Photonic Crystal (PhC)-based Dielectric Laser Accelerator (DLA)

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(see also INFN position paper LoI #44)
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[LOI discussed also during September AF6 workshop: (https://indico.fnal.gov/event/45651/)
New Acceleration Concepts, Convener: Pietro Musumeci (UCLA)]

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Dielectric Laser Accelerators (DLAs)

We require:
1. an optical **Hollow-core** waveguide that is constructed out of **dielectric** materials,
2. transverse **size** on the order of a **wavelength** (~ 1-5 µm)
3. supports a **mode** with **speed-of-light phase velocity** (for electrons).

**laser-driven microstructures**
- **lasers**: high rep rates, strong field gradients, commercial support
- **dielectrics**: higher breakdown threshold \(\rightarrow\) **higher gradient** (1-10 GV/m) leverage industrial fabrication processes

**Goal**: lower cost, more compact, energy efficient, higher gradient

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• The first experimental demonstration (300 MeV/m) [E. Peralta et al., Nature, vol. 503, no. 7474, 91, 2013].


ACHIP design goals:
• Compact, chip-scale
• High gradient
• Modular accelerator components
• Robust fiber-based laser system
• Modest drive laser energy
• MHz rep rate

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**LoI Core Ideas:**

- **Hollow-core waveguides** for high power handling
- **High interaction impedance** $Z_c$ and accelerating gradient
- **Continuous wave (CW) laser operation** (1-5 µm)
- **Collinear co-propagating laser and beam**
- Sub-wavelength features for **sub-relativistic particles**
- Integrated **nano-proton-source** for proton-DLA

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**RFQ-like 2D Longitudinal PBG for tabletop proton-DLA**

**2D Longitudinal Photonic Crystal Directional Coupler**

**3D Silicon Woodpile mode launcher**

**3D woodpile mode converter side-coupler**

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Silicon woodpile waveguide
Fabrication & cold test at scaled mm-wave frequencies

• high speed and precision dicing saws
• silicon wafers 850 µm thick with resistivity > 3 kΩcm
• stacking together 9 silicon layers
• geometrical tolerance of 10 µm

 TEAM
- INFN-LNS, INFN-LNF, UniBs & UniCT: Accelerator design
- PoliMi, Politecnico di Milano: Laser Source
- INFN-LASA: beam dynamics
- C2N, CNRS, Université Paris-Saclay design & manufacturing

Simulated vs Experimental S-parameters

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THANK YOU!!

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