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# Dielectric laser acceleration and focusing using short-pulse lasers with an arbitrary laser phase distribution

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# Motivation

- In addition to acceleration, extending scale of DLAs beyond ~1 mm necessitates focussing
- Ideally, compatible with laser-driven accelerating structures
- 1-D grating accelerating structures ideally accelerate high aspect ratio beams, or many round beams in parallel
- Focussing structure supporting multiple parallel beams, powered by short-pulse lasers



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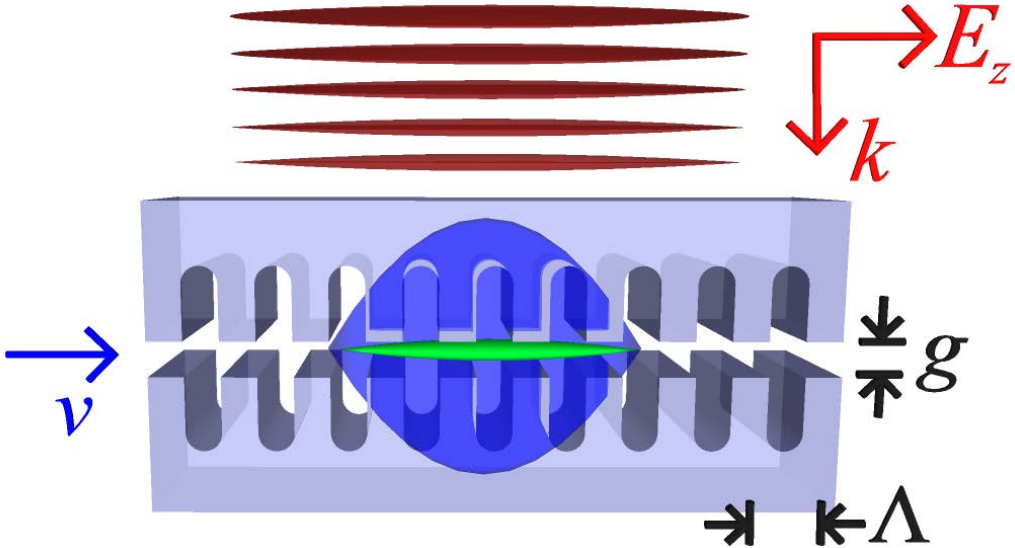
# Short pulse lasers for DLA

- Use measured laser temporal distribution to determine gradient

$$G = \frac{\Delta\epsilon}{\Delta\epsilon_1}$$

Measured change in energy (keV)

Change in energy arising from interaction with an accelerating gradient of 1 GV m$^{-1}$



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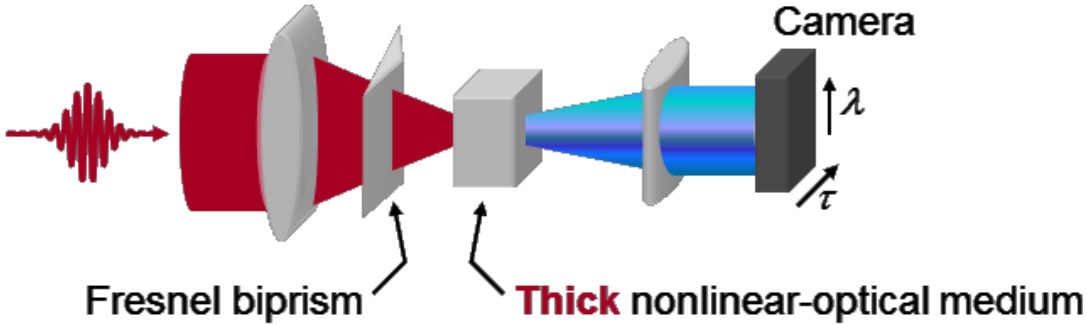
# Laser pulse measurement

- FROG (GRENOUILLE)
- Measurement of SHG intensity interferogram in time and wavelength
- Reconstruction of fs pulse amplitude and phase using phase retrieval algorithm




http://www.swampoptics.com/



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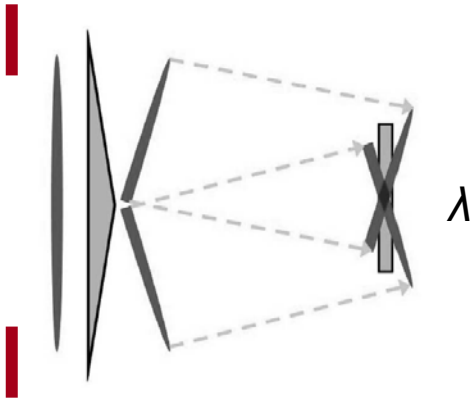
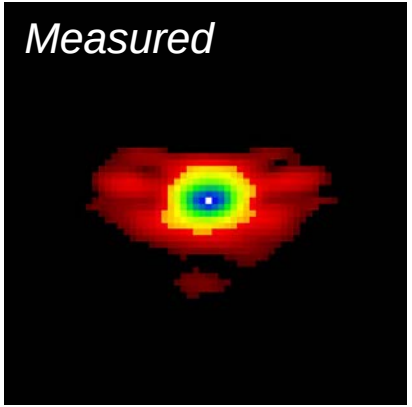
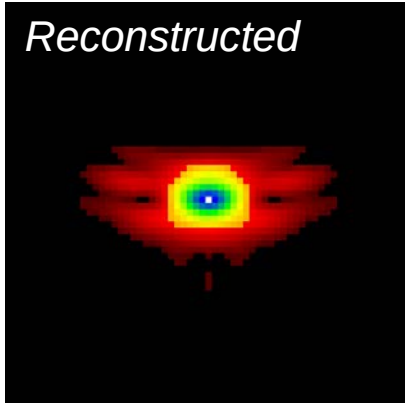
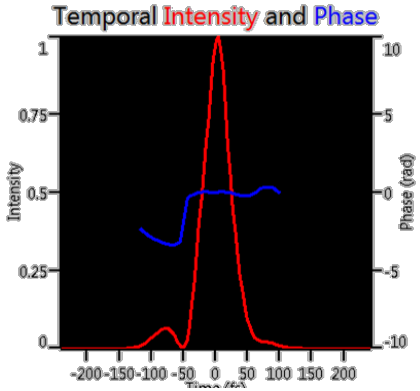
# FROG measurements – SHG intensity interferogram




*t*

D. Lee, et al., J. Opt. Soc. Am. B, 25, A93 (2008).

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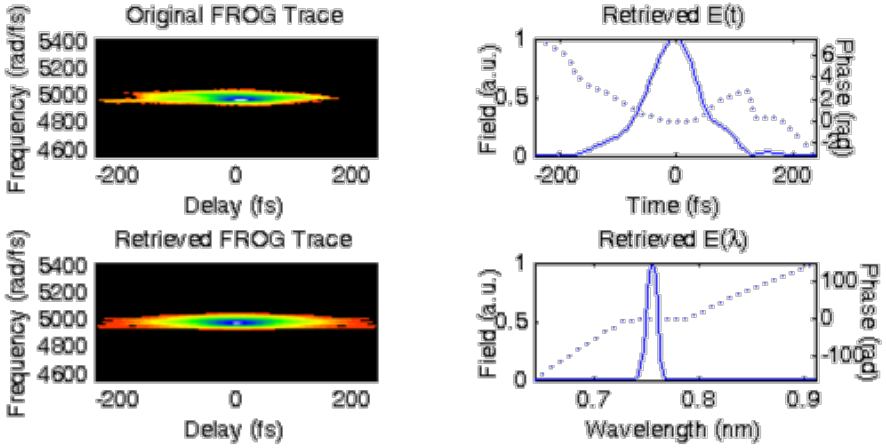
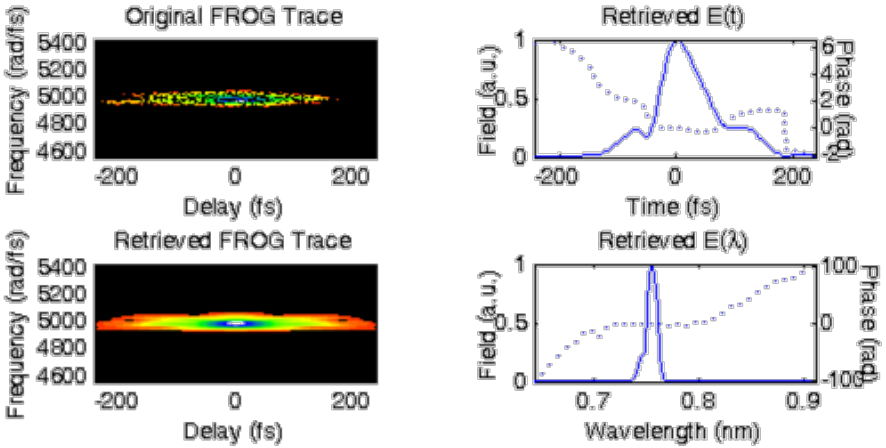
# FROG uncertainties - bootstrap statistical resampling

FROG




Bootstrapping resampling → FROG




* There is a reversal-of-time ambiguity in SHG FROG retrieval, which occurred here

Z. Wang, et al., J. Opt. Soc. Am. B 20, 2400 (2003).

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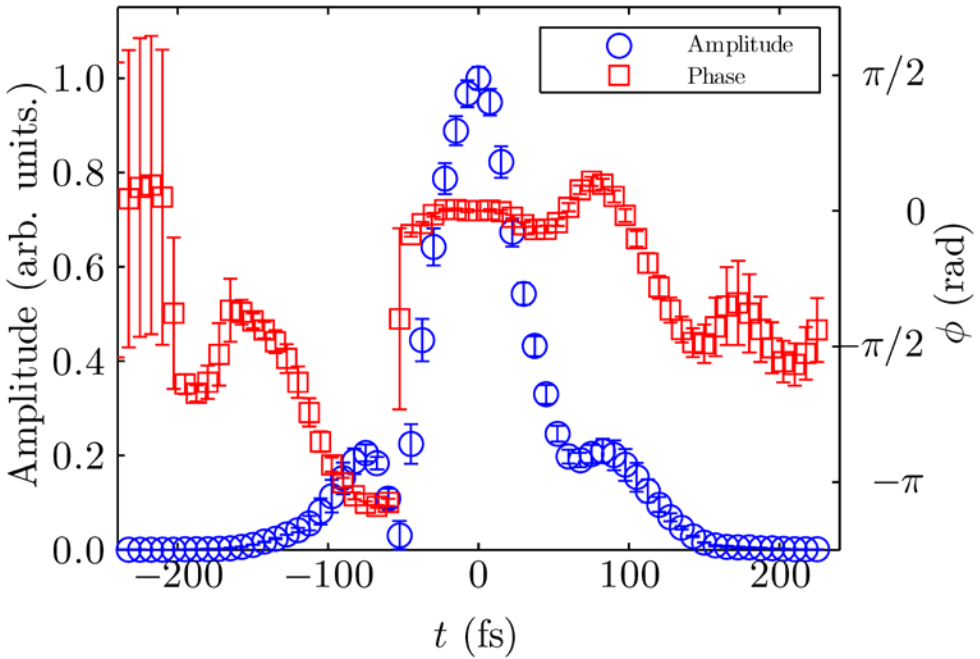
# FROG uncertainties - bootstrap statistical resampling

- Temporal profile of pulse from reconstruction

$$A(t)\cos\phi(t)$$

Amplitude Phase

- Scaled to peak gradient of $1\ GV\ \mathrm{m}^{-1}$



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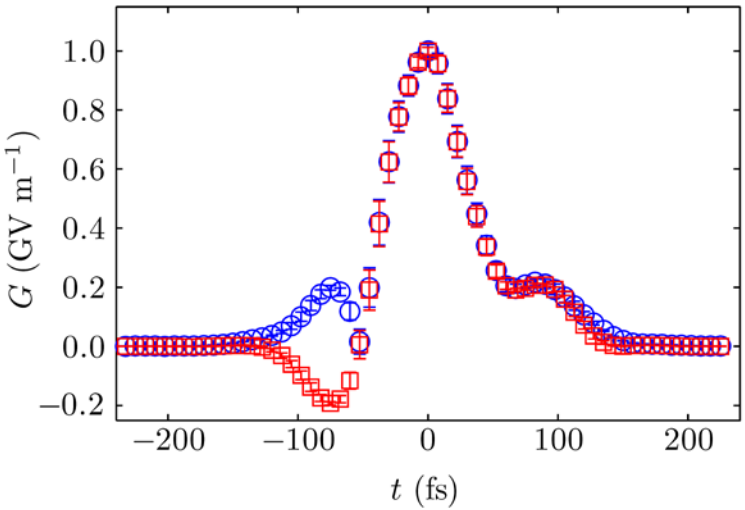
# Laser Pulse Measurement – Interpretation

- Electrons accelerated by main peak are (partially) decelerated by tails
- 25% difference between flat phase and measured phase




Flat phase (circles)

$$E = A(t)$$

$$\Delta\epsilon_1 = 27.0 \pm 1.5 \text{ keV}$$

Measured phase (squares)

$$E = A(t)\cos\phi(t)$$

$$\Delta\epsilon_1 = 21.5 \pm 2.0 \text{ keV}$$

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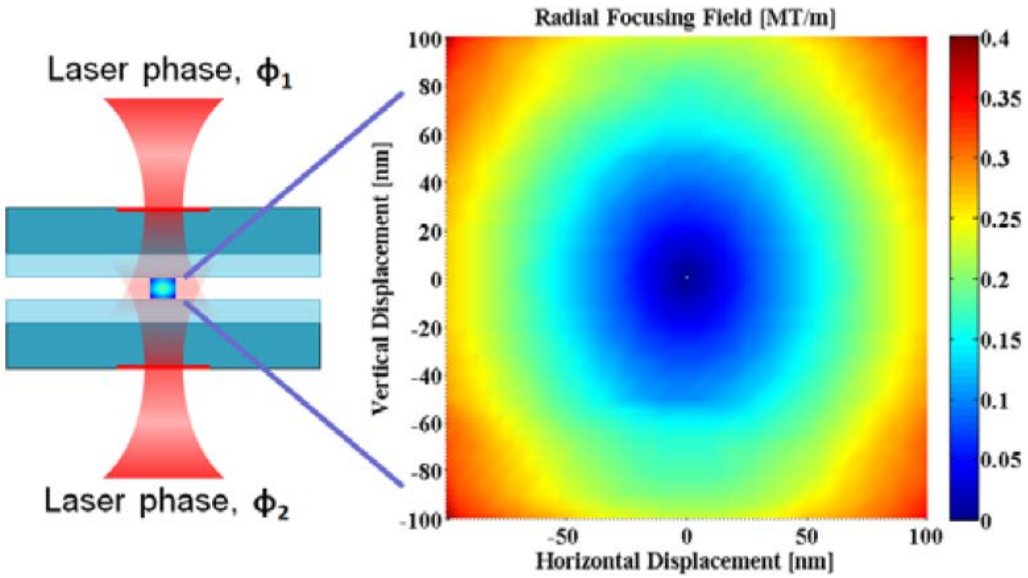
# Focussing structures

- Previous laser-driven focussing structures support single electron beams




T. Plettner, et al., *J. Mod. Opt.,* 58, 1518-1528 (2011)
K. Soong, et al., *AIP Conf. Proc., 1507*, 516-520 (2012)

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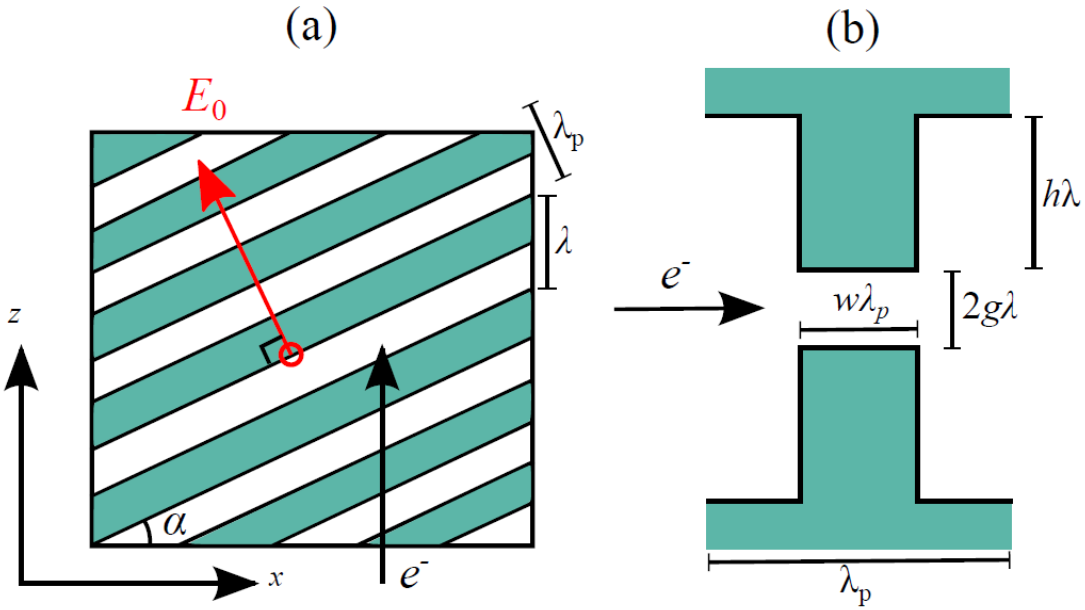
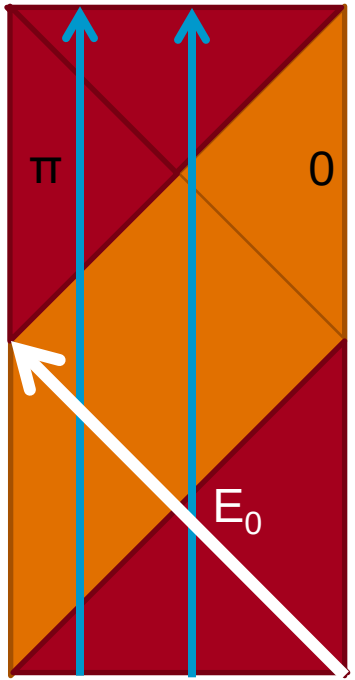
# Deflecting structure




T. Plettner and R. L. Byer, Phys. Rev. ST Accel. Beams, 11, 030704 (2008).



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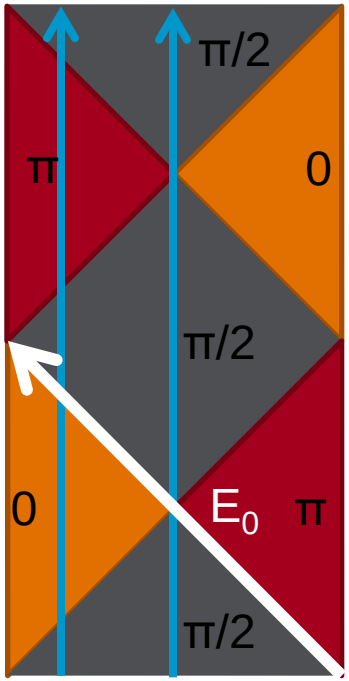
# Checkerboard focussing structure

- Deflecting structure at 45˚
- Half-wavelength scale unit cell
- Square pillars, three heights



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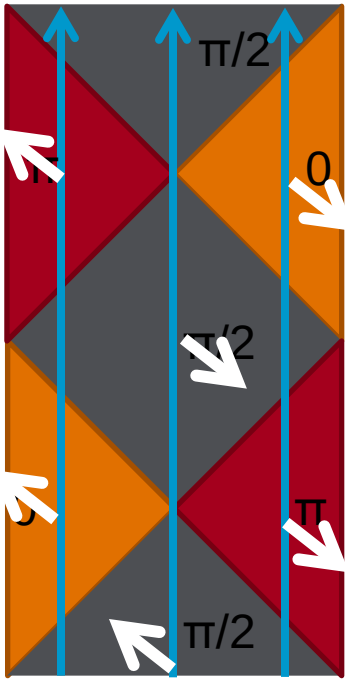
# Force on electron

- Centre designed for zero net force



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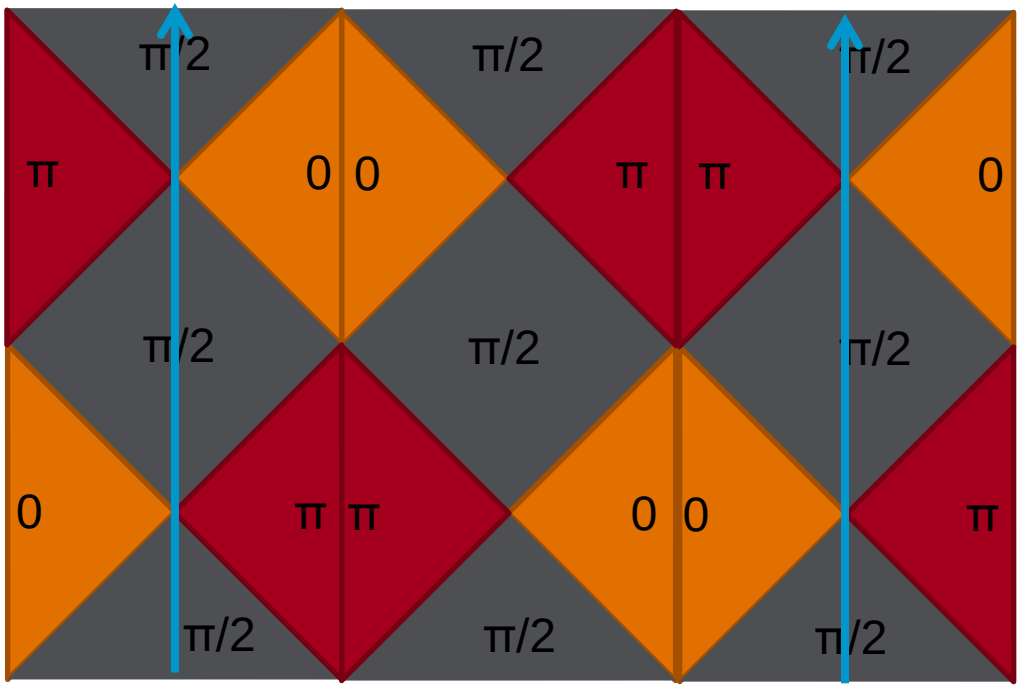
# Checkerboard focussing structure

- Periodic structure
- Reversal of cells
- Supports multiple beams at wavelength spacing

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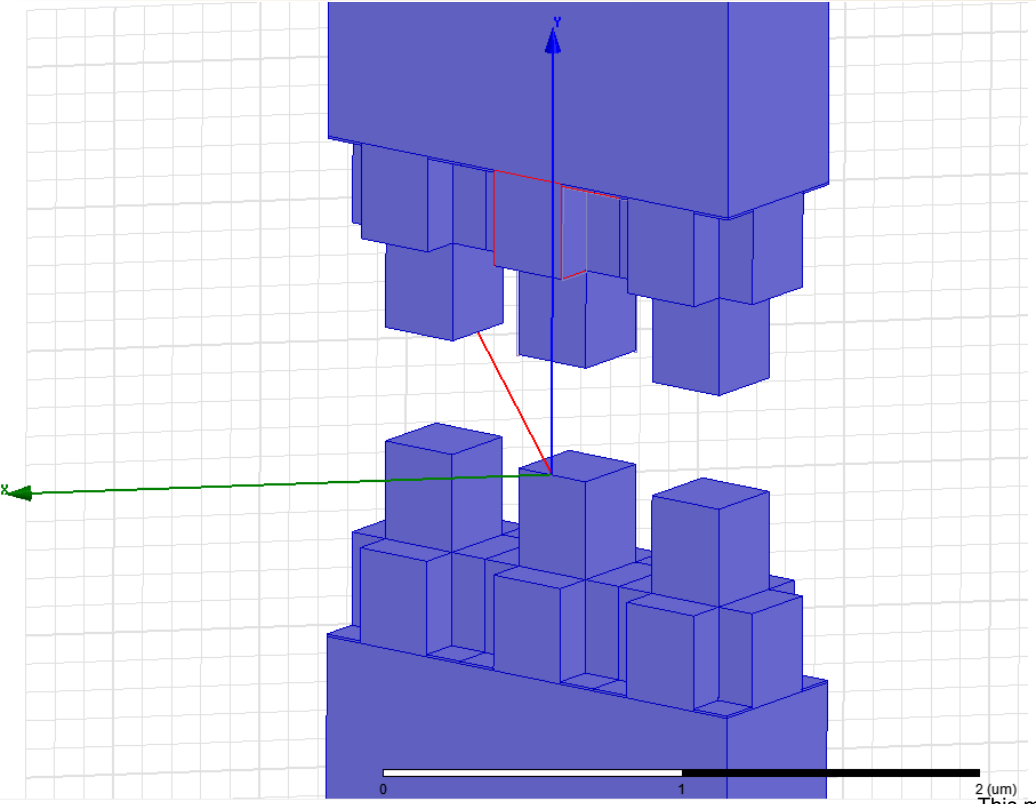
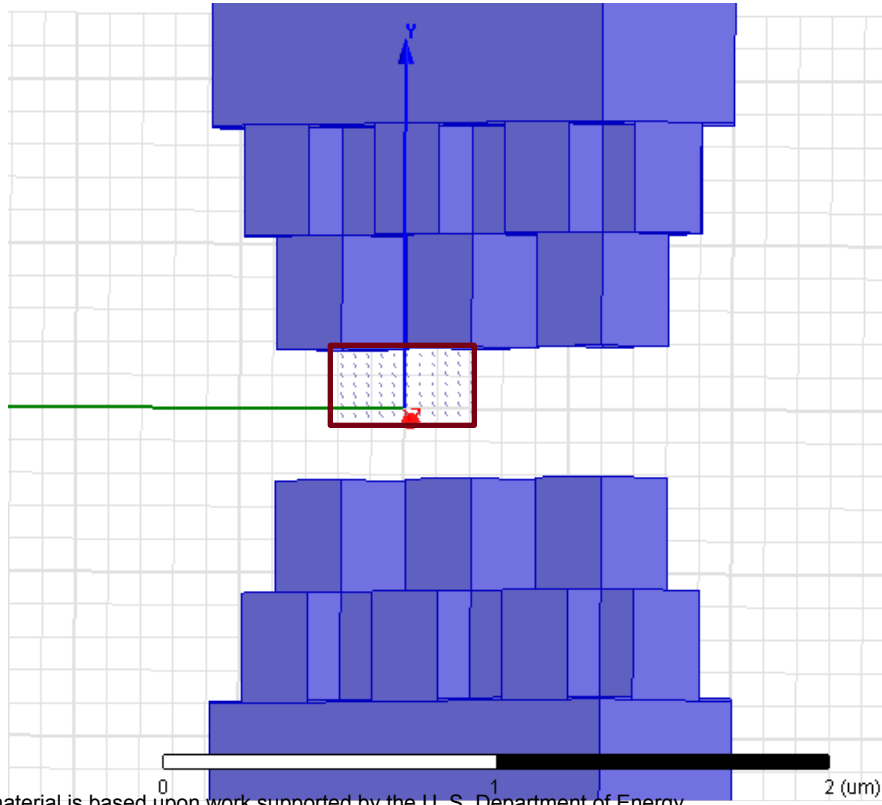
# Checkerboard focussing structure – HFSS model

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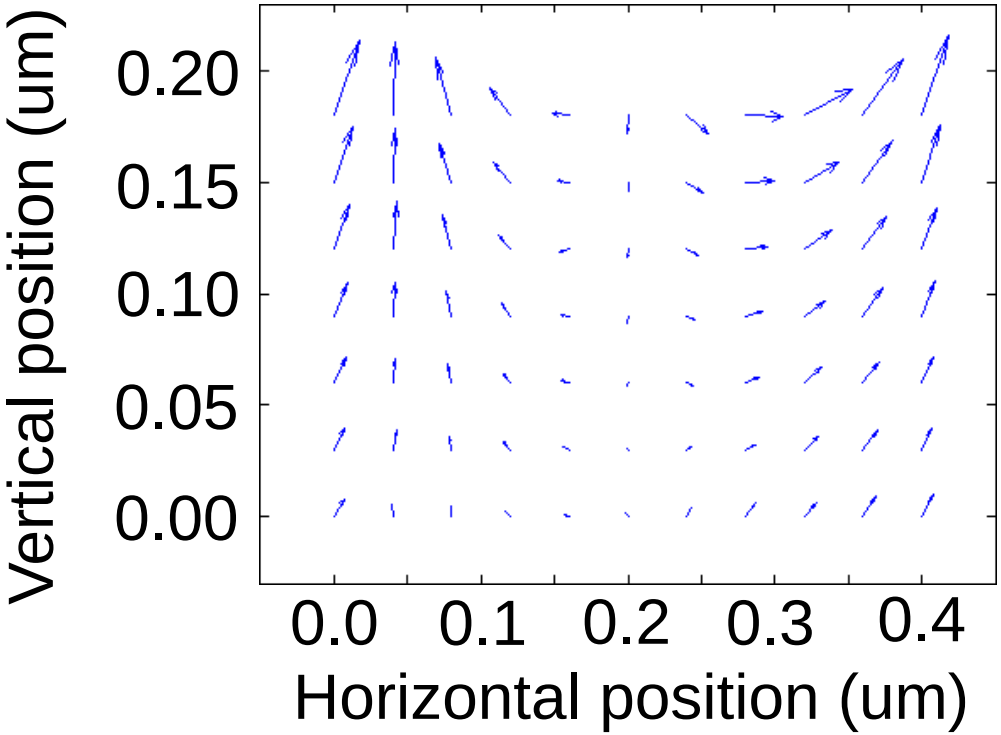
# Focussing force

- Phase where force is focussing
- Equivalent focussing gradient of 2.0 MT $m^{-1}$
- c.f. Plettner structure, 0.4 MT $m^{-1}$

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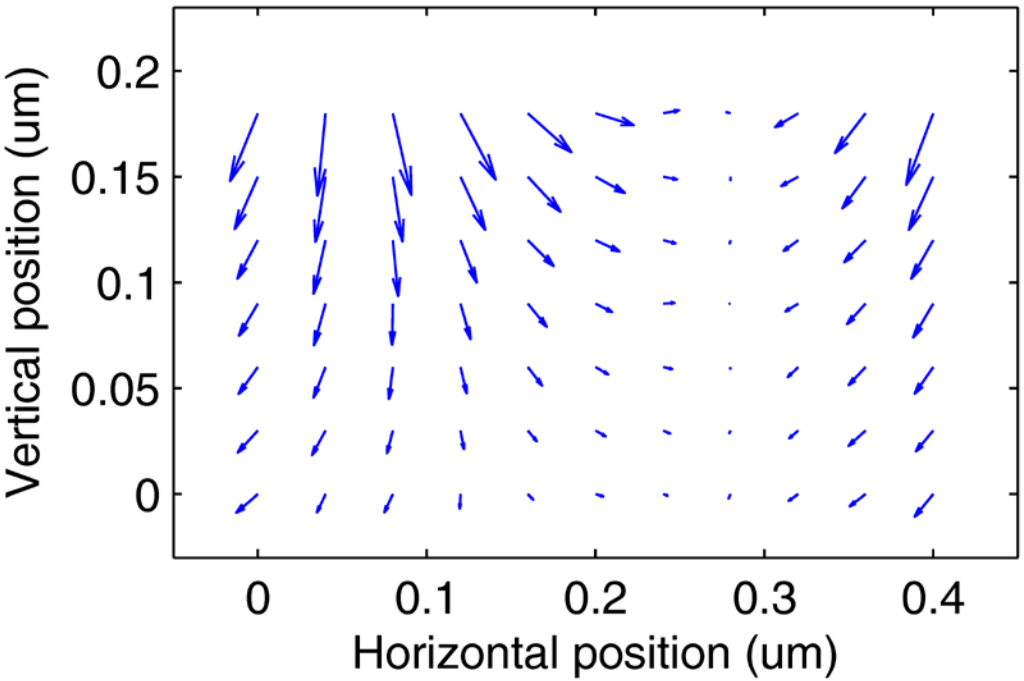


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# Future work and conclusions

- Simulations of a laser-driven focussing structure supporting multiple (parallel) beams
- Focussing gradient 2.0 MT $m^{-1}$
- In order to fabricate, need characterisation of alignment tolerances
- Geometry not necessarily optimised
- Consider angles other than 45˚



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# Acknowledgements

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# Backup

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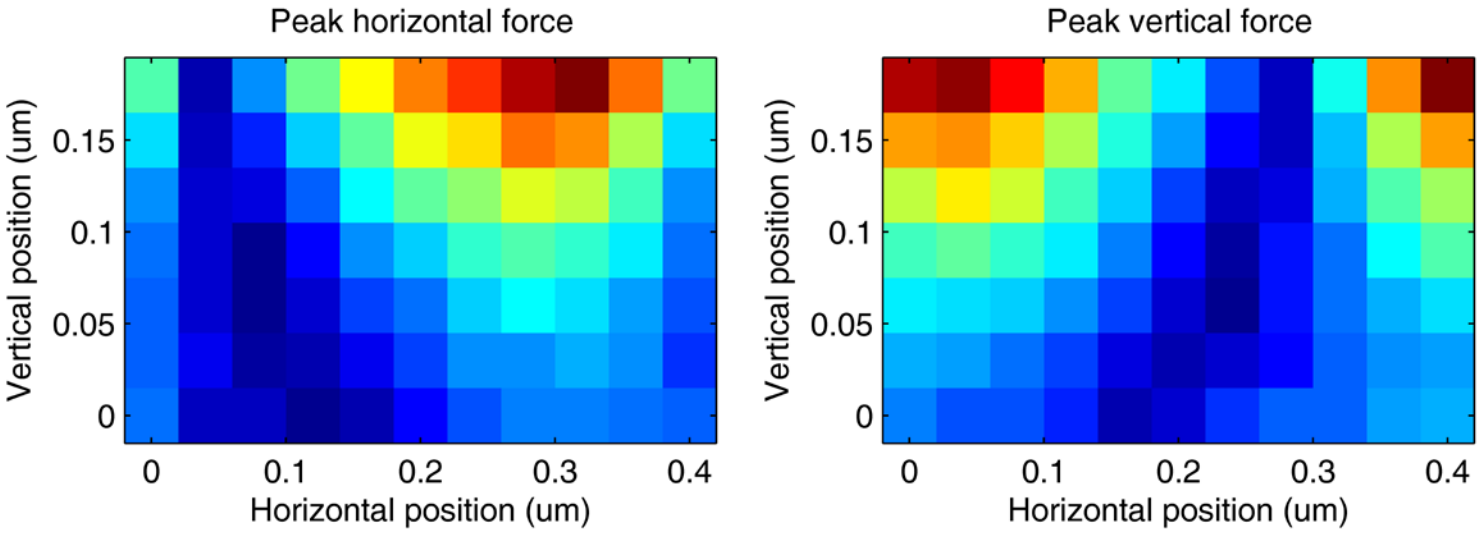
# Checkerboard focussing structure – peak force

- Peak transverse force



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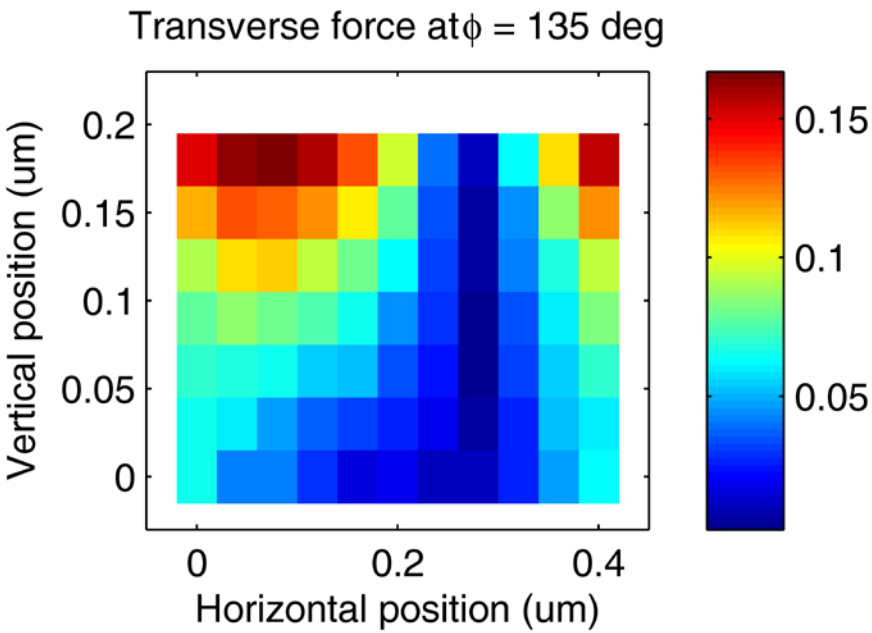
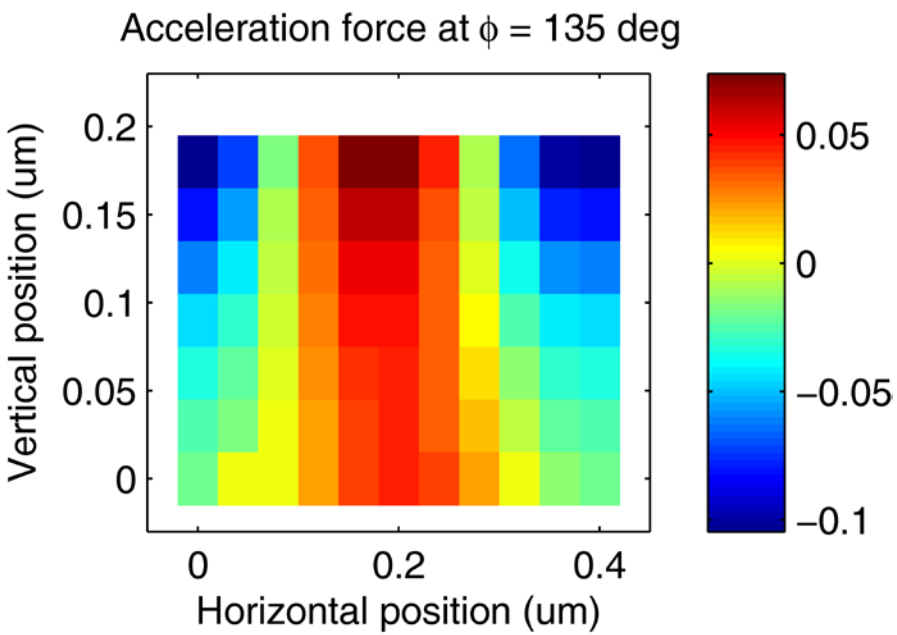
# Checkerboard focussing structure – transverse and accelerating forces

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