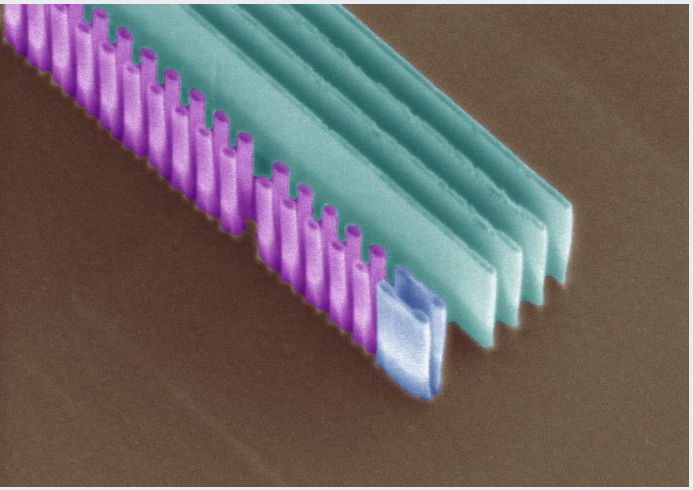
FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
NATURWISSENSCHAFTLICHE FAKULTÄT

bmb+f Bundesministerium für Bildung und Forschung

GORDON AND BETTY MOORE FOUNDATION

Alternating phase focusing in dielectric laser acceleration



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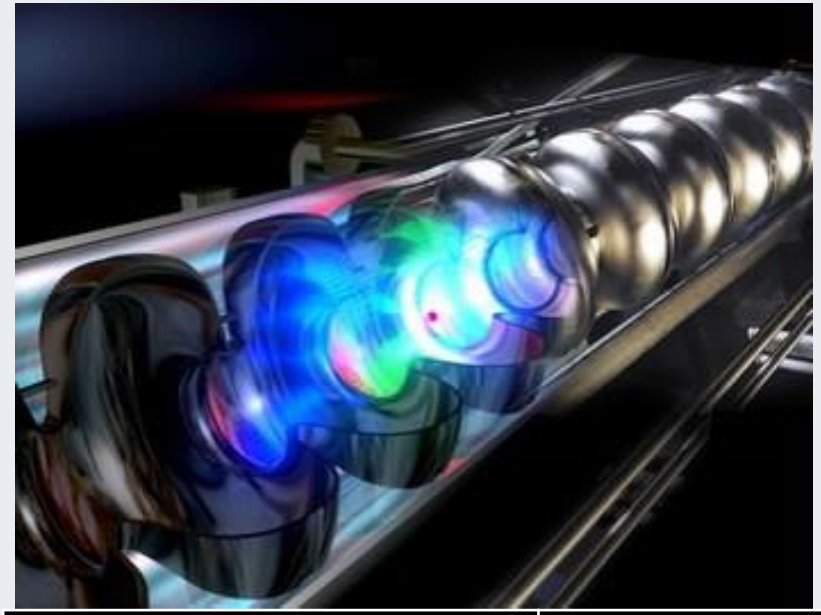
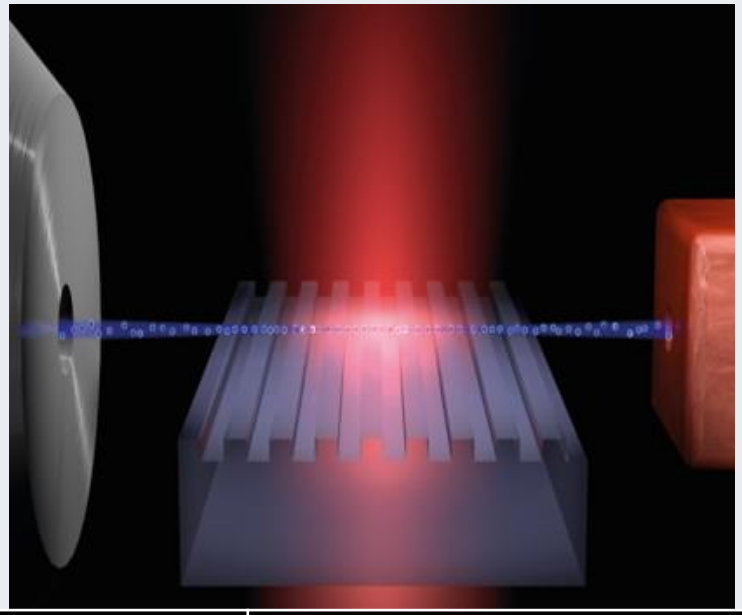
Motivation



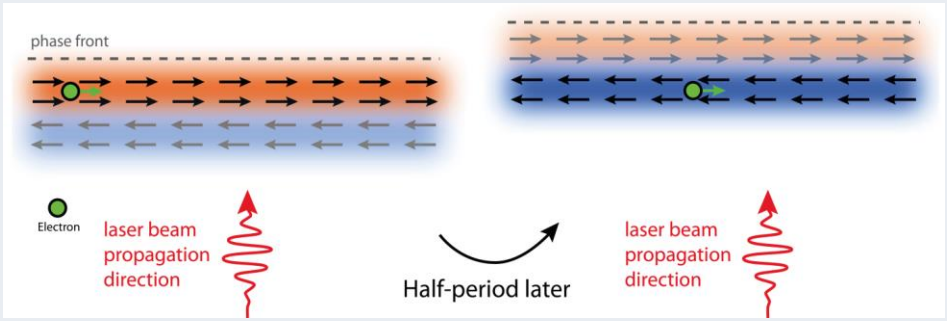


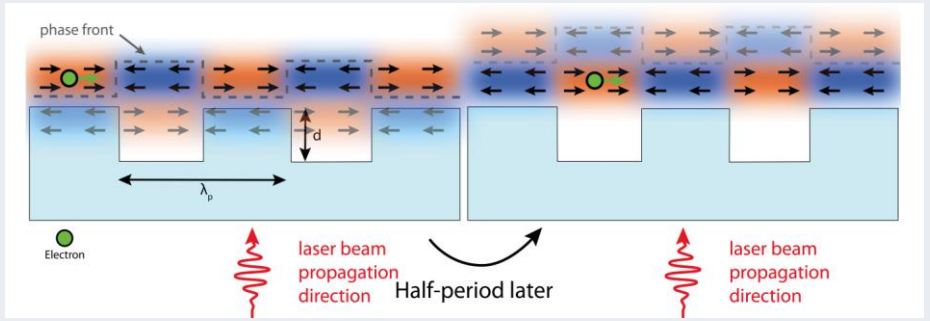
	RF accelerator	Dielectric laser accelerator (DLA)
Based on	(Supercond.) RF cavities	Dielectric grating structures
Peak fields limited by	Surface breakdown: 200 MV/m	Damage threshold: up to 3 GV/m
Max achievable gradients	50 MeV/m	3 GeV/m

DLA principle

Free space interaction between particles and laser field impossible

⇨ Dielectric structure necessary to reach synchronicity condition

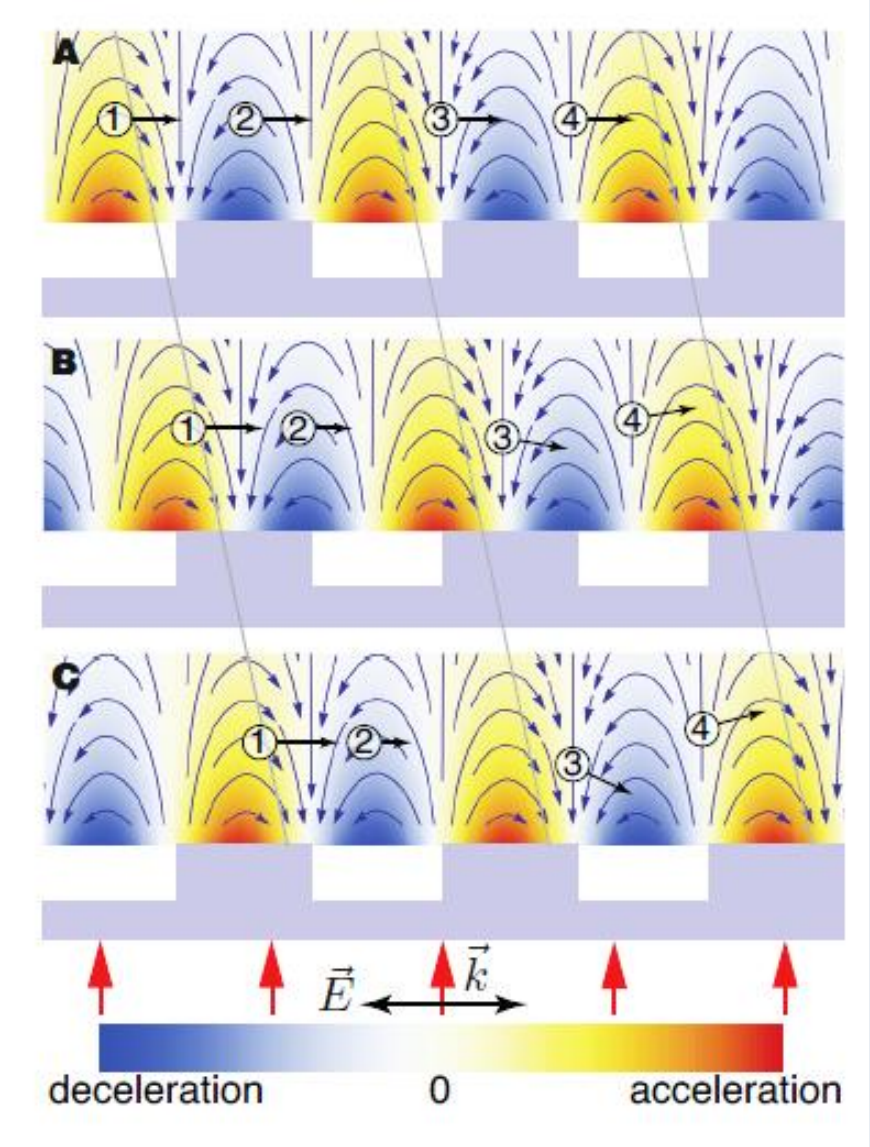


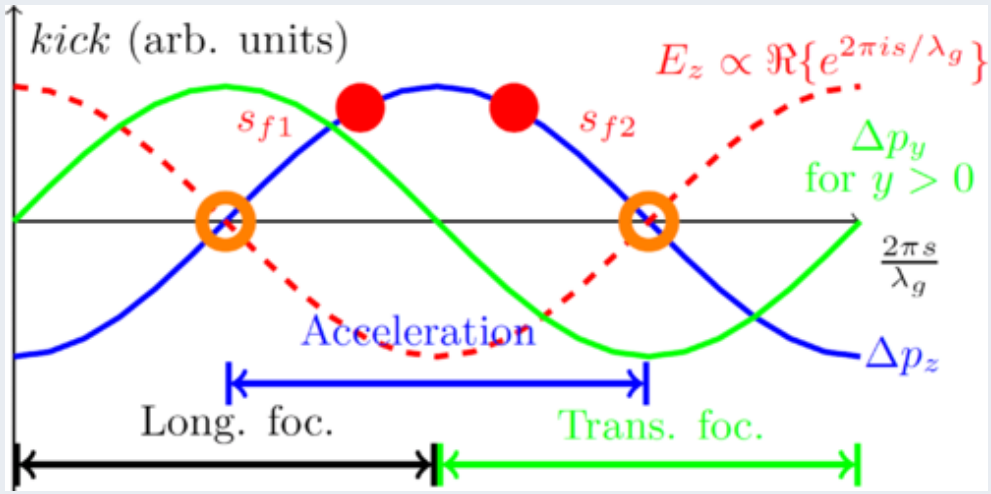


$$\lambda_p = n\beta\lambda$$

λ_p = *grating period*
n = order of harmonic
β = *v/c*
λ = *wavelength*

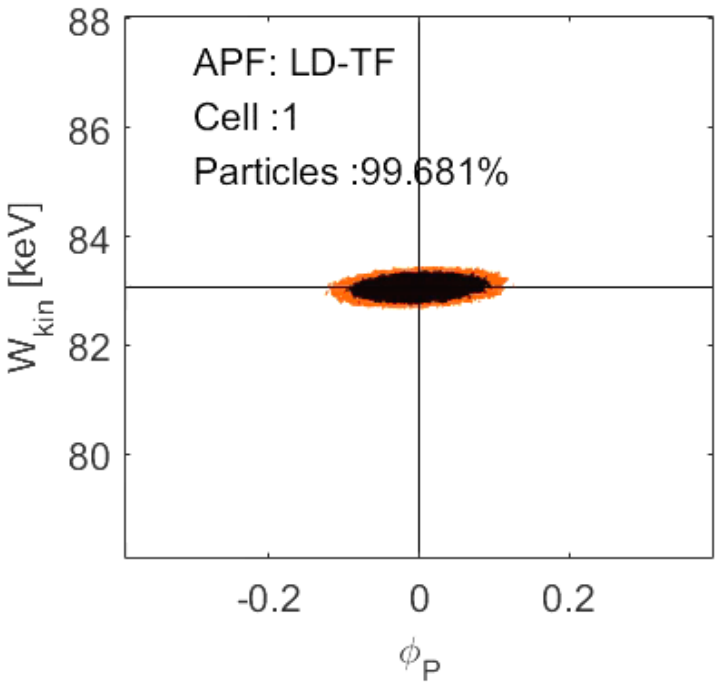
APF – Theory

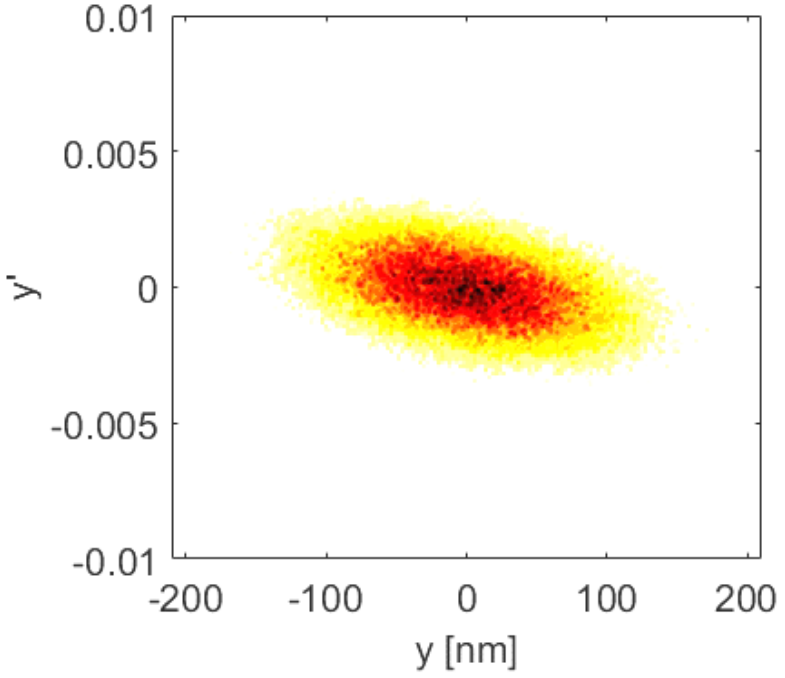




- Depending on the phase relation between e beam and Laser, particles see accelerating decelerating and transverse forces
- By alternating the phase between electron beam and laser beam one can both accelerate and focus in one structure

APF – Theory



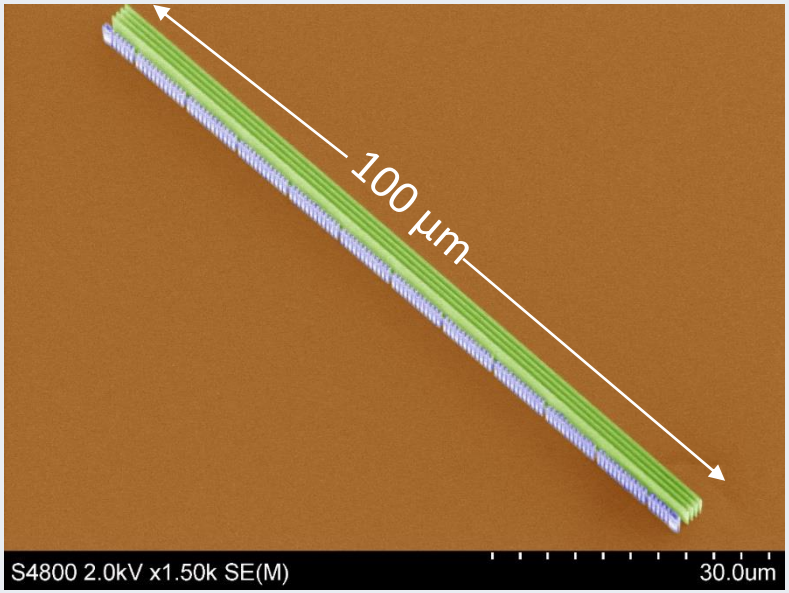


U. Niedermayer, TU Darmstadt

First structure design that allows building the accelerator on a chip with initial energy **83 keV** to more than **1 MeV**:
56% transmission for 100pm rad,
93% for 25pm rad emittance

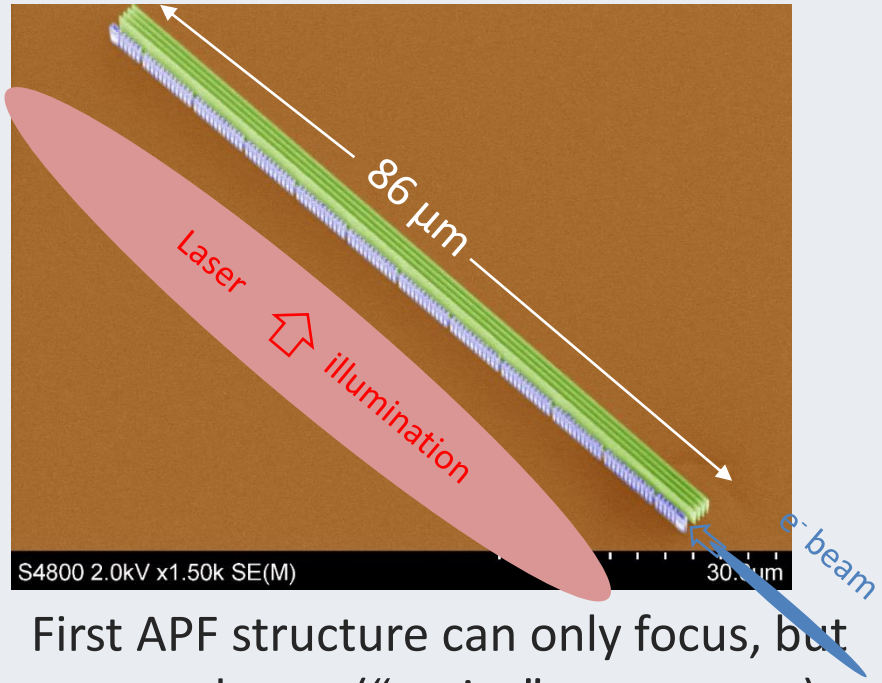
U. Niedermayer et al., Alternating-Phase Focusing for Dielectric-Laser Acceleration, Phys. Rev. Lett. 121, 214801

APF - The “proof-of-principle” structure



- First APF structure can only focus, but not accelerate (“easier” to measure)
- Goal is to see a laser on/off contrast in the transmitted electron signal
- Cylinder shaped, stretched in time laser pulses are used to ensure illumination of the whole structure

APF - The “proof-of-principle” structure



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APF – Preliminary Data

APF - Discussion

What does agrees with theory

- APF is visible in the data (Guiding at low field strengths, overfocusing at high field strength)
- Spectral shape vs field strength follows theory prediction

What does not agrees with theory

- Maximal guiding is lower than expected
- Defocusing sets in at much higher field strengths than predicted
- Energy spread and survival rate do not match

What if the structure factor is off?

- e_1 mode = structure factor * incident peak electric field
- Only e_1 was used for simulation and a structure factor of 0.2 as assumed to calculate the peak electric field
- A structure factor of ~2 fits the data very good, but would mean the structure is resonant (not observed in DLA so far)

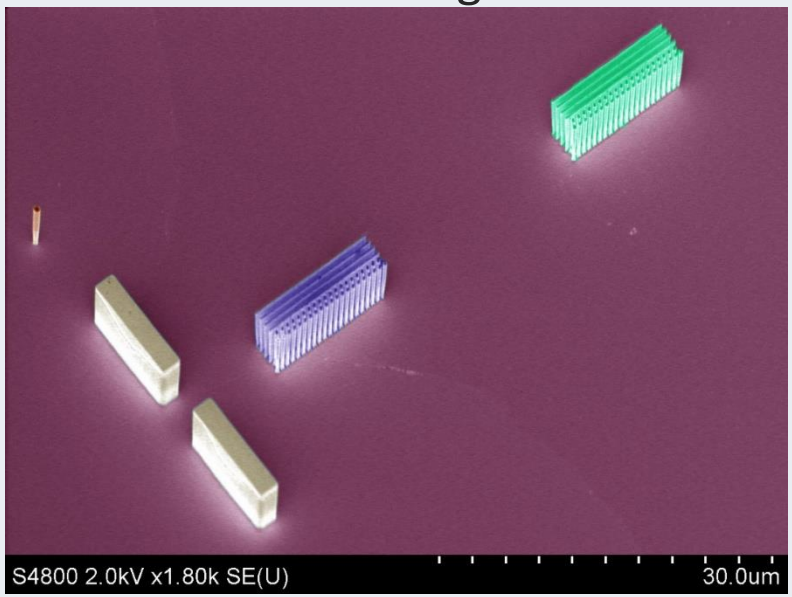
APF - Discussion

Future possible explanations:

- Slight energy mismatch (28.4 keV instead of 28.5 keV)
- Electron beam drift in current and position
- Imperfections in the structure
- Low count rate resulting in high statistical uncertainty
- Electron incident angle might be different in experiment and simulation
- Electron emittance and pulse length might be different in experiment and simulation
- Error in the identification of the peak electric field present at the structure in the experiment

APF - Outlook

Bunching



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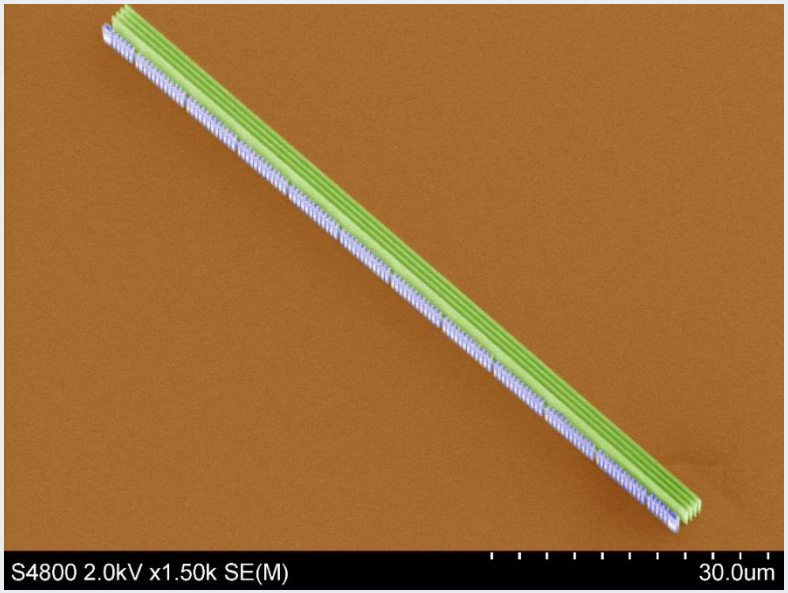
APF



Next step :

Combining bunching and APF to achieve net acceleration!

- Structures of about 1 cm length would allow to accelerate to relativist electrons
- Extensive laser pulse shaping necessary to illuminate such a long structure
- Additional focusing in the other transverse direction necessary for such a structure

The Achip collaboration

Thank you for your attention!

Questions?