Generation and characterization of attosecond micro-bunched electron pulse trains via dielectric laser acceleration

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Particle accelerators: from RF to optical/photonic drive?

|                  | Conventional linear accelerator (RF) |
|------------------|--------------------------------------|
| Based on         | (Supercond.) RF cavities              |
| Peak field limited by | **Surface breakdown:** 200 MV/m     |
| Max. achievable gradients | **100 MeV/m**                      |

RF cavity (TESLA, DESY)
### Particle accelerators: from RF to optical/photonic drive?

|                      | Conventional linear accelerator (RF) | Laser-based dielectric accelerator (optical) |
|----------------------|--------------------------------------|---------------------------------------------|
| Based on             | (Supercond.) RF cavities              | Silicon nano structures                     |
| Peak field limited by| Surface breakdown: 200 MV/m          | Damage threshold: 30 GV/m                   |
| Max. achievable gradients | 100 MeV/m                           | 10 GeV/m                                    |

**RF cavity (TESLA, DESY)**
Acceleration by phase-synchronous propagation

- $t = 0$
- $t = \pi/2$
- $t = \pi$

1. Acceleration
2. Deceleration
3. Deflection
4. Deflection
Setup

Ti:Sa laser → BS → THG → BS → OPA → FP filter → Attenuator → BS → ASL → MCP → Spectrometer
Dielectric Laser Acceleration

Incident field: 0.5 GV/m
Pulse duration: 650 fs

P. Yousefi et al., Optics Letters Vol. 44, Issue 6, pp. 1520-1523 (2019)
Dielectric Laser Acceleration

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Dielectric Laser Acceleration: Dynamics

![Graph showing energy and longitudinal position](image)

- Energy (keV): 27.7, 27.9, 27.5
- Longitudinal position (μm): 0, 0.31, 0.62
- Bunching
- Distance: 130 as
Streak camera

http://rasmus-ischebeck.de/media/Accelerator%20Physics/Drawings/PDFs/slides/Streak%20Camera.html
Streak camera

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Dielectric Laser Acceleration: Dynamics
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Experiment vs. Simulation

Electron density

Phase space

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Shortest bunches
Bunching

Minimal bunch length achievable ~125 as
Net acceleration
Net acceleration

buncher

strong acceleration
Net acceleration

buncher

strong acceleration

![Graph showing net acceleration over z (m)](image)
Measured net acceleration

- Relatively low energy gain due to large input energy spread into second structure
- Inclusion of demodulator would greatly increase acceptance
Phase-reset structure – towards a photonic LINAC
Keeping the beam together

Alternate between transverse focusing-longitudinal defocusing and transverse defocusing-longitudinal focusing

net focusing
Keeping the beam together

Alternate between transverse focusing-longitudinal defocusing and transverse defocusing-longitudinal focusing

net focusing
Keeping the beam together

*Alternate between transverse focusing-longitudinal defocusing and transverse defocusing-longitudinal focusing*

**net focusing**
Keeping the beam together

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**net focusing**

83 keV $\rightarrow$ >1 MeV:
56% transmission for 100pm, 93% for 25pm emittance

U. Niedermayer, T. Egenolf, O. Boine-Frankenheim, P. Hommelhoff, Phys. Rev. Lett. 121, 214801 (2018)
Thank you for your attention!