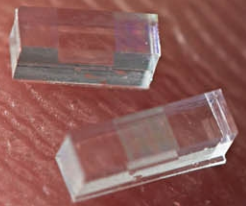
Accelerators for energy-frontier electron-positron linear colliders

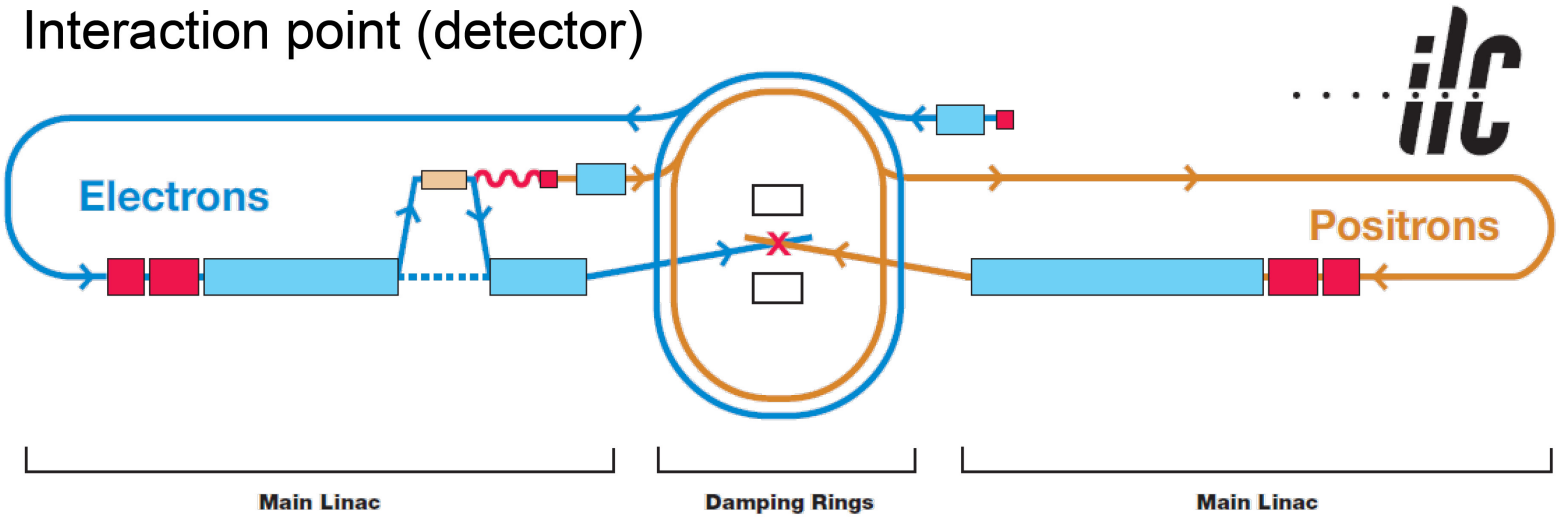
Kent P. Wootton – SLAC National Accelerator Laboratory

24th April 2017



Linear Colliders

- Electron (positron) source
- Damping ring
- Linac
- Interaction point (detector)



Kent P. Wootton

PhD student, Uni. Melbourne

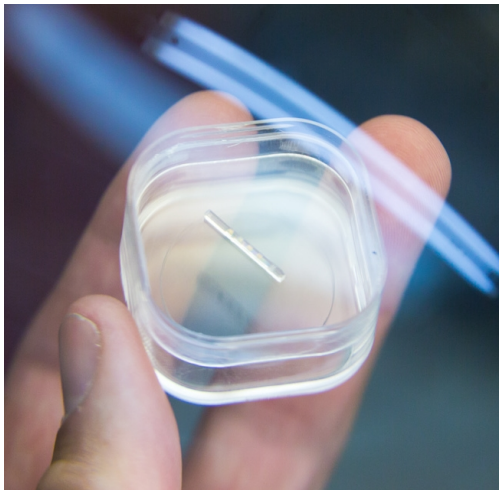
(2010 – 2014)

Storage ring diagnostics

Postdoc, SLAC

(2014 – present)

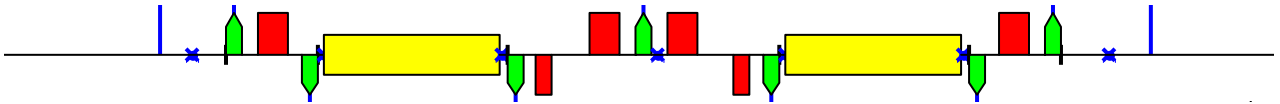
Accelerator On-A-Chip



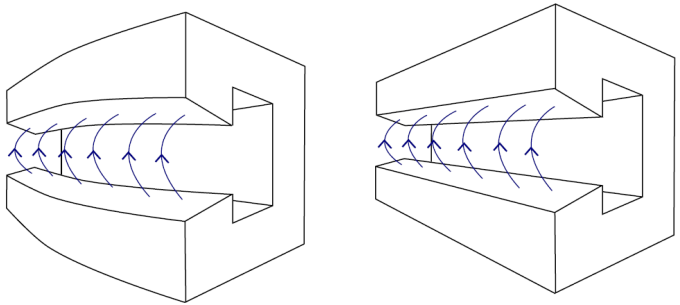
PhD – Energy measurement of low emittance rings

Lower horizontal emittance by incorporating defocussing gradient into bending magnet

- DBA, TBA, MBA, TME lattices heading in this direction



Build a straight, rectangular magnet with defocussing gradient

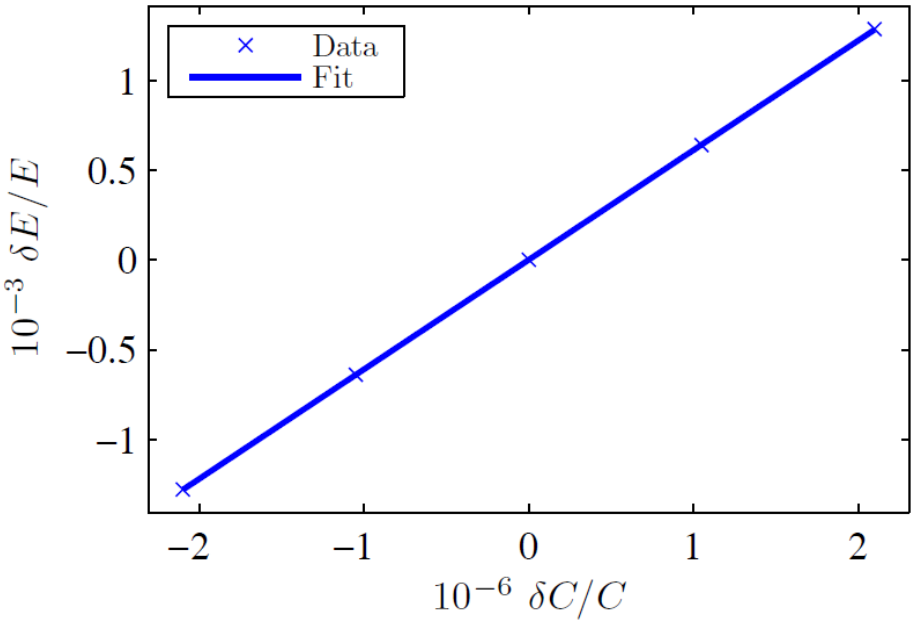


PhD – Energy measurement of low emittance rings

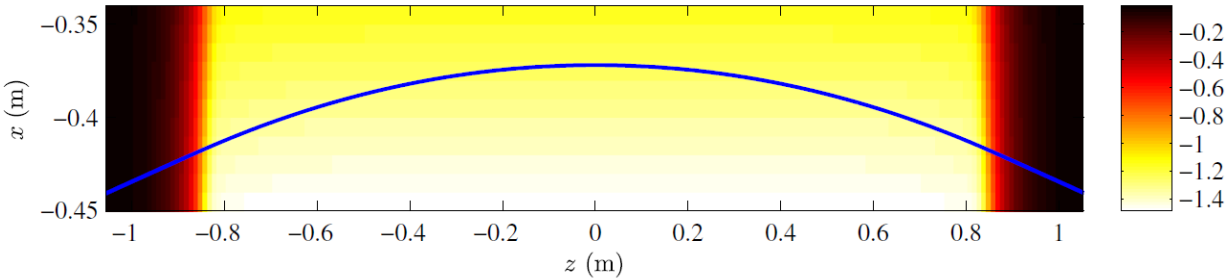
$$f_{\text{spin}} = 0.25362(2)\ \text{MHz}$$

$$E = 2.997251(7)\ \text{GeV}$$

Ring	Measured Energy (GeV)
AS	3.013408(8)
SPEAR3	2.997251(7)



PhD – Energy measurement of low emittance rings

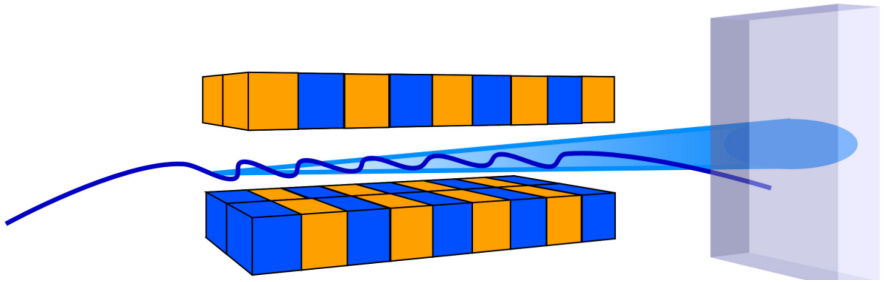


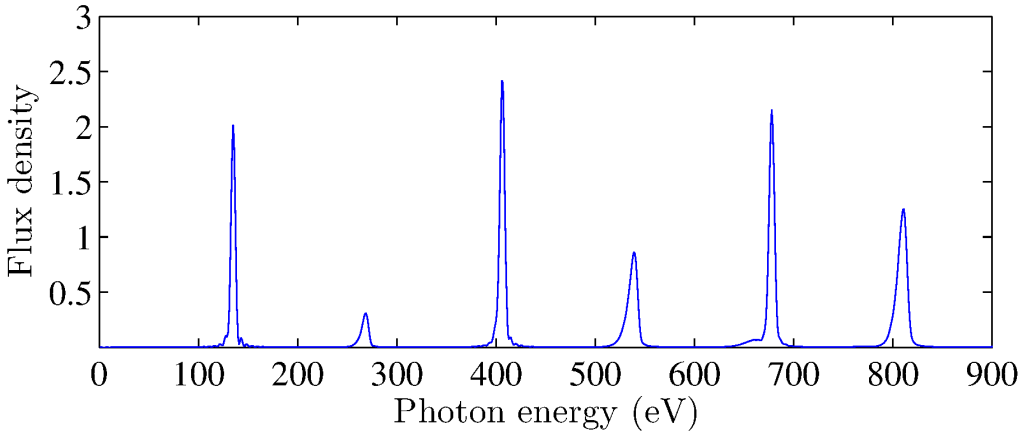
Approach	AS	SPEAR3
Linear hyperbolic cosine	0.00205	0.00162
Numerical	0.00211	0.00165
Measured	0.00211(5)	0.00164(1)

- Numerical integration a better model for trajectory than usual hyperbolic cosine
- Accuracy arises from correct distribution of the dipole field
- Modelling approach for future rings with gradient bending magnets (FACET-II PDR)

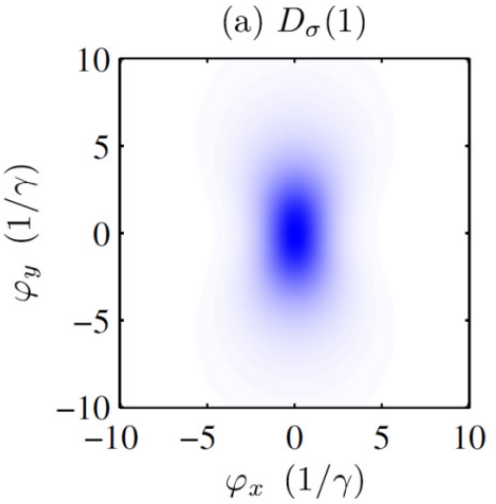
K.P. Wootton et al., Phys. Rev. ST Accel. Beams. 16, 074001 (2013)

PhD – Electron ring vertical emittance measurement





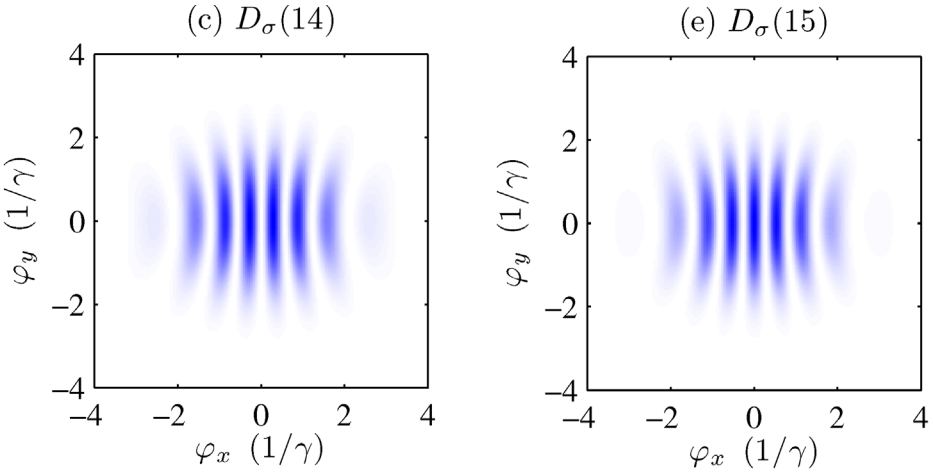
- Low harmonics ~Gaussian angular distribution

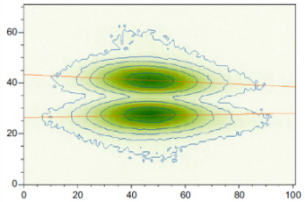


K.P. Wootton, et al., Phys. Rev. Lett., 109, 194801 (2012)

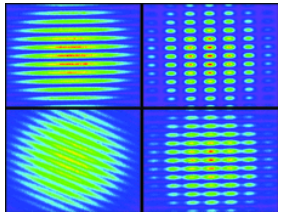
PhD – Electron ring vertical emittance measurement

- Angular distribution of high harmonics resembles interferogram

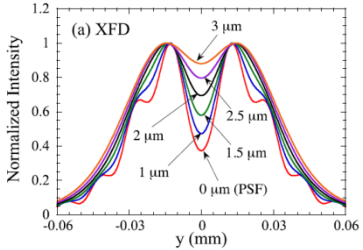




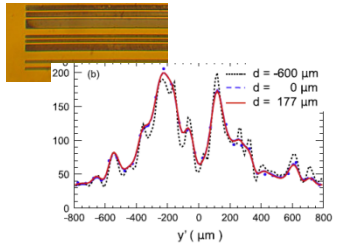
Andersson, NIMA 591, 437-446 (2008)



Masaki DIPAC01, PS17 (2001)



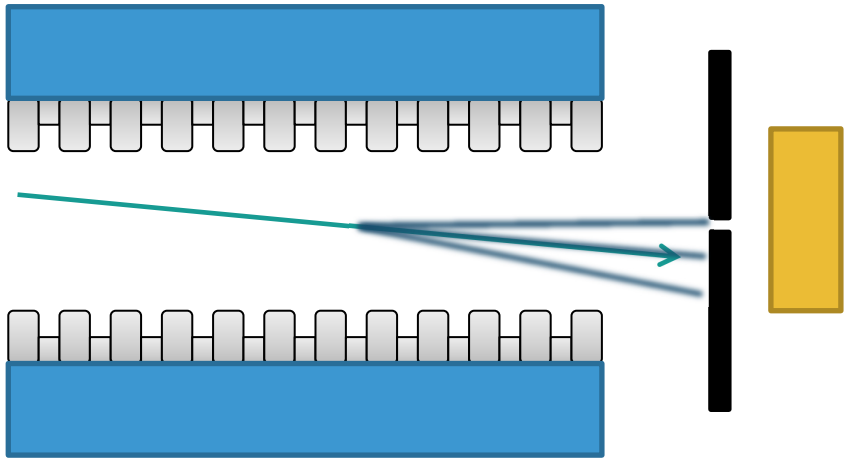
Masaki PRSTAB 18, 042802 (2015)

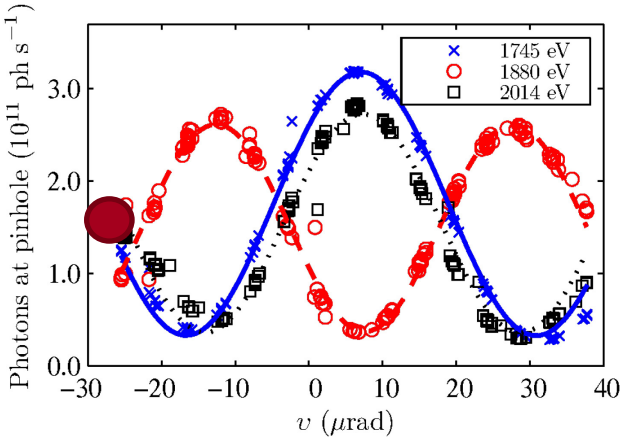


Alexander, NIMA 748, 96 (2014)

K.P. Wootton, et al., Phys. Rev. Lett., 109, 194801 (2012)

PhD – Electron ring vertical emittance measurement





PhD – Electron ring vertical emittance measurement

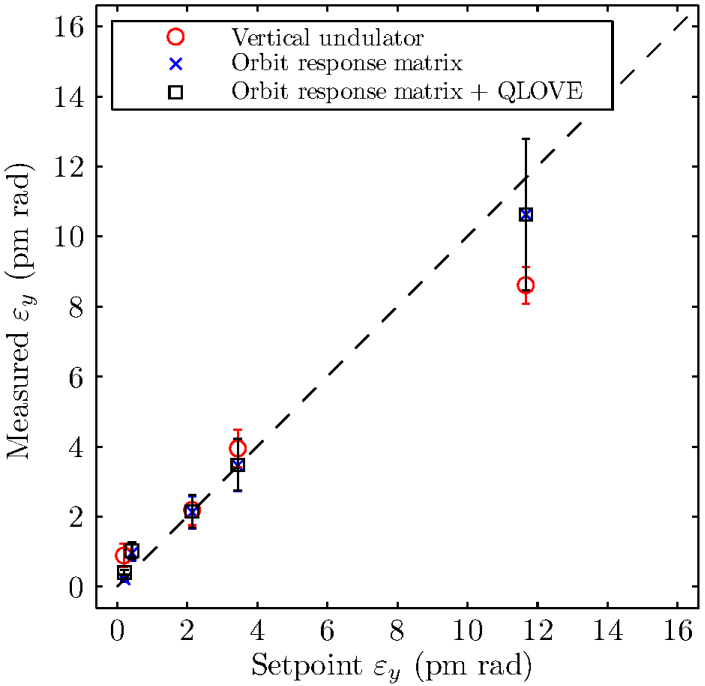
Lattices with various vertical emittances

Emittance measured using

- Orbit bumps through undulator
- LOCO and quantum limit

Measurements agree within uncertainty, except lowest value

$$\varepsilon_y = 0.9 \pm 0.3 \text{ pm rad}$$



K.P. Wootton, et al., Phys. Rev. ST Accel Beams, 17, 112802 (2014)

Postdoc - Motivating compact electron accelerators

- High gradients enable compact linear accelerators

1947

~MeV m^{-1}

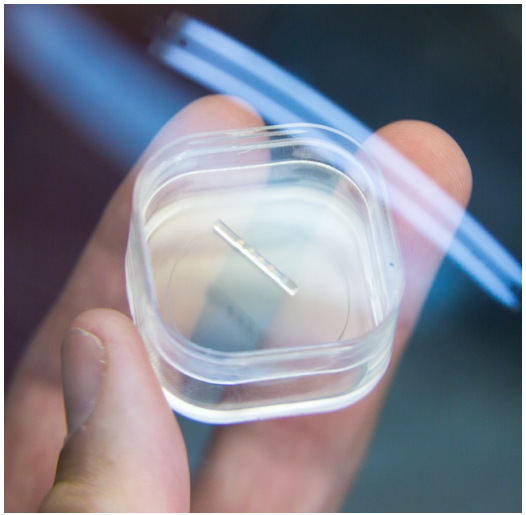
SLAC Archives, ARC127

$$G = \frac{\Delta\epsilon}{\Delta z}\ (\mathrm{eV\ m^{-1}})$$

Applications:

- Radiotherapy
- Industrial/security
- Attosecond science
- Linear colliders

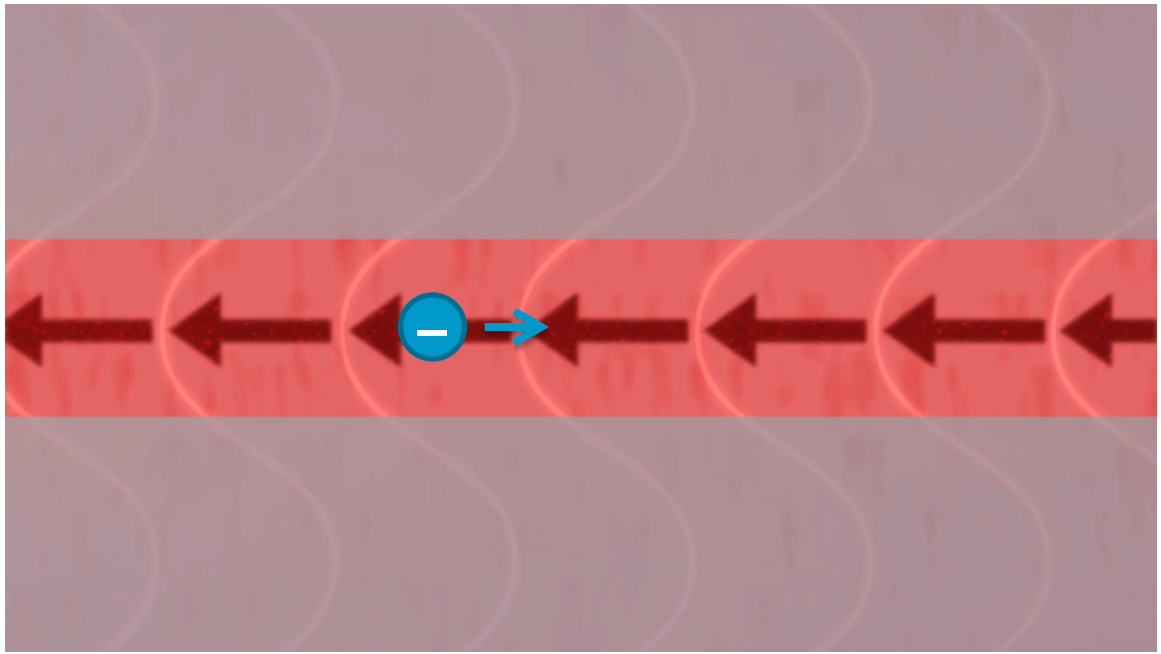
2013

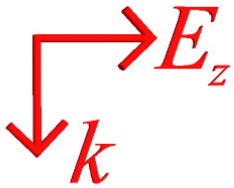


~GeV m^{-1}

SLAC National Accelerator Laboratory

Postdoc – DLA – Dual grating

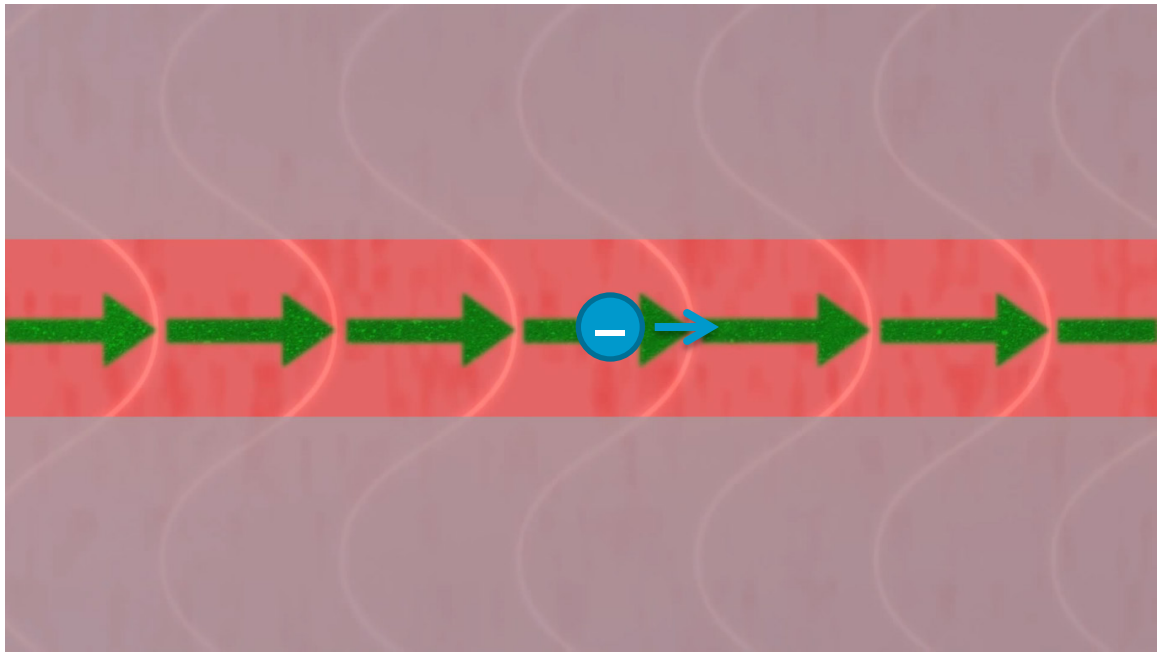


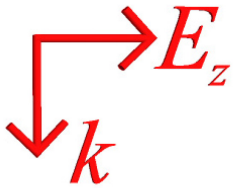


- Plane wave
- No acceleration

SLAC National Accelerator Laboratory https://youtu.be/V89qvy8whxY

Postdoc – DLA – Dual grating





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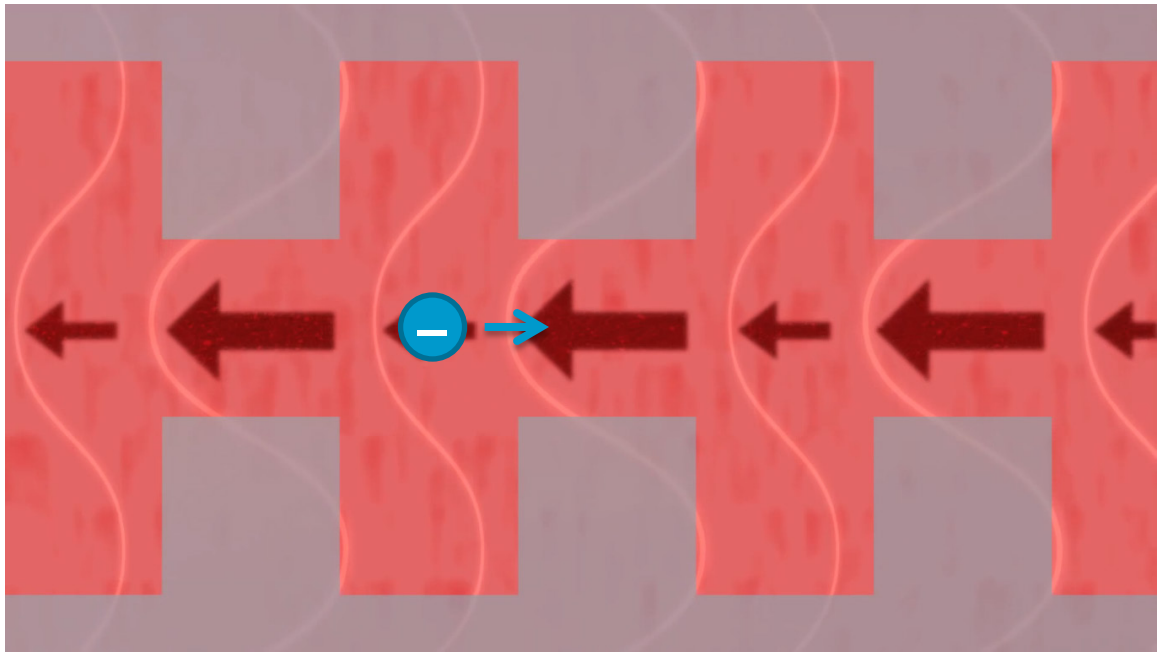
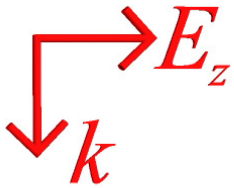
SLAC National Accelerator Laboratory https://youtu.be/V89qvy8whxY

Postdoc – DLA – Dual grating

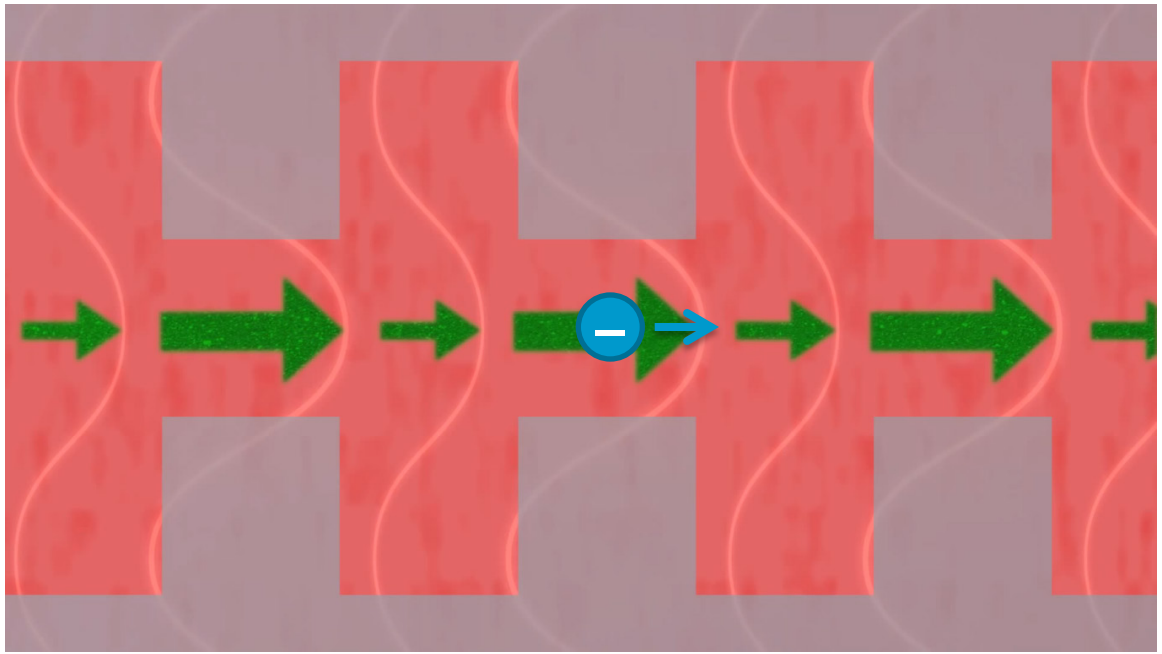


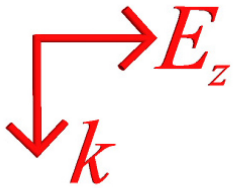
SLAC National Accelerator Laboratory https://youtu.be/V89qvy8whxY



- Plane wave
- No acceleration
- Refractive index modifies phase
- Acceleration

Postdoc – DLA – Dual grating



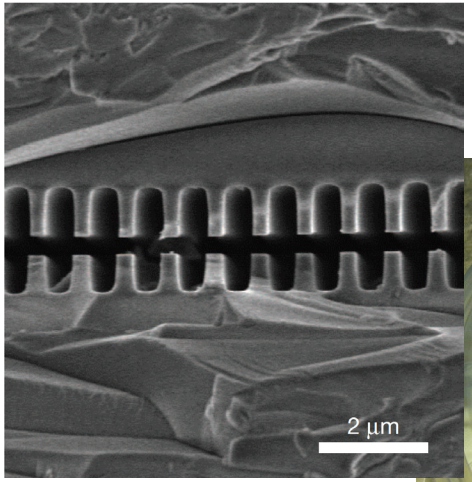


- Plane wave
- No acceleration
- Refractive index modifies phase
- Acceleration

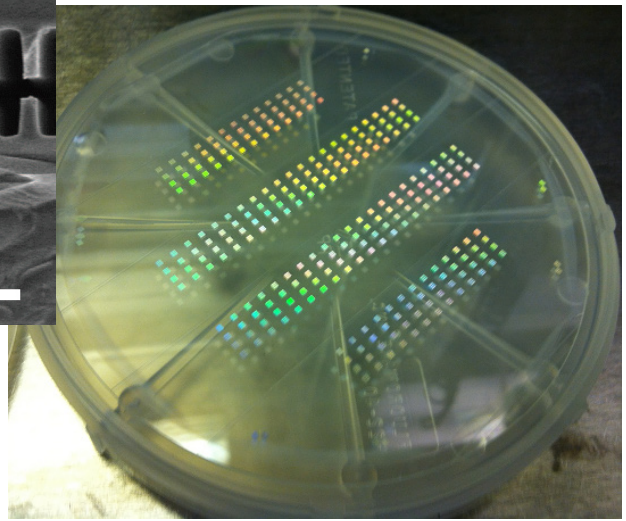
SLAC National Accelerator Laboratory https://youtu.be/V89qvy8whxY

Postdoc – Accelerating structure

- ‘Phase reset’ structure
- Fused silica dual grating
- UV lithography fabrication
- 800 nm period, designed for 800 nm laser wavelength



Peralta, et al., *Nature,* 503, p. 91 (2013)



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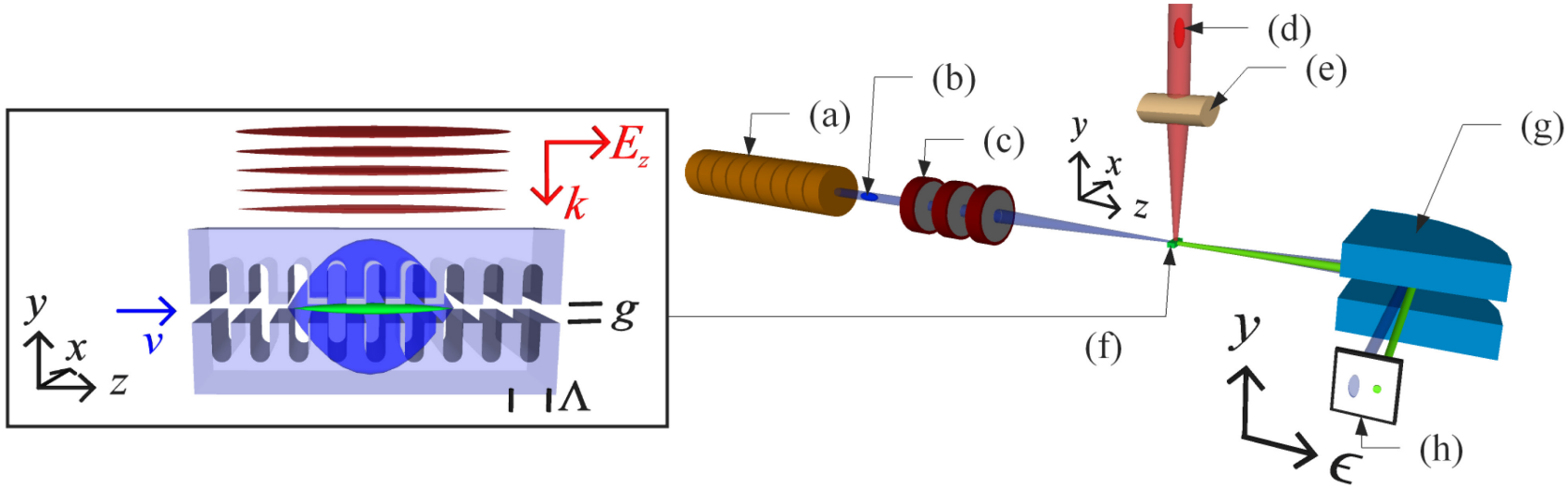
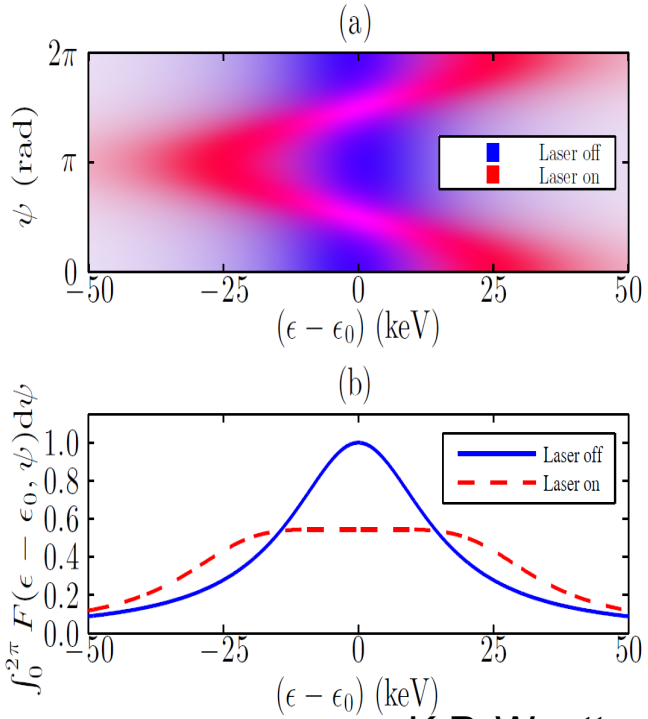
Postdoc – Experimental arrangement at NLCTA

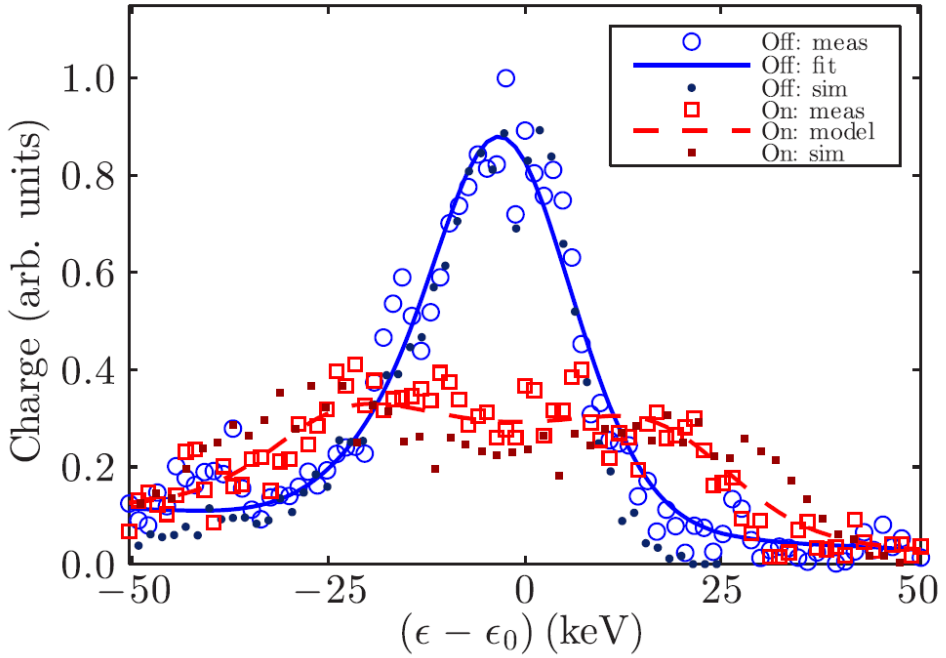


- 60 MeV electrons from linac, 170 fs bunch length (60 cycles)
- 800nm wavelength laser, 90 fs pulse duration
- Bending magnet spectrometer

Postdoc – Model – Electron beam response to DLA



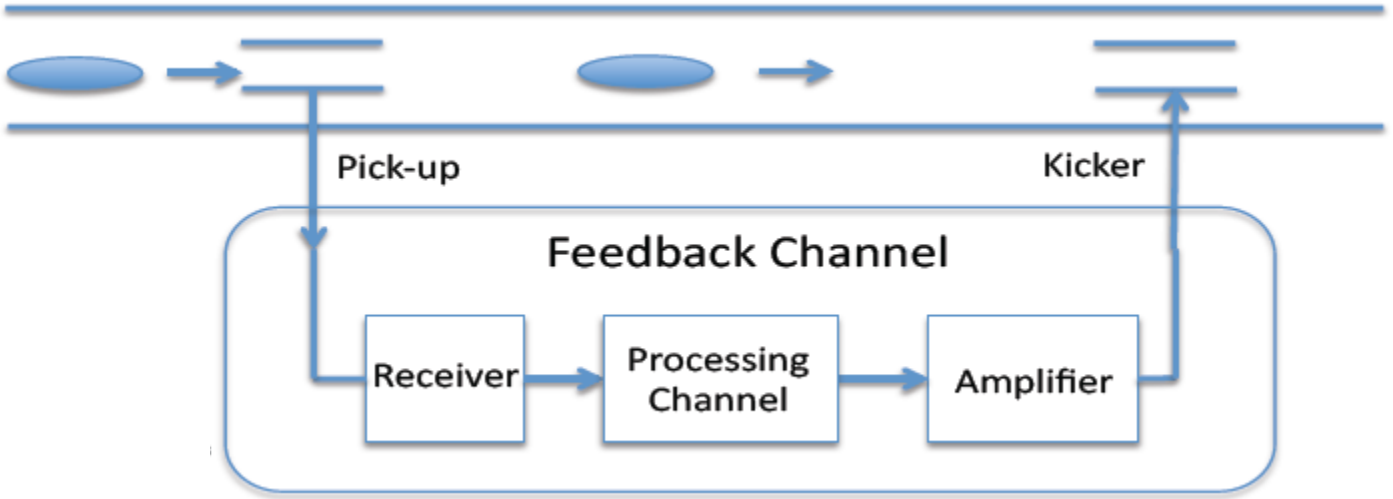
$$G = 0.69 \pm 0.10 \text{ GeVm}^{-1}$$



K.P. Wootton, et al. Opt. Lett. 41, 2696 (2016)

LARP – Wide-band feedback system

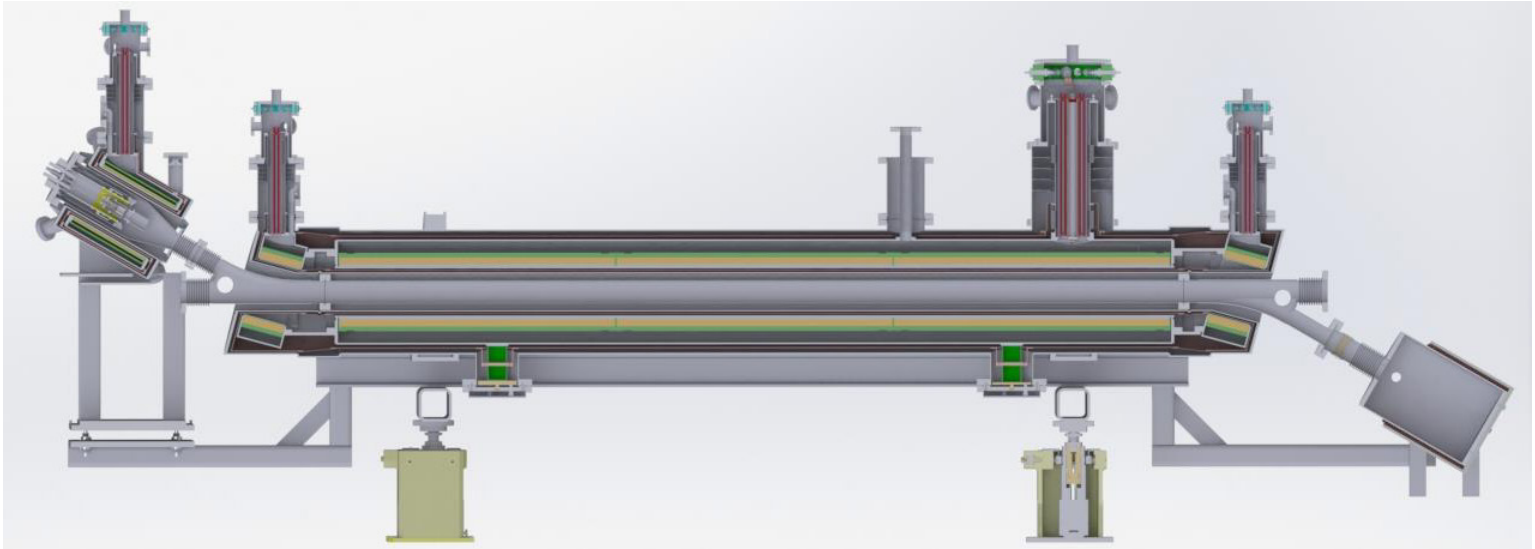
- Head-tail and electron cloud instabilities
- Intrabunch (~1 ns) and coupled bunch modes (~40 ns)



Rivetta, DOE LARP Review, Feb 2014

LARP – Hollow electron lens

- Halo control, collimation, beam-beam compensation



D. Perini, C. Zanoni, arXiv: 1702.00234 (2017)