Brief Overview of Wakefield Acceleration

Eugene S. Evans\textsuperscript{1}

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\textsuperscript{1}University of California, Berkeley
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

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Brief Overview of Wakefield Acceleration
1. **History**

2. **Basic Theory**

3. **Research**
   - LOASIS/BELLA
   - FACET

4. **Future Accelerators**
In the beginning... 

- 1978: Tajima and Dawson

**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$^2$ shine 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 pulsed electron beams 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\textsuperscript{[4]}):

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Useful Equations\textsuperscript{[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): \( a = \sqrt{\frac{e^2 \Omega_0^2 I^2 L^2}{4 \pi^2 (mc^2)^2}}, \Omega_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \)
- LWA maximum wakefield amplitude: \( \frac{E_{\text{max}}}{E_0} = \frac{a^2}{\sqrt{1+a^2}} \)
Simulated (3D PIC) wakefield with electrons (NERSC Incite7: Plasma Wakefield Acceleration Visualization)
LOASIS: Lasers, Optical Accelerator Systems
Integrated Studies

- BELLA: Berkeley Lab Laser Accelerator\textsuperscript{2}\textsuperscript{4}
- technology: laser wakefield acceleration
- goal: 10 GeV in 80 cm (!)
SLAC

- technology: plasma wakefield acceleration (using electron beams)
- goal: 23 GeV $\rightarrow$ 46 GeV in 40 cm
To 1 TeV and beyond!

Schematic for 1 TeV linear collider[^2]
References


Lasers, Optical Accelerator Systems Integrated Studies (LOASIS), Lawrence Berkeley National Laboratory


Wikipedia (http://en.wikipedia.org/wiki/Plasma_acceleration)