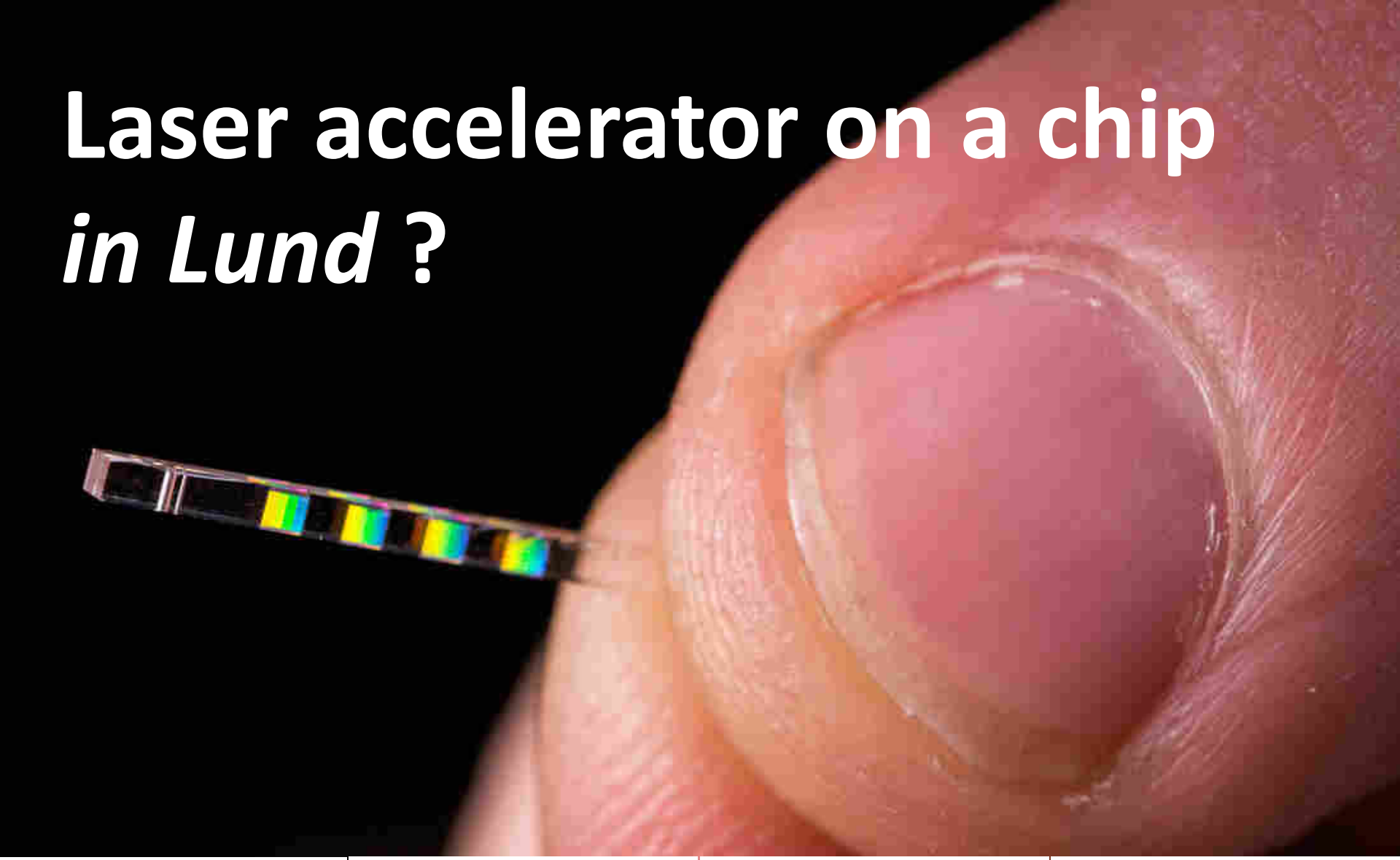
Laser accelerator on a chip *in Lund* ?



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NANO LUND
AT THE FOREFRONT OF NANOSCIENCE

LUND UNIVERSITY

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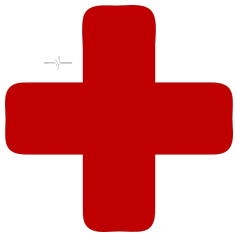
Why particle accelerators matter

Discovery Science

Particle accelerators are essential tools of discovery for particle and nuclear physics and for sciences that use x-rays and neutrons.



Medicine

Tens of millions of patients receive accelerator-based diagnoses and therapy each year in hospitals and clinics around the world.

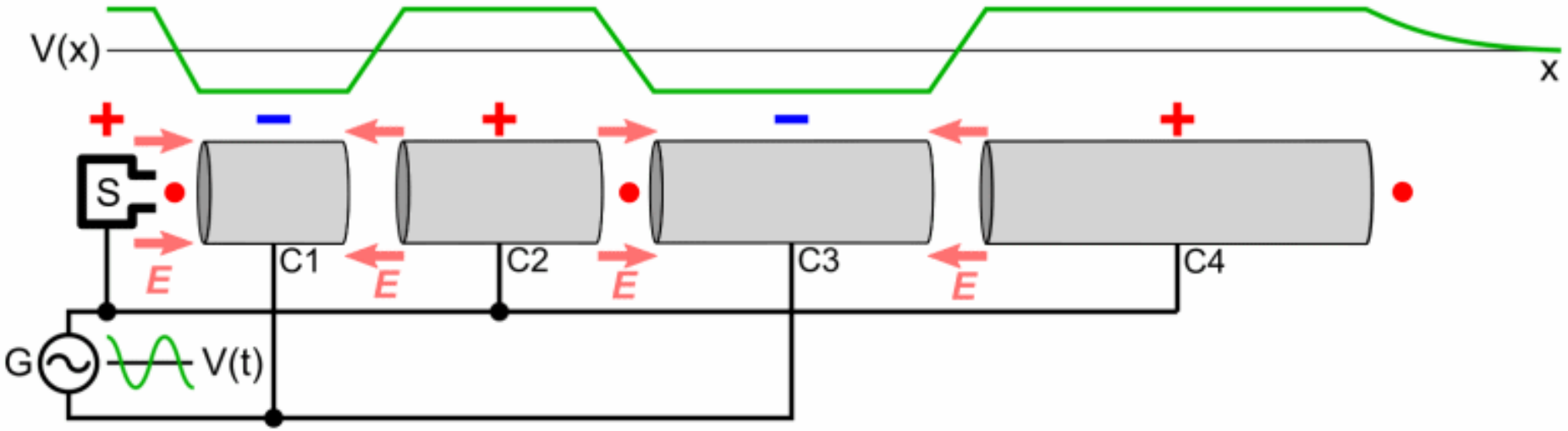
Industry

Worldwide, hundreds of industrial processes use particle accelerators – from the manufacturing of computer chips to the cross-linking of plastic for shrink wrap and beyond.

Security

Particle accelerators play an important role in ensuring security, including cargo inspection and materials characterization.

Linear particle accelerator



Ising 1924

Wideroe 1928

Need for new acceleration techniques

LHC at CERN

European XFEL

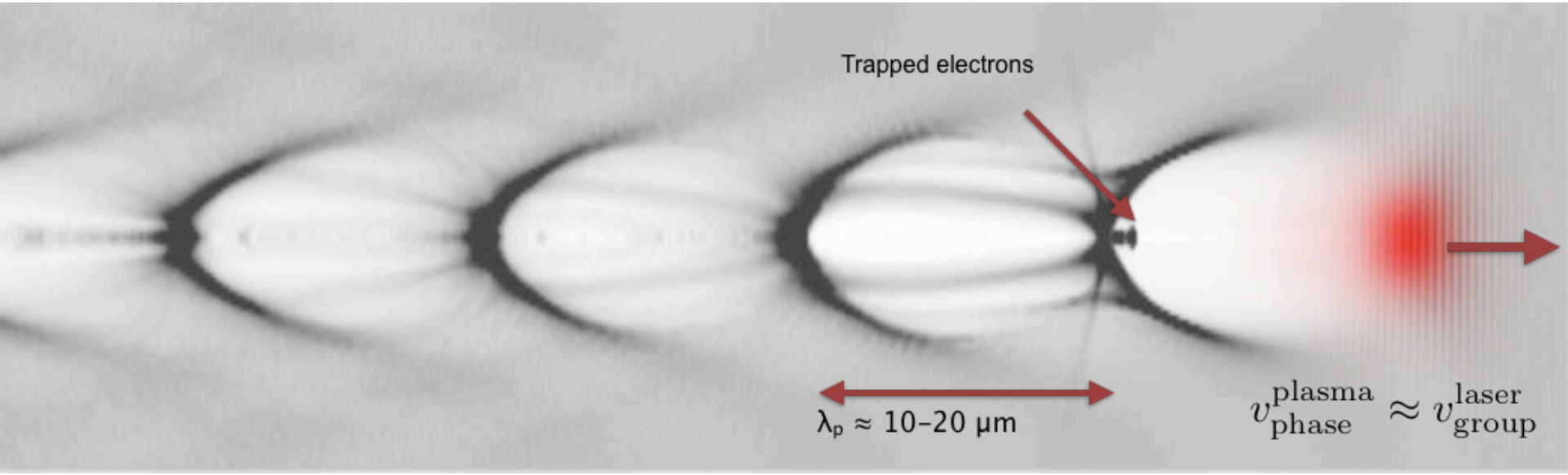
Maximum electric field = few 10 MV/m (breakdown)

$R > R_{min}$ (synchrotron radiation)

Increased energy → Longer accelerator → Higher cost

Higher E-fields in: PLASMAS DIELECTRICS

Laser wakefield accelerator

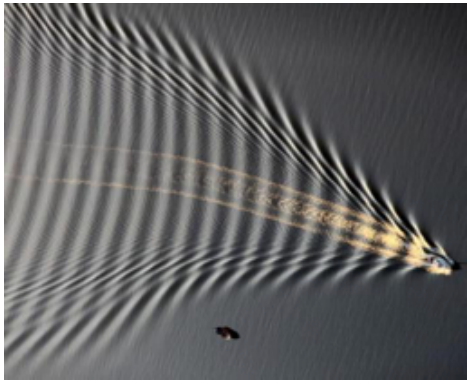


Laser drives a wake wave in plasma

Electrons can ‘surf’ the wake field

Accelerated electron pulse has duration of few fs

Wave in wake of boat



3D PIC simulation with CALDER-Circ

Advanced accelerator concepts

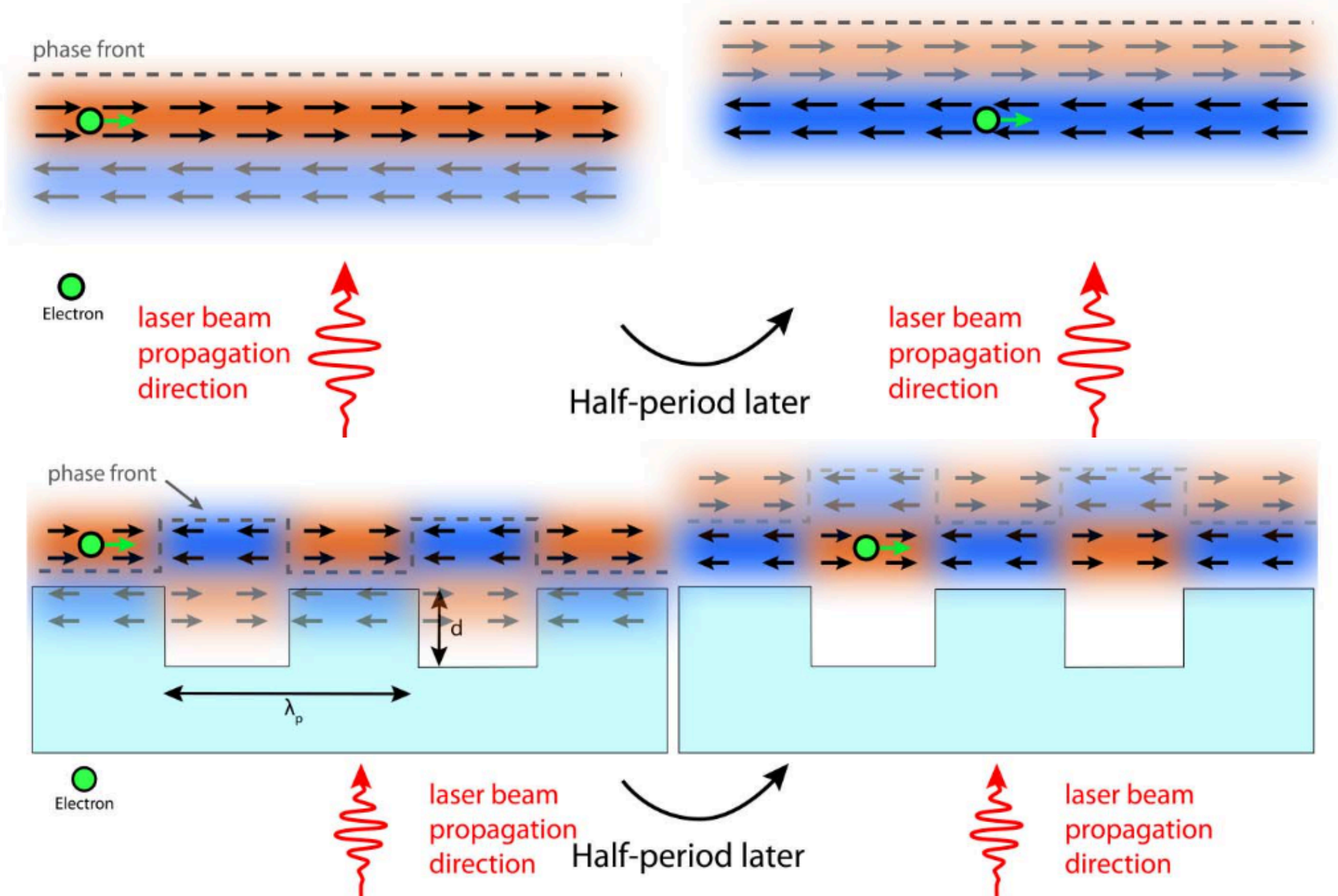
Driver \ Medium	Dielectric	Plasma
Laser pulse	Dielectric Laser Accelerator **DLA**	Laser Wakefield Accelerator **LWFA**
Particle Bunch	Structure Wakefield Accelerator **SWFA**	Plasma Wakefield Accelerator **PWFA**

Experimental results achieved in acceleration of e-

	Energy Gain	ΔE/E	Length	Acc. field	Reference
PWFA	42 GeV	100 %	80 cm	53 GV/m	Blumenfeld, Nature 445, 741-744 (2007)
	1.6 GeV	0.7 %	36 cm	4.4 GV/m	Litos, Nature 515, 92 (2014)
LWFA	7.8 GeV	100 %	20 cm	39 GV/m	Gonsalves, Phys Rev Lett 122, 084801 (2019)
	4.2 GeV	3 %	9 cm	47 GV/m	Leemans, Phys. Rev. Lett. 113, 245002 (2014)
SWFA	30 MeV	0.7 %	9 cm	320 MV/m	O'Shea, Nat. Comm. 7, 12763 (2016)
DLA	24 keV	100 %	35 µm	690 MV/m	Wooton, Optics Letters 41, 2696 (2016)

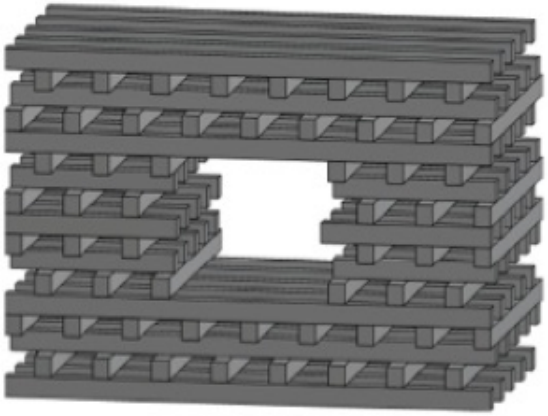
"Towards a Proposal for an Advanced Linear Collider", Alegro Collaboration, 2017

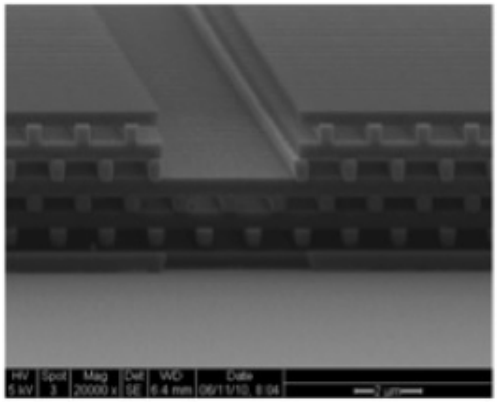
Acceleration at a dielectric structure



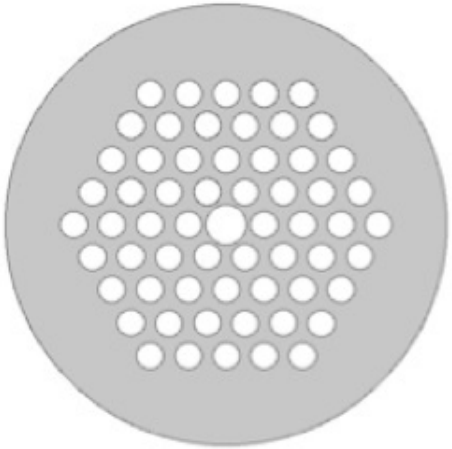
Proposed topologies

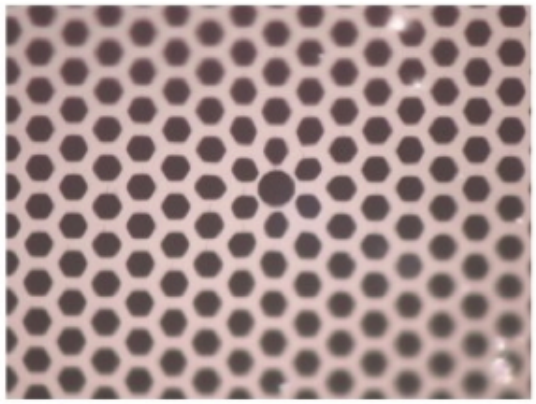
3D photonic crystal structure



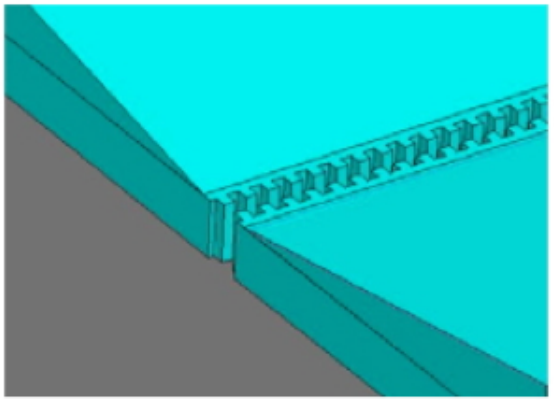


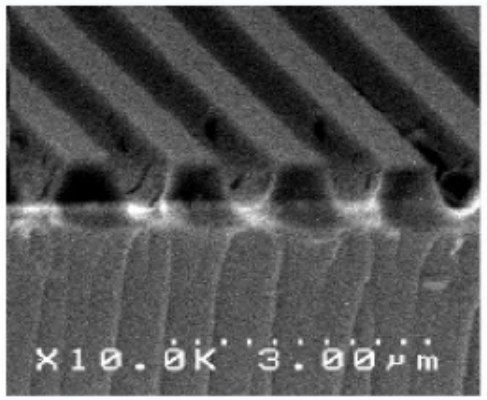
Hollow-core photonic bandgap fiber





Phase-reset grating

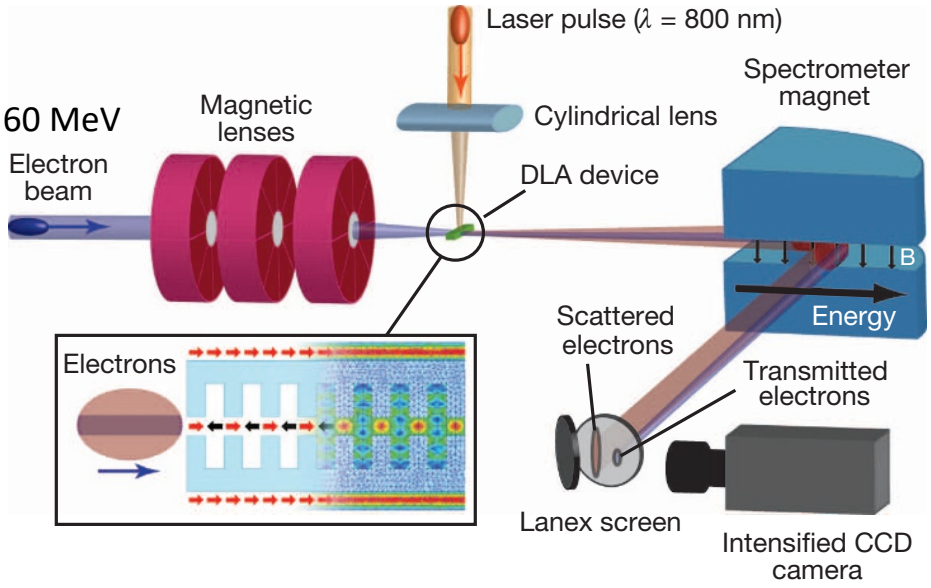




For a review and an extensive list of references, see
"Dielectric laser accelerators", R J England *et al*, Rev Mod Phys **86**, 1337 (2014)

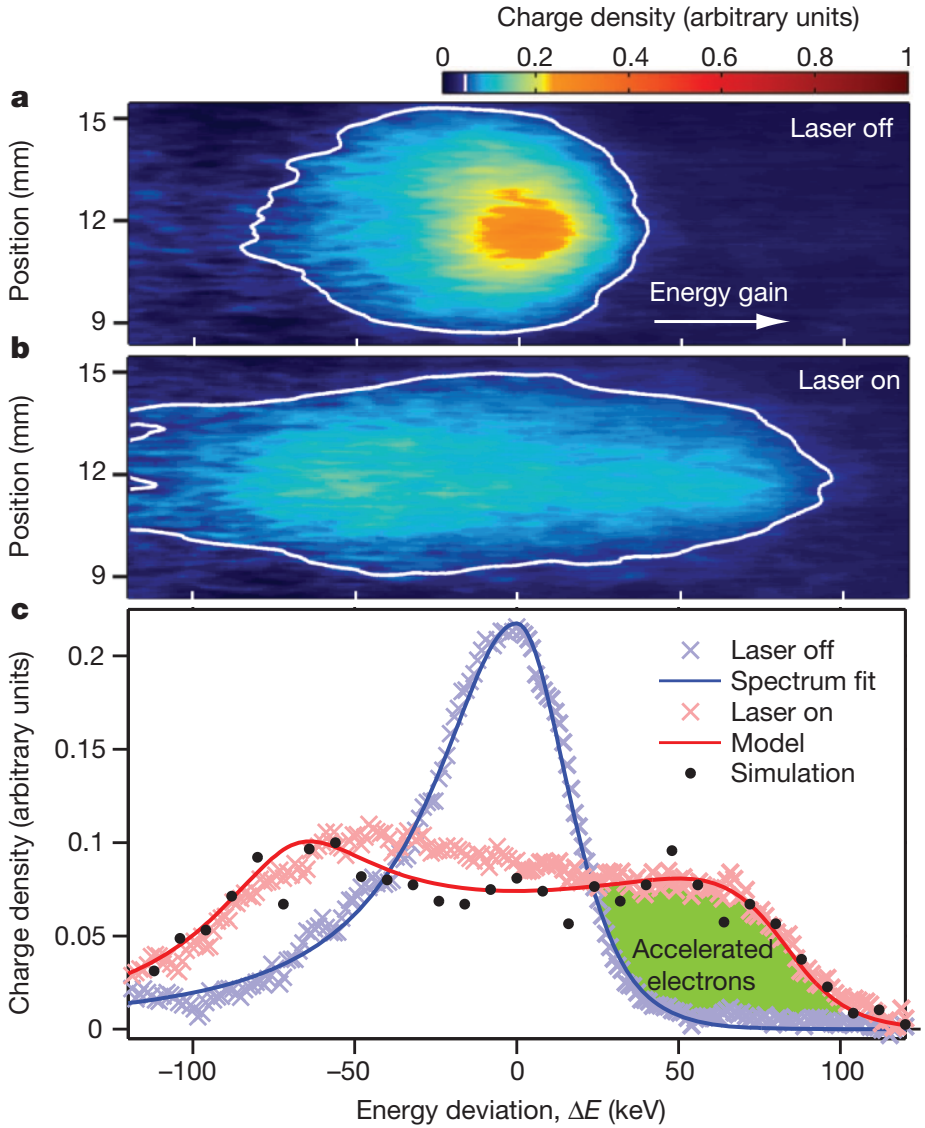
DLA demonstration at SLAC

Dual-sided grating structure



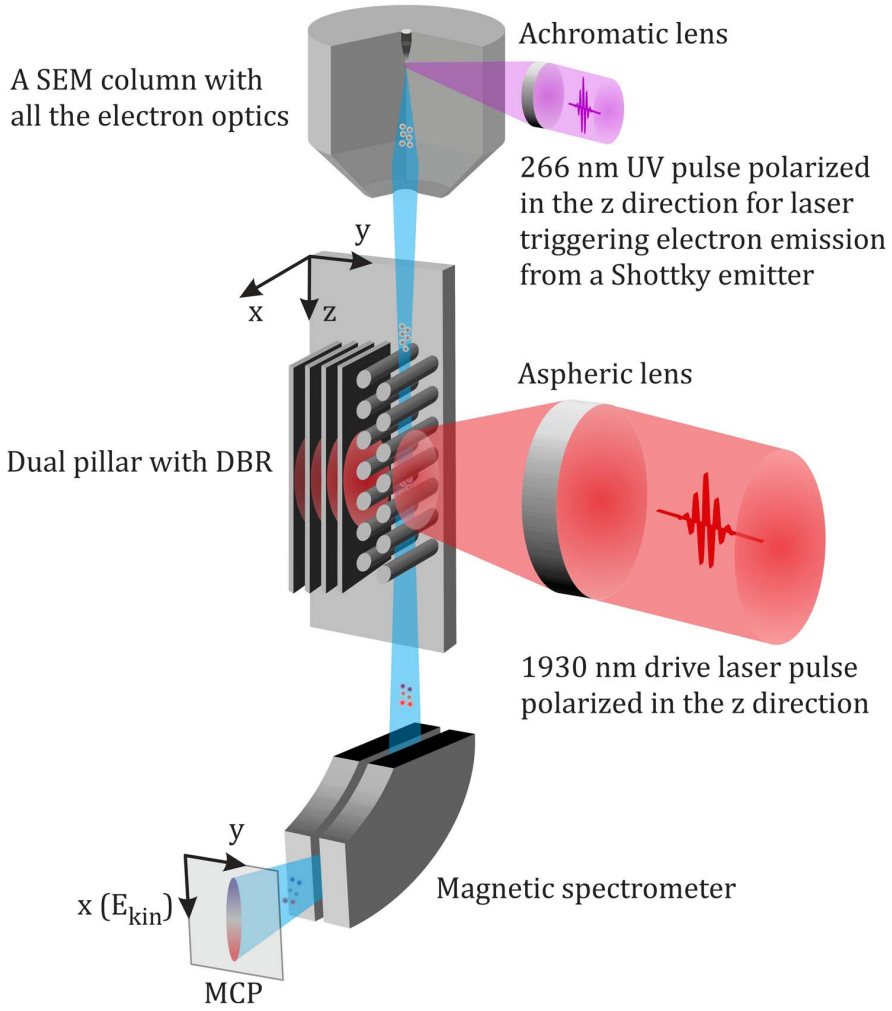
Peralta *et al.*, Nature **503**, 91-94 (2013)

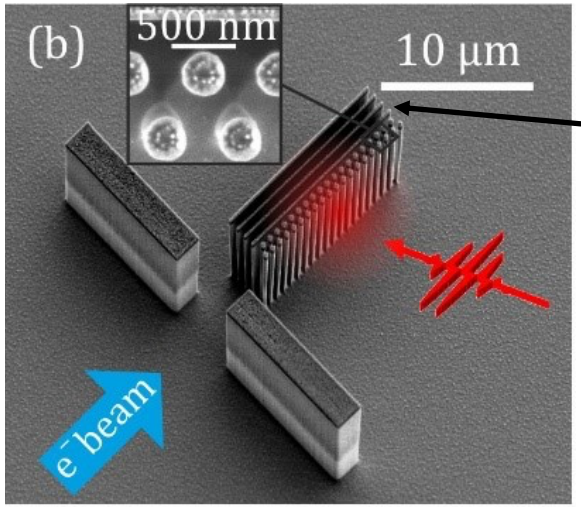
>250 MeV/m



Dual pillar gratings

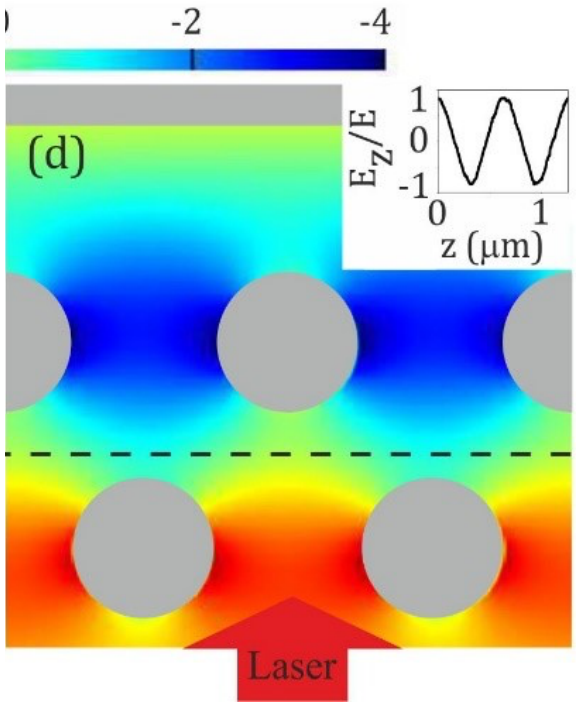
Yousefi *et al.*, Opt Lett **44**, 1520 (2019)





Distributed Bragg reflector

200 MV/m

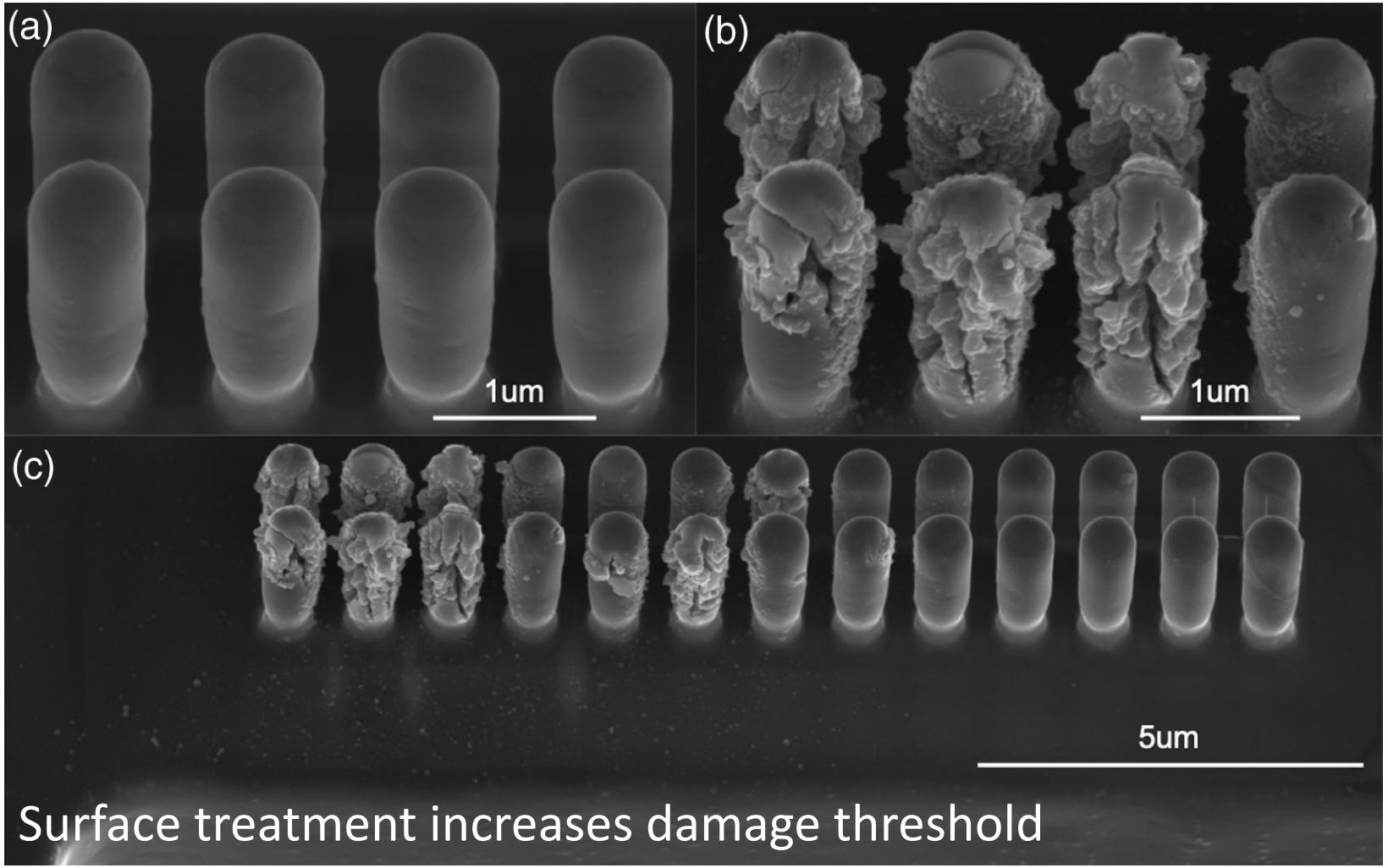


FDTD field simulation

Laser damage limits the intensity

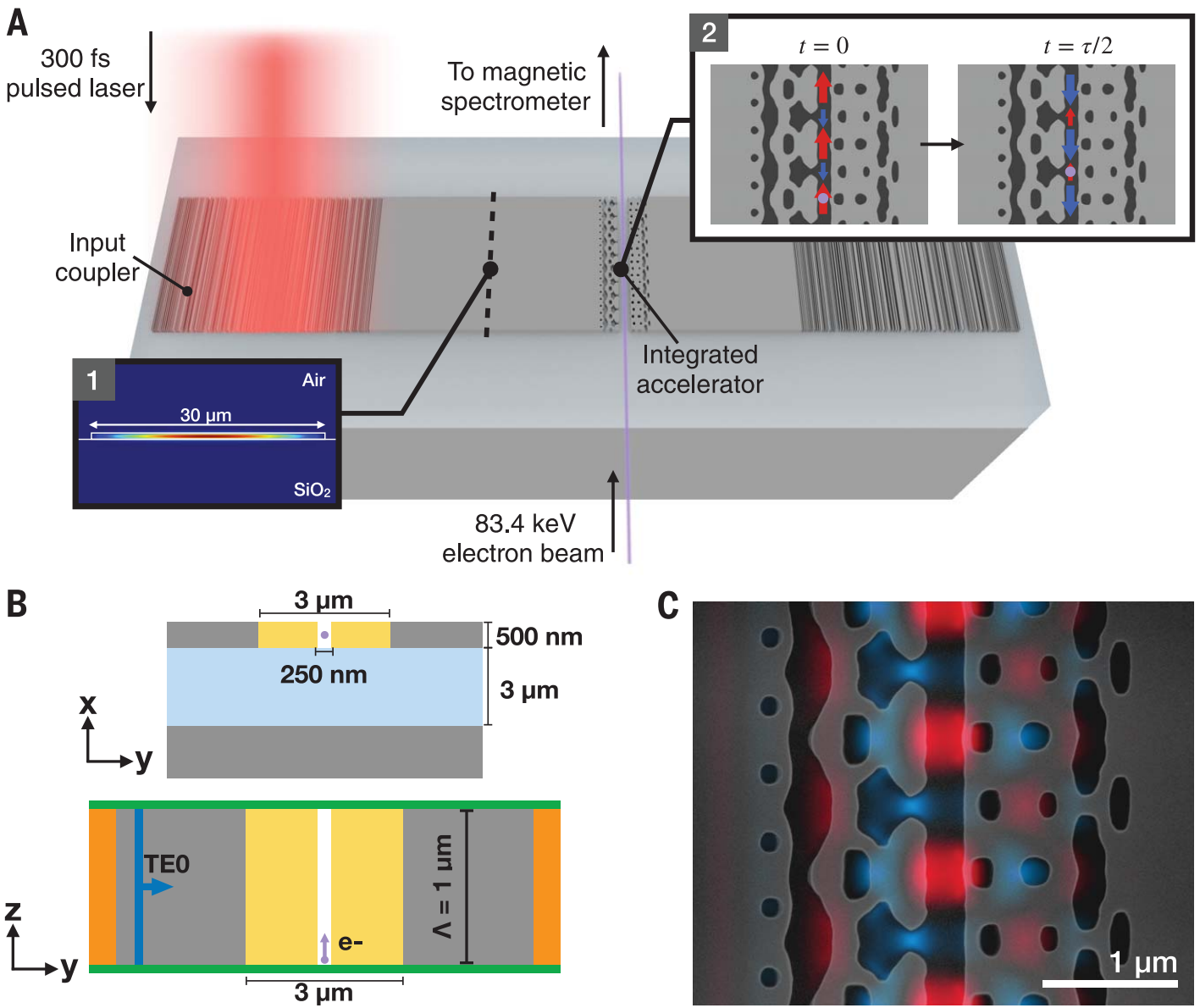
Before laser irradiation

After laser irradiation



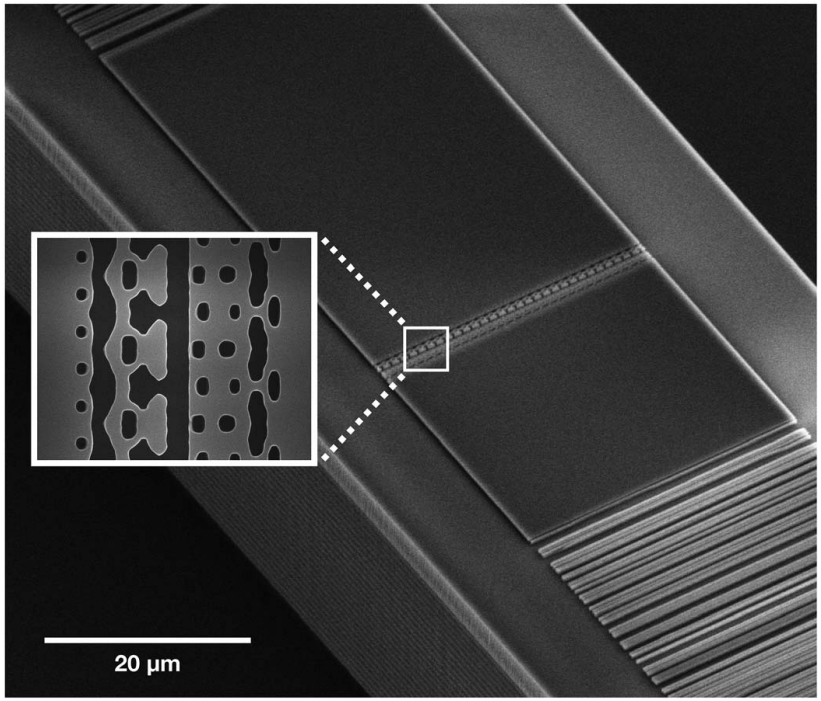
"Surface treatments of dielectric laser accelerators for increased laser-induced damage threshold", Optics Letters **45**, 391 (2020)

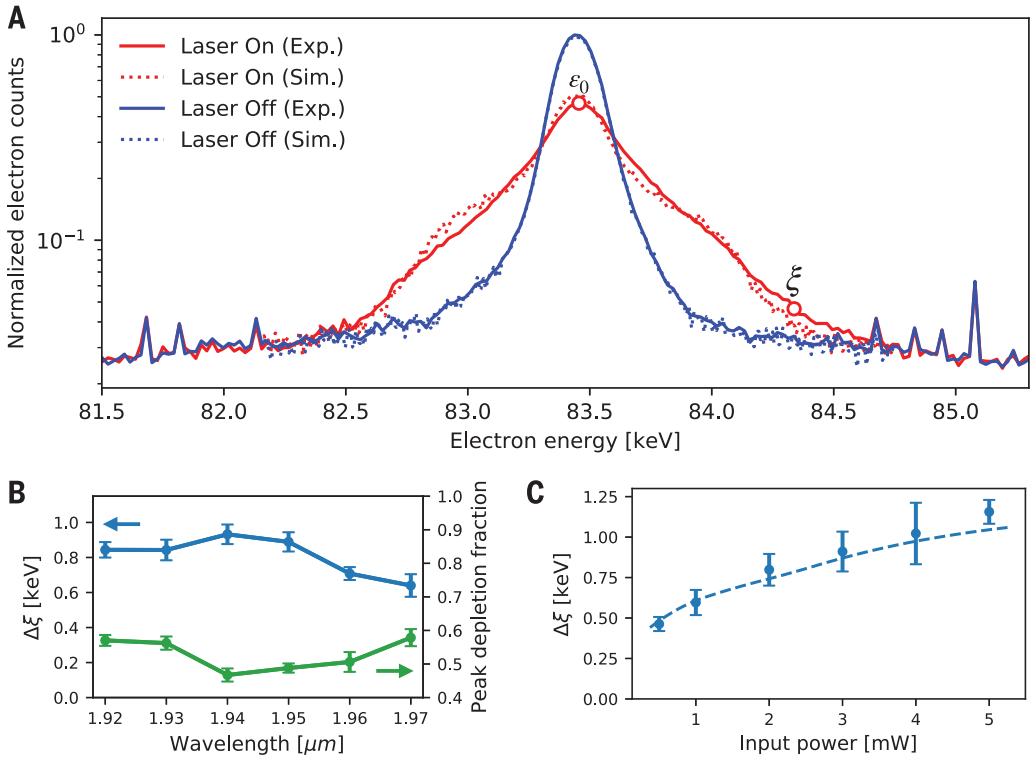
On-chip integrated laser accelerator



Sapra *et al*, Science 367, 79-83 (2020)

On-chip integrated laser accelerator



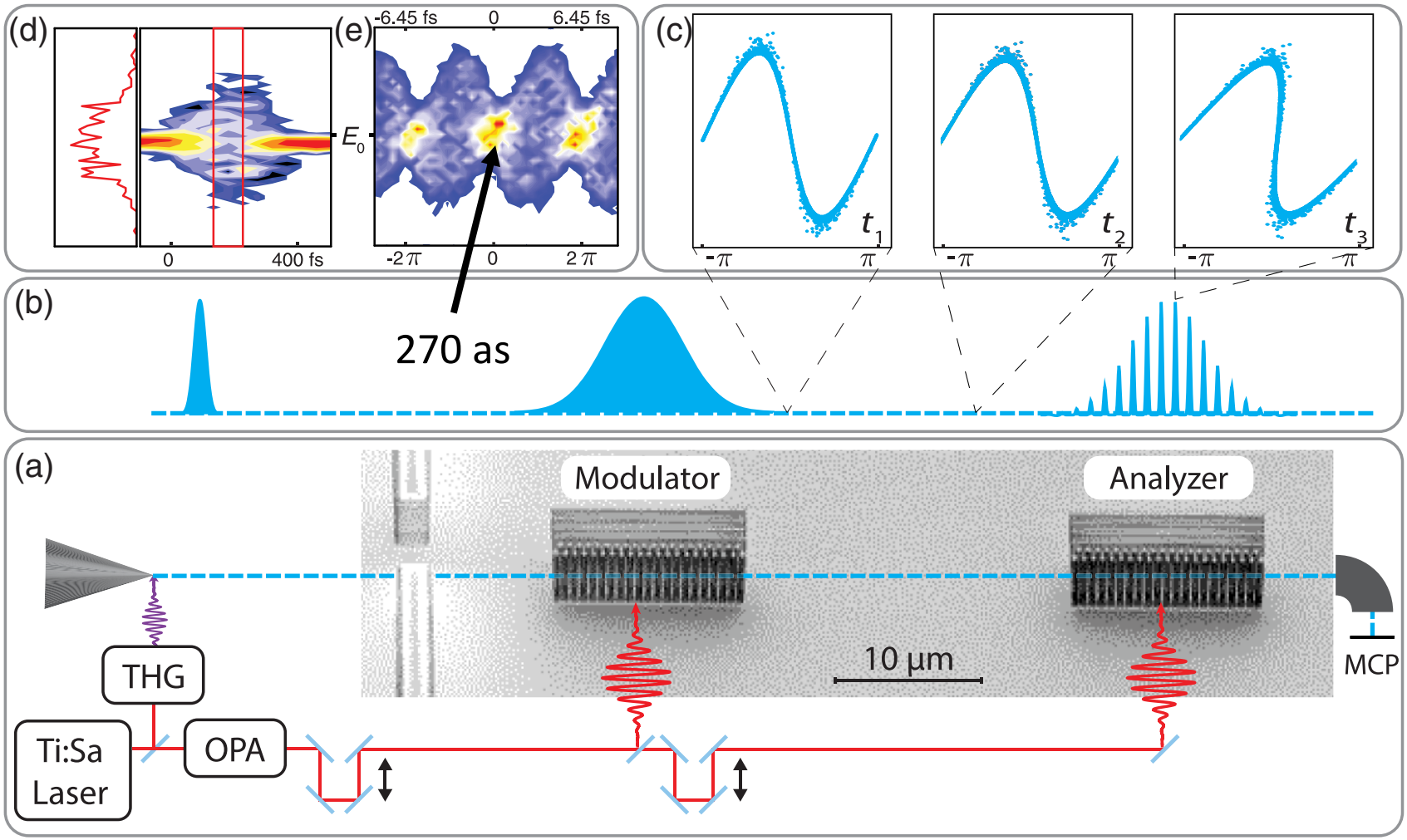


30 MV/m over 30 µm

Sapra *et al*, Science 367, 79-83 (2020)

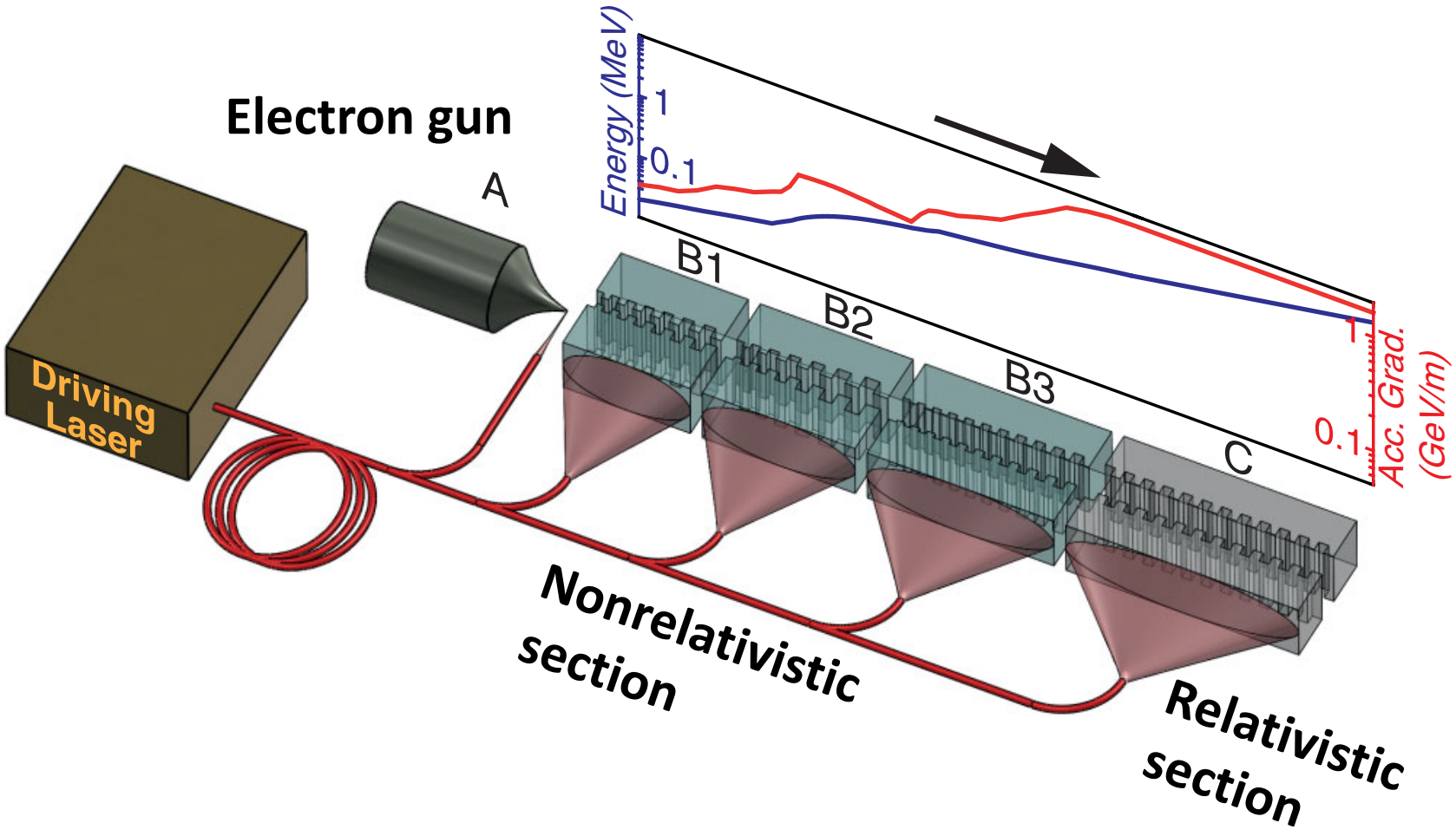
Attosecond electron pulses

In DLA, electron bunching within a fraction of the laser wavelength
-> Attosecond electron pulses!



Schönenberger *et al*, Phys Rev Lett 123, 264803 (2019)

Concept for an all-optical accelerator



Laser accelerator on a chip *in Lund* ?

Can the electron source be integrated with the accelerating structure?

Can the laser also be integrated on the chip?

Can one build structures for significant energy gain (MeV)?

Can one achieve small energy spread (%)?

Nanofabrication
Nanophotonics
Electron microscopy

Femtosecond lasers
Plasma acceleration
Attosecond science

Accelerator development (e- and p+)
Beam dynamics and Beam instrumentation
Accelerator facilities

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