Brief Overview of Wakefield Acceleration

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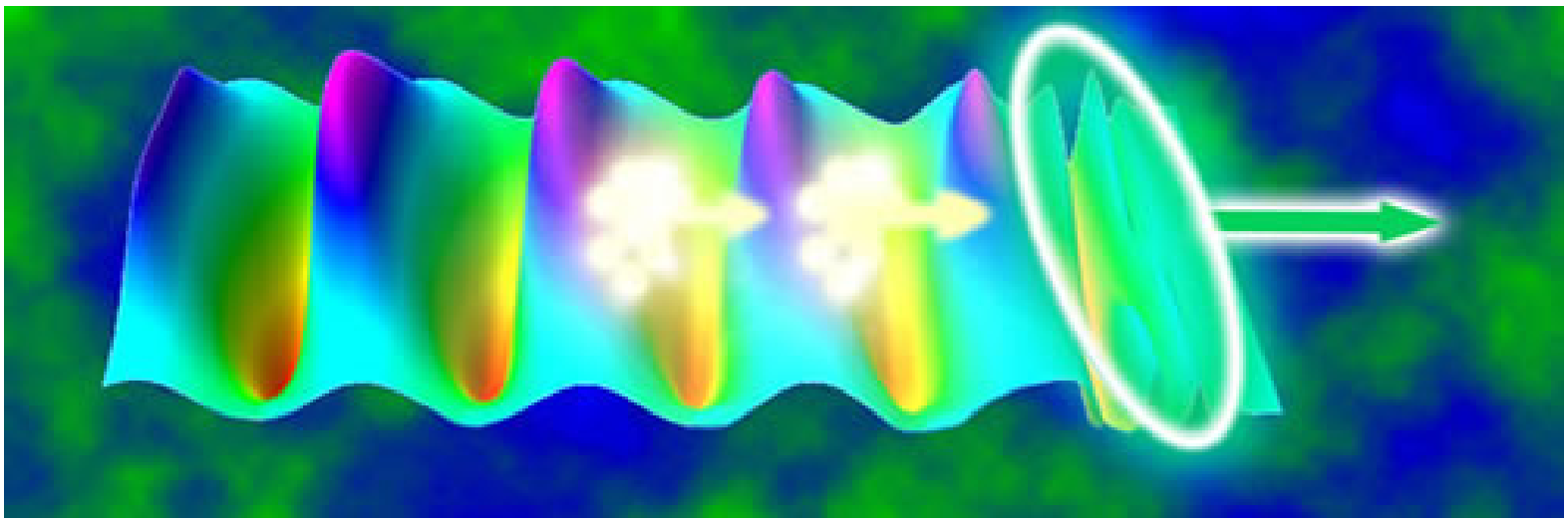
The Problem with Conventional Accelerators

Large Hadron Collider at CERN[5]

Wakefield Acceleration to the Rescue!

wakefield acceleration: the electric field of particle or laser beam sets up waves in a plasma, which trap and accelerate charged particles



Outline

In the beginning. . .

- 1978: Tajima and Dawson

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Laser Electron Accelerator

T. Tajima and J. M. Dawson
Department of Physics, University of California, Los Angeles, California 90024
(Received 9 March 1979)

An intense electromagnetic pulse can create a weak of plasma oscillations through the action of the nonlinear ponderomotive force. Electrons trapped in the wake can be accelerated to high energy. Existing glass lasers of power density 10^{18}W/cm^2 shone on plasmas of densities 10^{18} cm^{-3} can yield gigaelectronvolts of electron energy per centimeter of acceleration distance. This acceleration mechanism is demonstrated through computer simulation. Applications to accelerators and pulsers are examined.

- 1988: Rosenzweig et al first observes wakefield acceleration (plasma wakefield acceleration)

More recently. . .

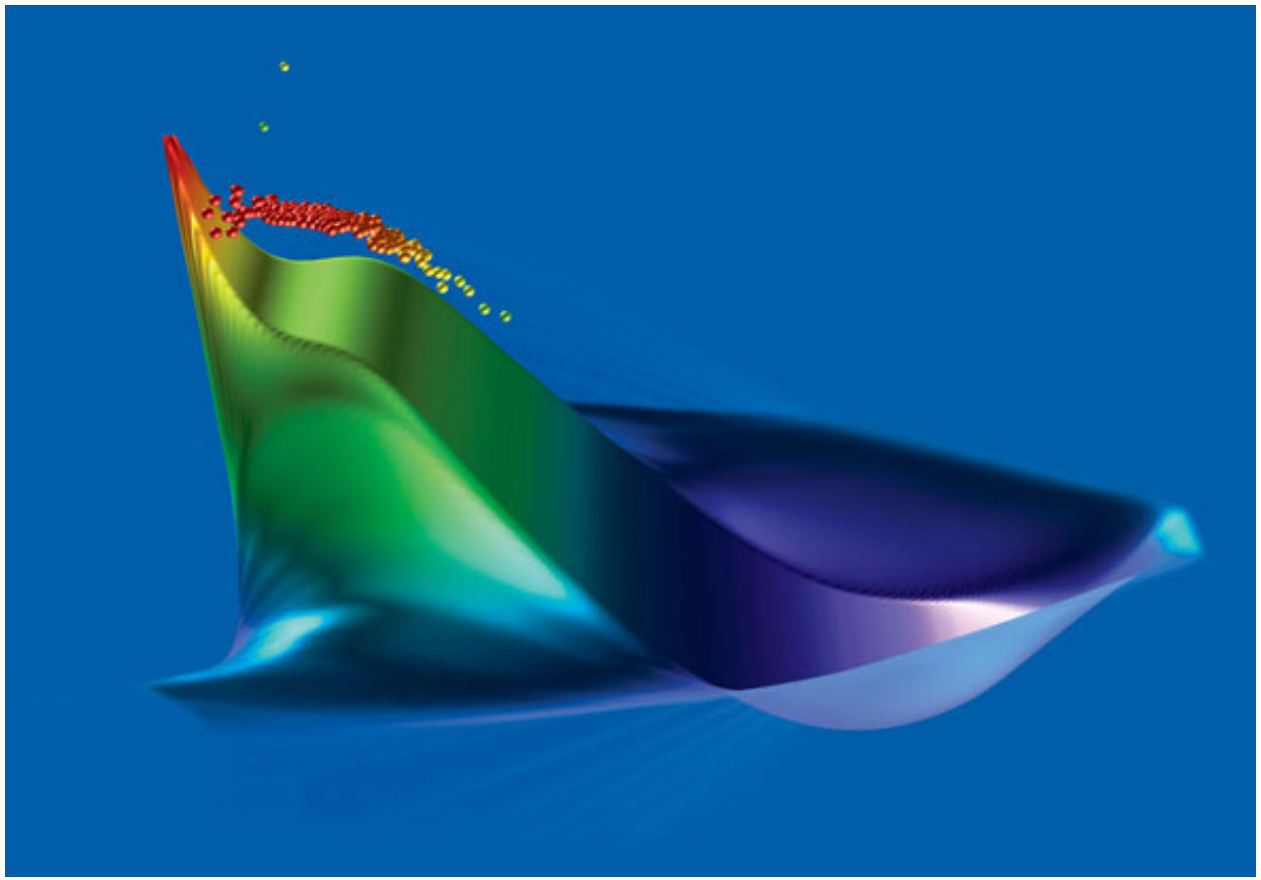
- 2006: *"GeV electron beams from a centimetre-scale accelerator"* Leemans et al.
  1 GeV electron beams from a 3.3 cm laser wakefield accelerator
- 2007: SLAC team achieved 45 GeV energy gain from an 85 cm plasma wakefield accelerator.

Types of Wakefield Acceleration

- PWA: plasma wakefield acceleration
- BWA: beat wave acceleration
- LWA: laser wakefield acceleration
- sm-LWA: self-modulated laser wakefield acceleration

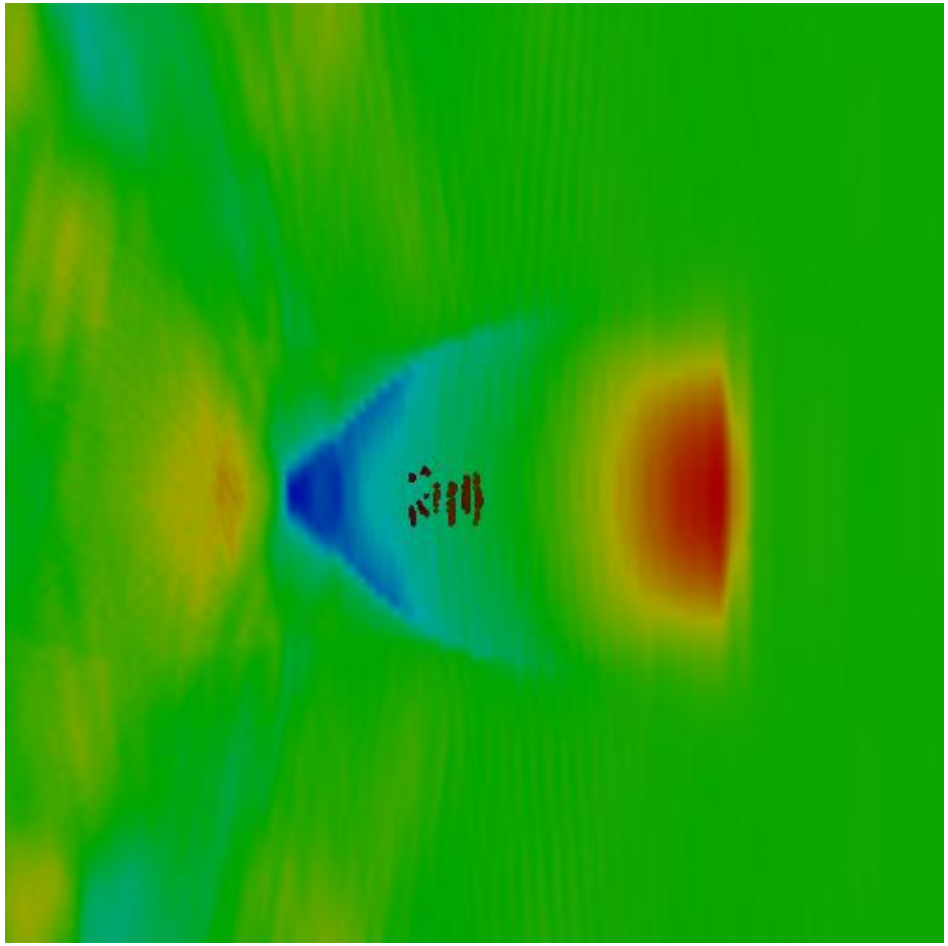
Introducing the Wakefield

Wakefield (simulation[4]):



Useful Equations[3]

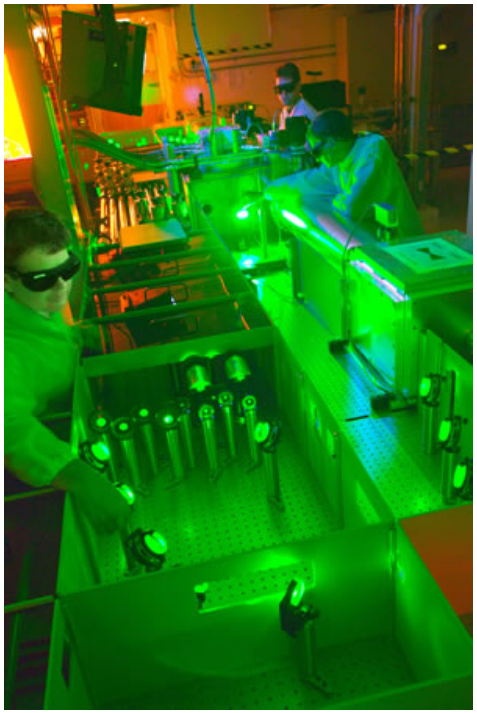
- Linear plasma wave: $E_0 = \frac{m_e \omega_p c}{e}$, $\omega_p = \sqrt{\frac{n_p e^2}{\epsilon_0 m_e}}$
- Normalized vector potential (laser): $a = \sqrt{\frac{e^2 \Omega_0 \lambda_L^2 I}{4\pi^2 (mc^2)^2}}$, $\Omega_0 = \sqrt{\frac{\mu_0}{\epsilon_0}}$
- LWA maximum wakefield amplitude: $\frac{E_{max}}{E_0} = \frac{a^2}{\sqrt{1+a^2}}$



Simulated (3D PIC) wakefield with electrons (NERSC Incite7: Plasma Wakefield Acceleration Visualization)

LOASIS: Lasers, Optical Accelerator Systems Integrated Studies

- BELLA: Berkeley Lab Laser Accelerator[2][4]
- technology: laser wakefield acceleration
- goal: 10 GeV in 80 cm (!)

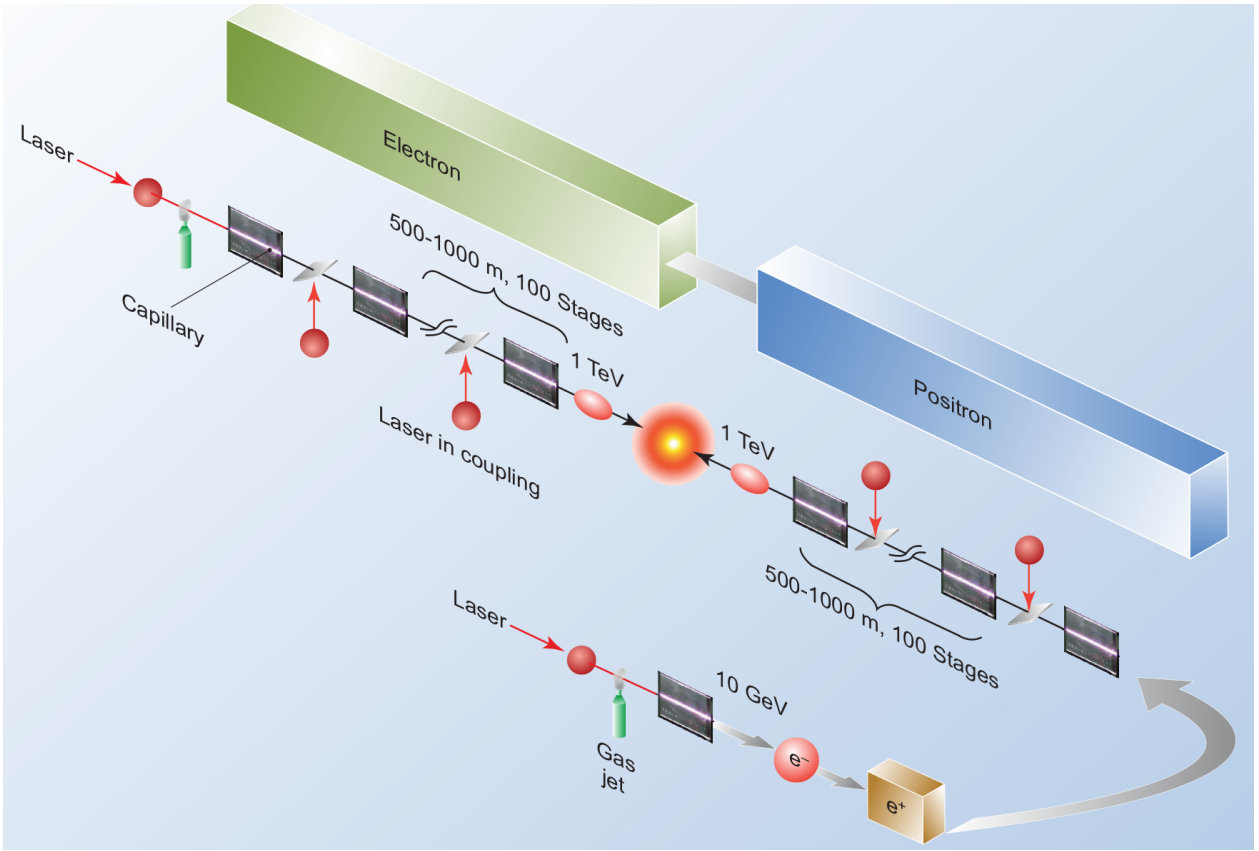


SLAC

- FACET: Facilities for Accelerator Science and Experimental Test Beams[4]
- technology: plasma wakefield acceleration (using electron beams)
- goal: 23 GeV $\rightarrow$ 46 GeV in 40 cm

Future Accelerators

To 1 TeV and beyond!



Schematic for 1 TeV linear collider[2]

References

- T. Tajima and J. M. Dawson, "Laser Electron Accelerator", Phys. Rev. Lett. 43, 267270 (1979).
- Lasers, Optical Accelerator Systems Integrated Studies (LOASIS), Lawrence Berkeley National Laboratory
- A. Ogata. "Status and Problems of Plasma Accelerators". *ICFA Beam Dynamics Newsletter*, No. 11, August 1996.
- "Crashing the Size Barrier", *Symmetry: dimensions of particle physics*, Vol. 6, Iss. 5, October 2009.
- CERN LHC image, http://est-div-lea-at.web.cern.ch/est-div-lea-at/atlas_lhcpicturesAERIAL.htm
- Wikipedia (http://en.wikipedia.org/wiki/Plasma_acceleration)