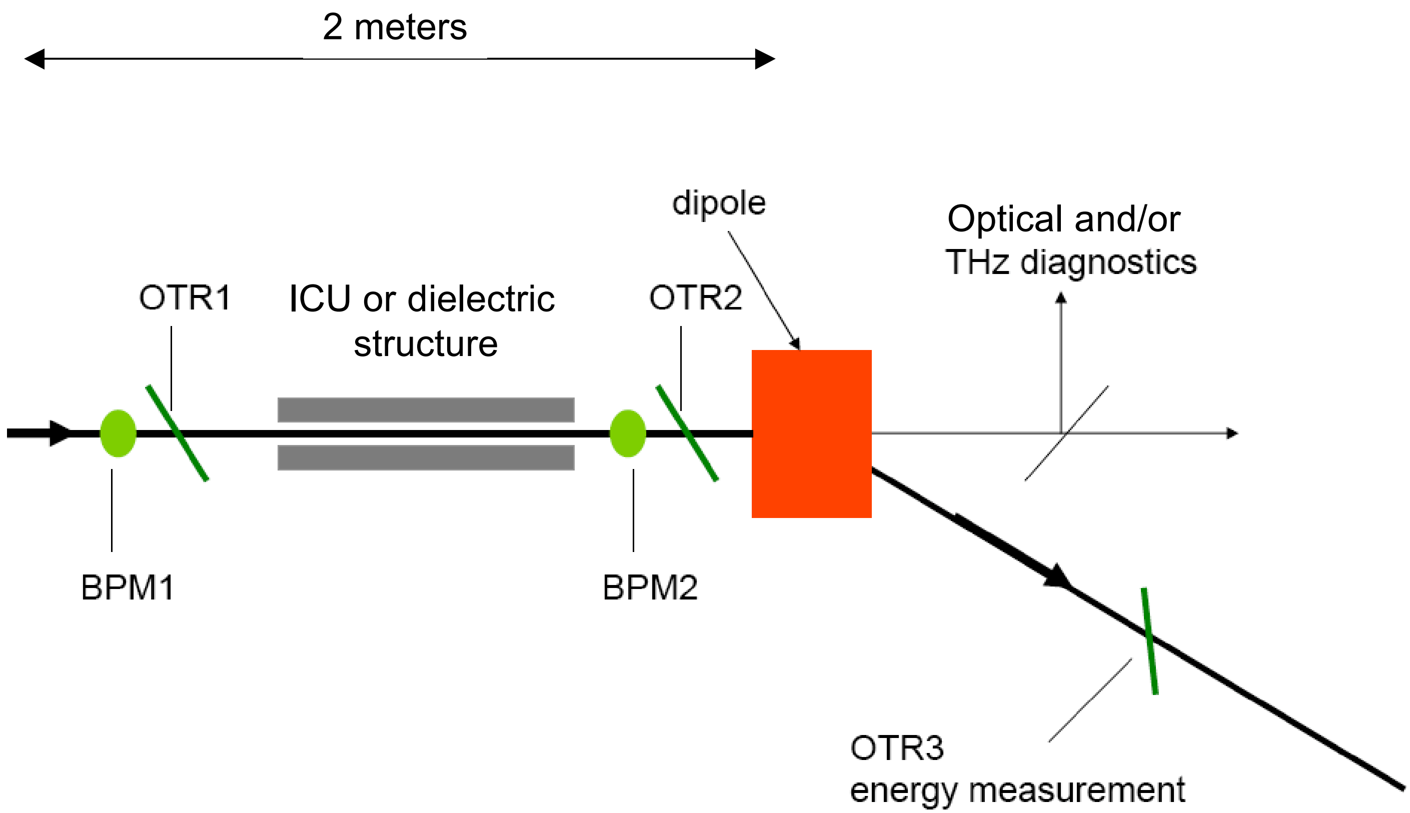
Y. Zhang et al., NIM A507, 459 (2003)



VORPAL4.0 simulation (collaboration NIU/Tech-X)

Experimental Configuration

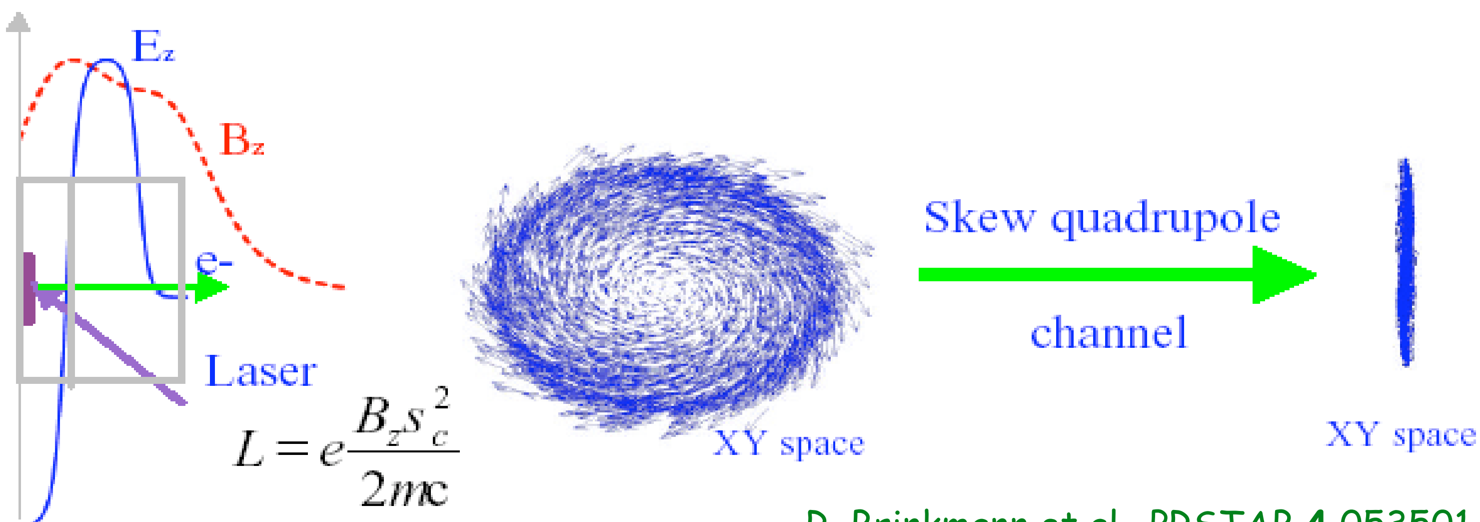
- Both experiments have very similar configuration



Ingredients: flat beams

- Flat beams with emittance ratio of ~100 have been demonstrated at the Fermilab's AOPI
- However the generation of
  - Flat beams with higher emittance ratio, and or
  - Compressed flat beams,

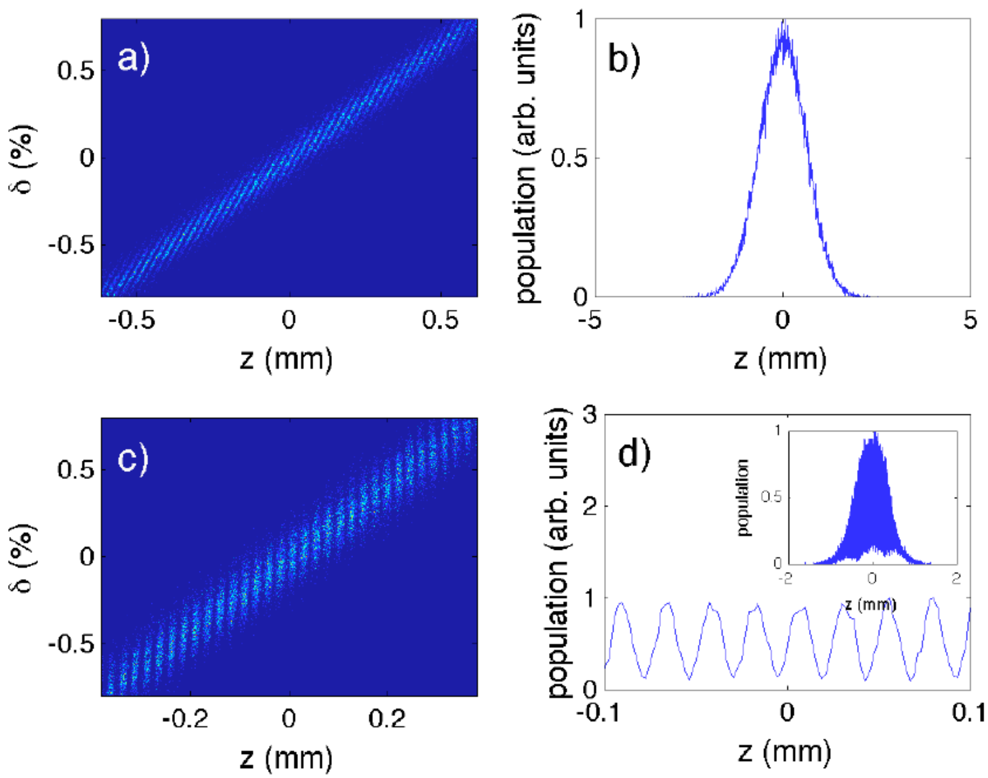
  are challenging Beam Physics topics

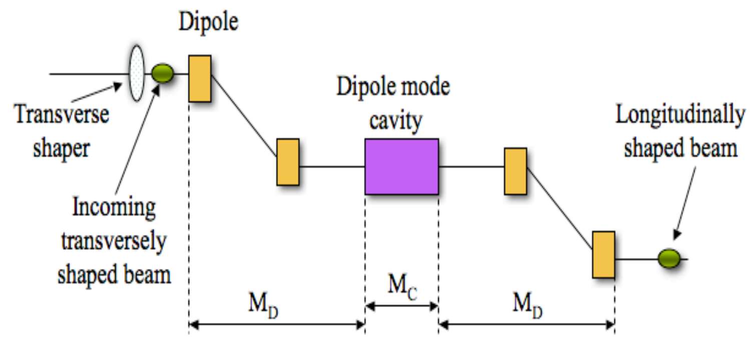


R. Brinkmann et al., PRSTAB **4** 053501 (2001)
P. Piot et al., PRSTAB **9**, 031001 (2006)

Ingredients: z-x phase space exchange

- The z-x phase space exchange can be used to generate "stratified" longitudinal phase spaces





- The local z-δ correlation can be removed using a bunch compressor to result in (though we might not this latter step for the two experiments mentioned here)

P. Piot, Proc. of AAC08 (2008)

Concluding remarks

- NML will possibly include phase space manipulations that might prove useful for testing new radiation source and acceleration concepts

- Two possible exciting applications were described

- Many Beam dynamics topics NIU hope to collaborate:
  - Bunch compression,
  - flat beam generation,
  - emittance exchange,
  - generation of witness/drive pulse