

Probing ultrafast dynamics with relativistic electrons

David Cesar

NaPAC 2019 awards session

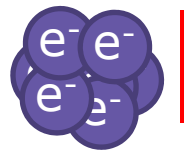
September 5, 2019



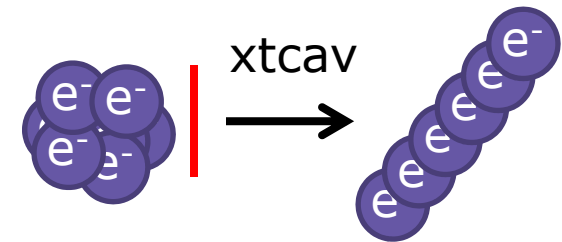
Stroboscopic



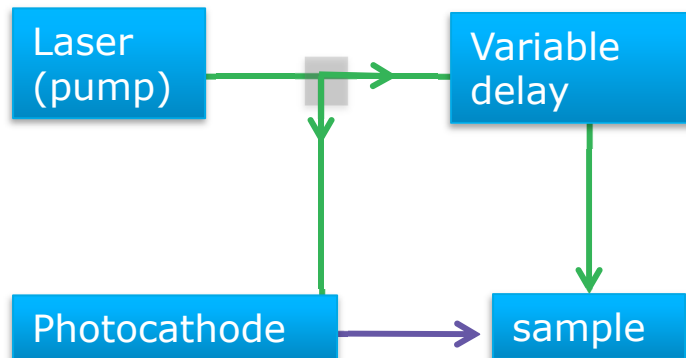
Single-shot



"Movie-mode"



Pump-probe

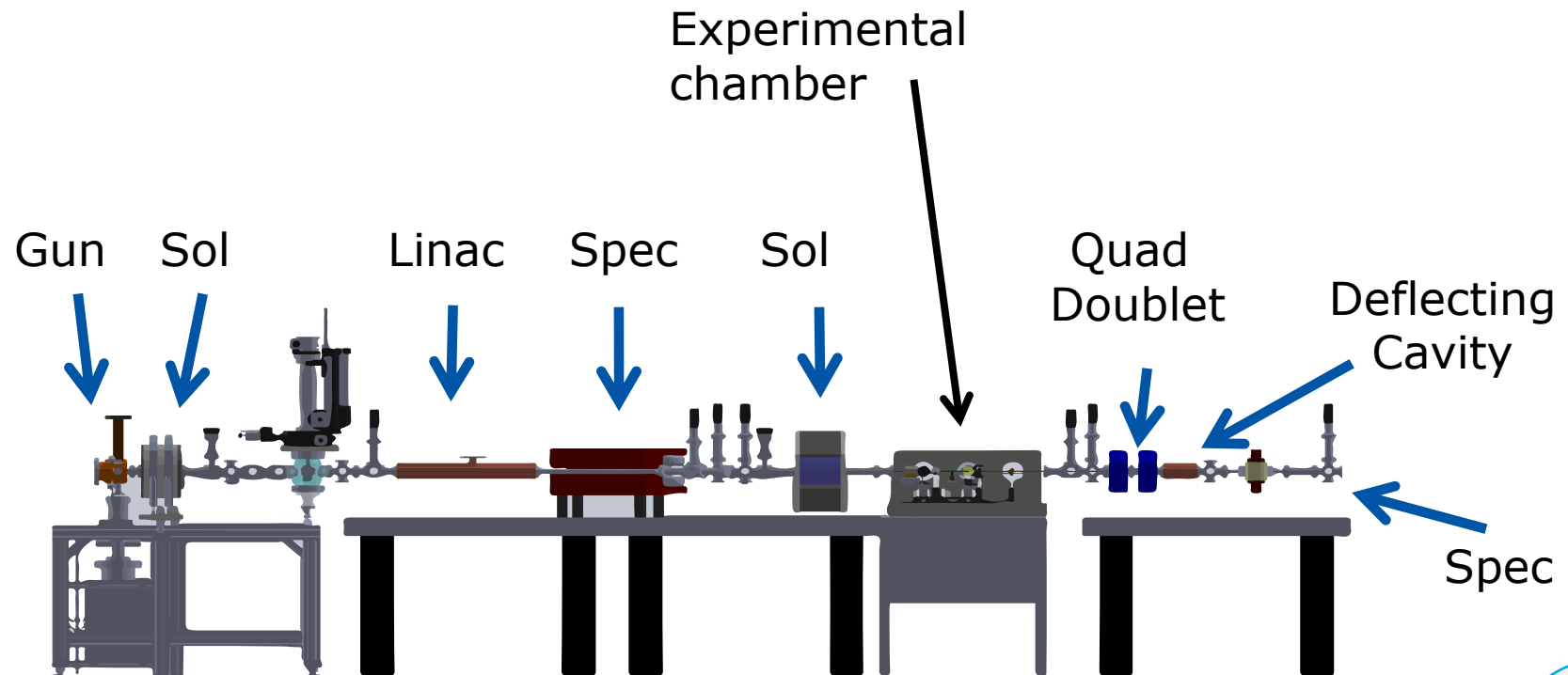


The MeV "revolution"

- Reduce importance of space-charge
- Reduces group velocity mis-match

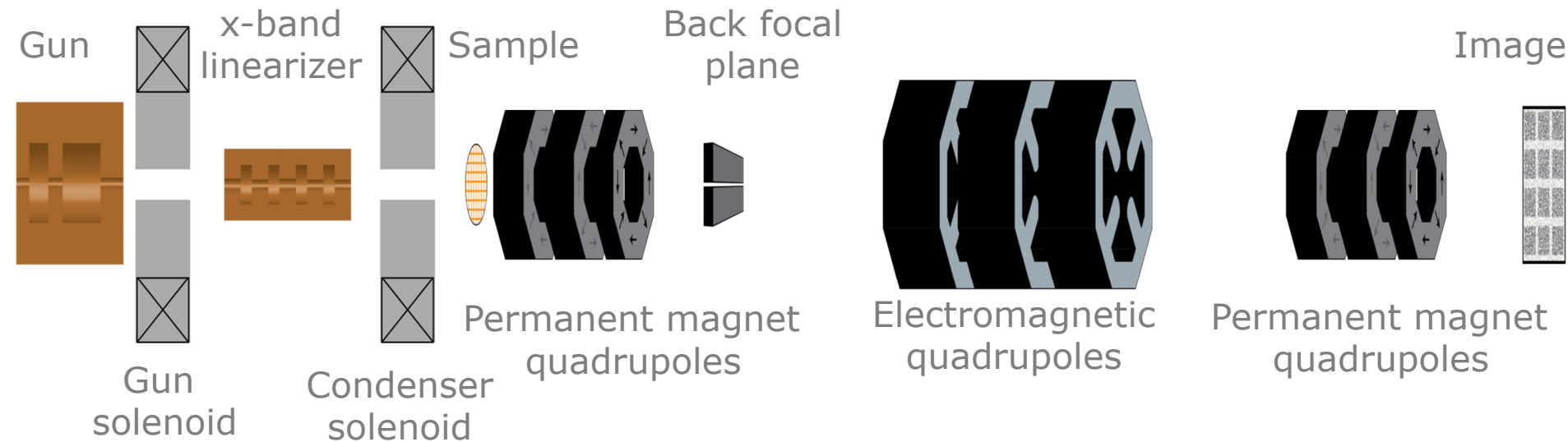
University-based RF photoinjector laboratory

Main Theme : Ultrashort laser + high brightness electron beams



MeV microscope “column”

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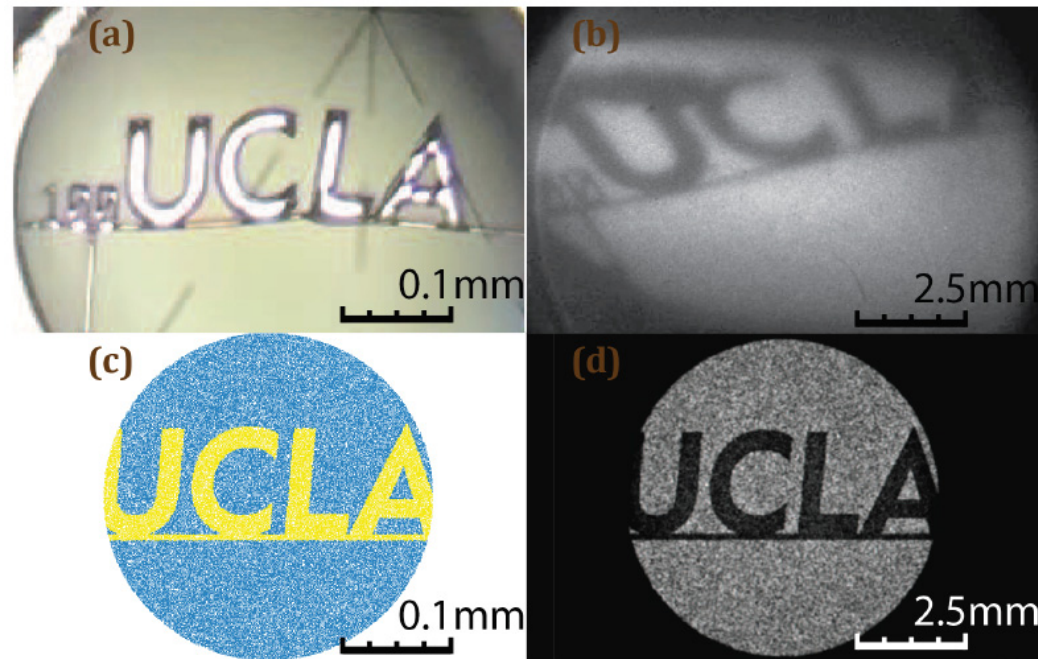
Key components

- High brightness RF photogun
- X-band cavity to minimize energy spread
- Compact PMQ- based electron lenses
- Electromagnetic lens to view diffraction plane
- High efficiency electron detectors

Design adapted from:
R. K. Li and P. Musumeci,
Phys. Rev. Applied **2**, 024003, 2014

First ps-scale, single-shot TEM images

- Lithographically etched sample
Cu 20+/-5 μ m thickness
- ~30x magnification
- 1 μ m resolution
- 0.9ps (rms) bunch length



An accelerator on a chip

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Electron source → injector stage → **acceleration stage(s)** + laser = application

Novel physics at each stage!

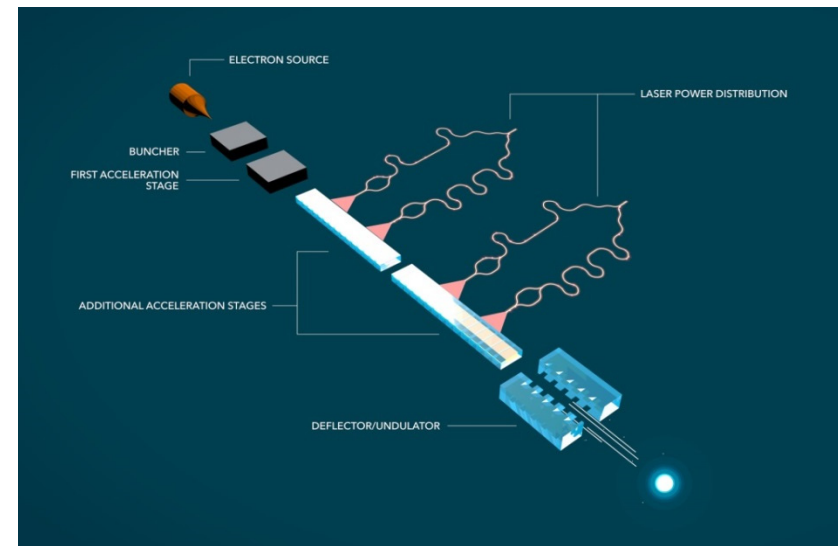
Acceleration stage goals

High gradients

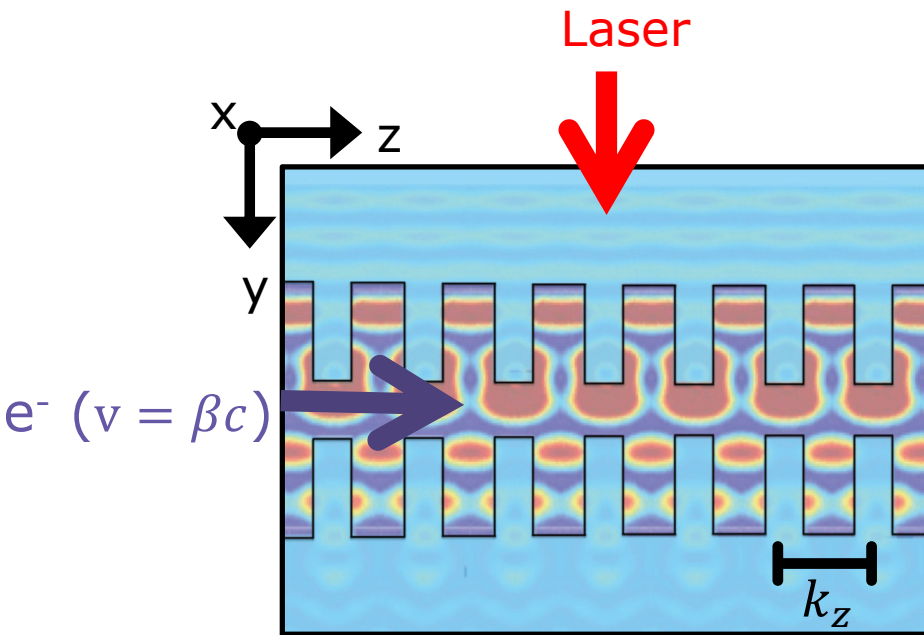
Large energy gain

Electron-DLA coupling

Mockup of potential DLA components



From SLAC newsroom: "\$13.5M Moore Grant to Develop Working 'Accelerator on a Chip' Prototype" (November 19, 2015)

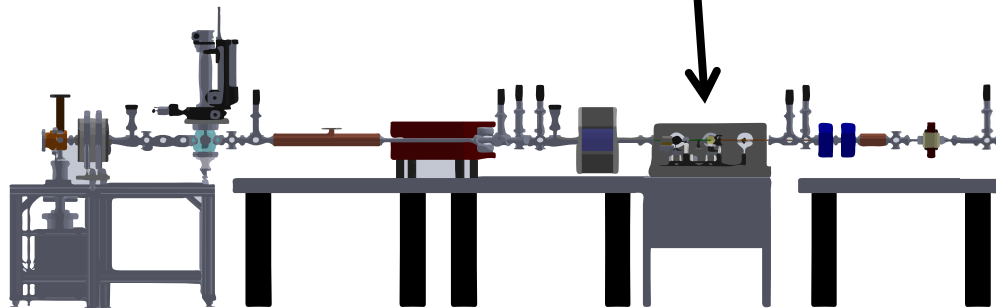
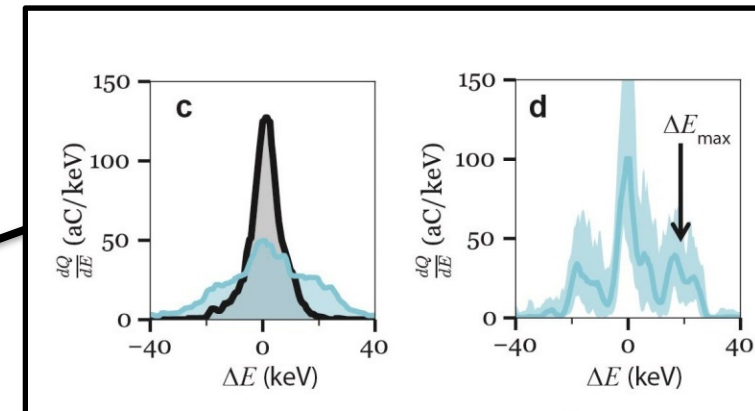


Measuring gradient:

- Assume fixed electron trajectories!
- Measure ΔE vs E_{inc}

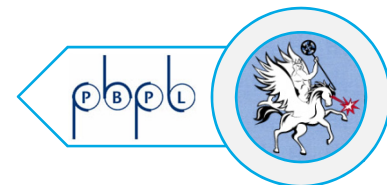
$$\Delta E = \kappa \int_{\vec{r}_e} qE(z, t) \approx \kappa q E_{inc} L_{accel} \sin(\psi_0)$$

Electron spectra



Pegasus beamline @ UCLA

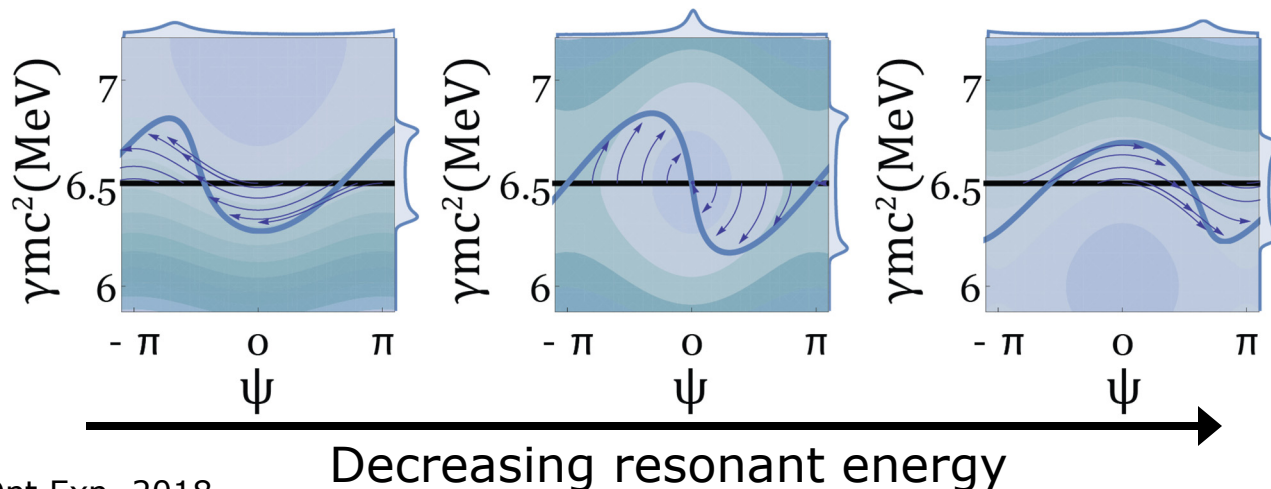
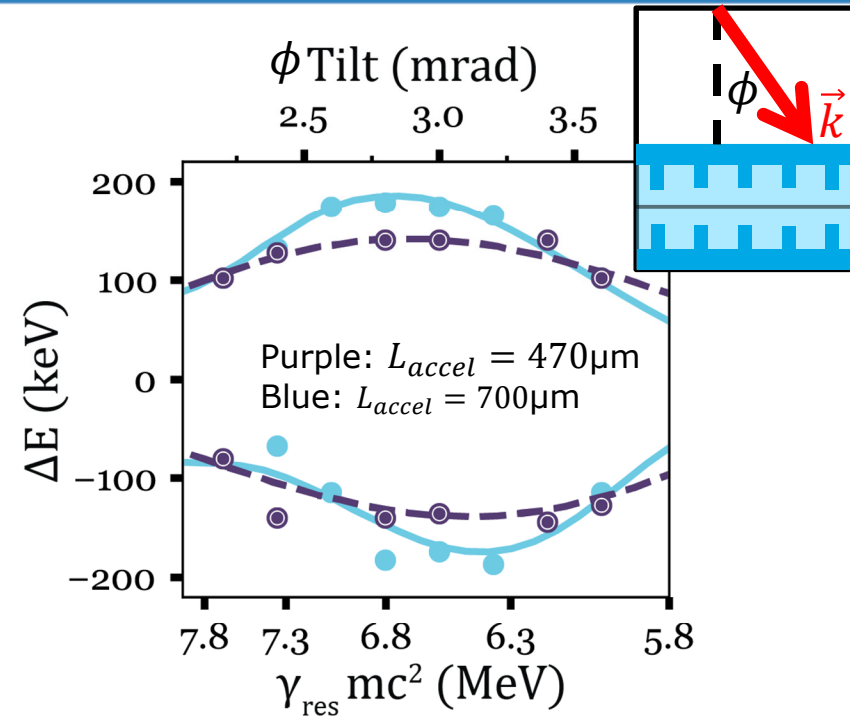
Up to 2GV/m



A tilted wavefront changes β :

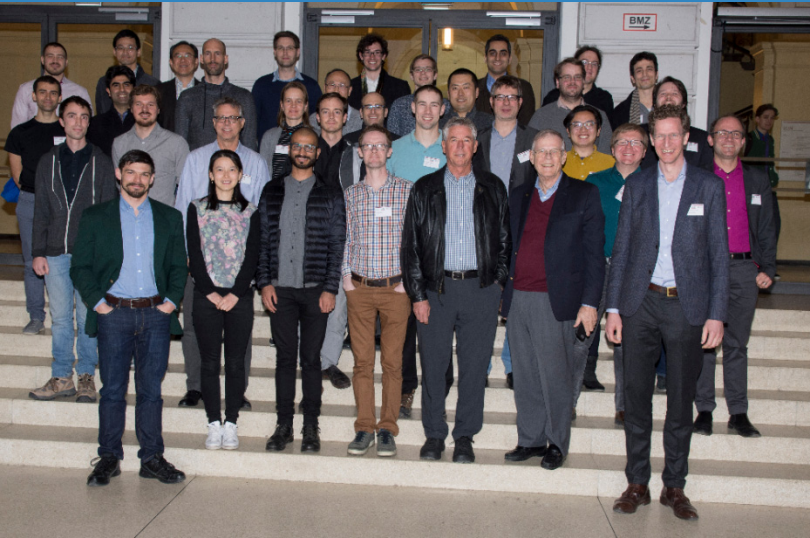
$$\beta = \omega / (k_g + \omega/c \sin \phi)$$

- Short accelerator $\rightarrow$ Symmetric dephasing
- Long accelerator $\rightarrow$ 2nd order energy gain



Thanks for listening!

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Collaborators/Coauthors

- Pietro Musumeci (PhD advisor)
 - Renkai Li
 - Jared Maxson
 - Jorge Navarro
 - Xinglai Shen
 - Emma Curry
 - Nick Sudar
 - Eric Cropp
 - Paul Denham
 - Joel England
 - Kent Wotton
 - Gerard Andonian
 - Finn O'Shea
 - Hoson To
 - Alex Murokh
- & the rest of PBPL + the ACHIP collaboration

