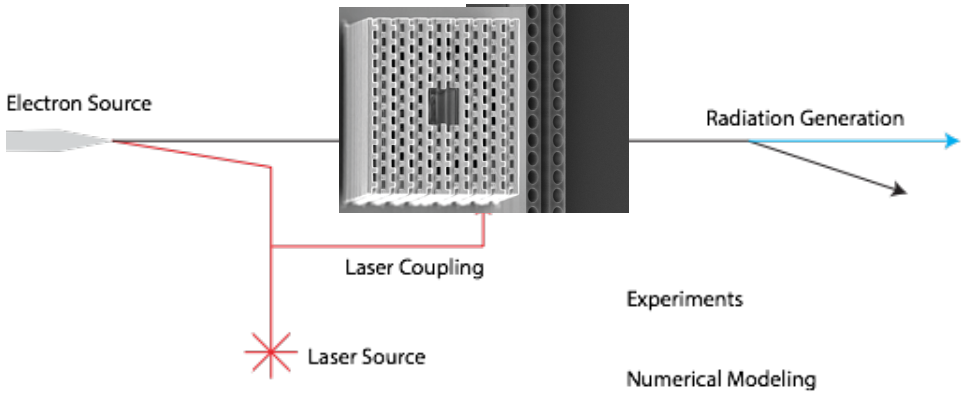
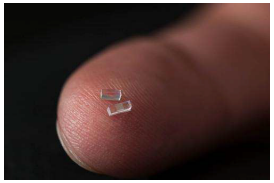
Photonic Crystal (PhC)-based Dielectric Laser Accelerator (DLA)





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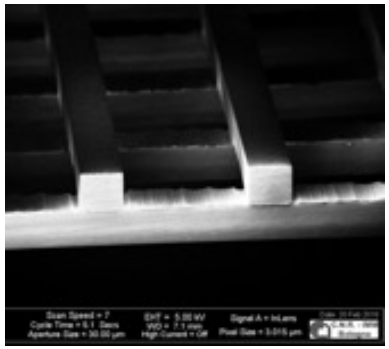
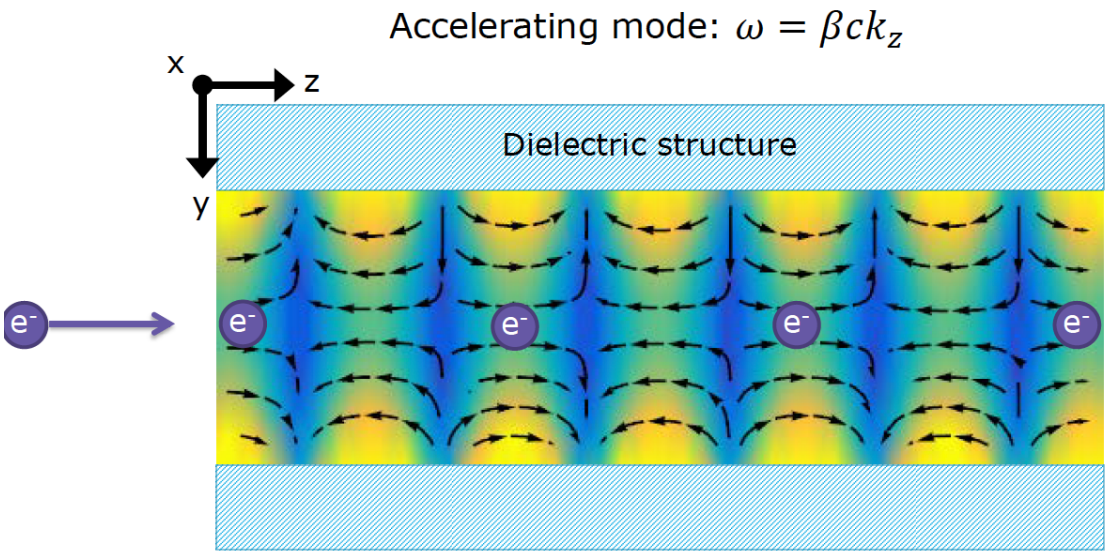


[LOI discussed also during September **AF6 workshop**: (https://indico.fnal.gov/event/45651/)
New Acceleration Concepts, **Convener**: Pietro Musumeci (UCLA)]

Dielectric Laser Accelerators (DLAs)

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

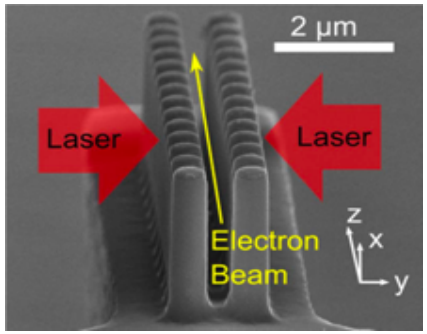


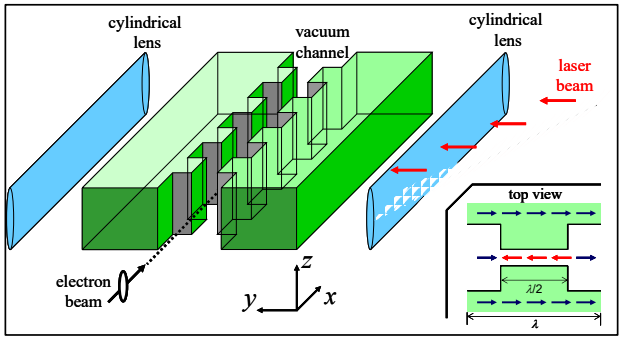
Goal: lower cost, more compact, energy efficient, higher gradient

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).**

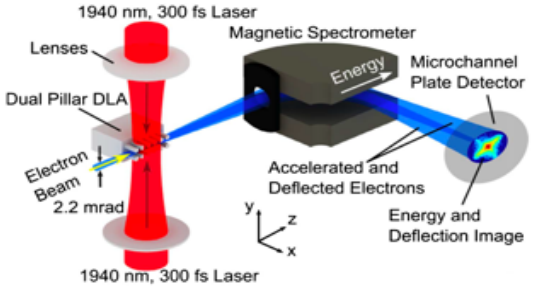
[New Acceleration Concepts.
"Dielectric Laser Acceleration", Joel England (SLAC)
Snowmass AF6 Meeting Sept 23, 2020]

"transverse-illuminated" ***Phase Reset Device***



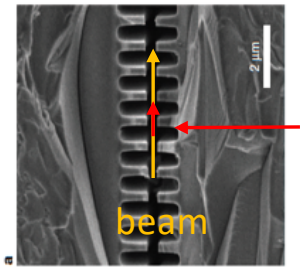


- [relativistic electrons energized by femtosecond laser pulses in silicon pillar and grating structures *[K. P. Wootton et al., Opt. Lett., vol. 41, no. 12, 2696, 2016]*, *[N. V. Sapra et al., Science, vol. 367, no. 6473, 79, 2020]*
- The first experimental demonstration (300 MeV/m) *[E. Peralta et al., Nature, vol. 503, no. 7474, 91, 2013].*
- Demonstrations of record accelerating gradients approaching the GV/m for sub relativistic [*K. J. Leedle et al., Optica, vol. 2, no. 2, 158, 2015*], *[J. Breuer et al., Phys. Rev. Lett., vol. 111, 134803, 2013]]*



ACHIP design goals:

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

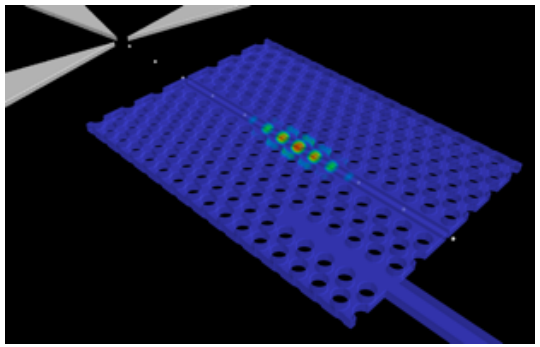


transverse-illuminated

↓

short interaction region

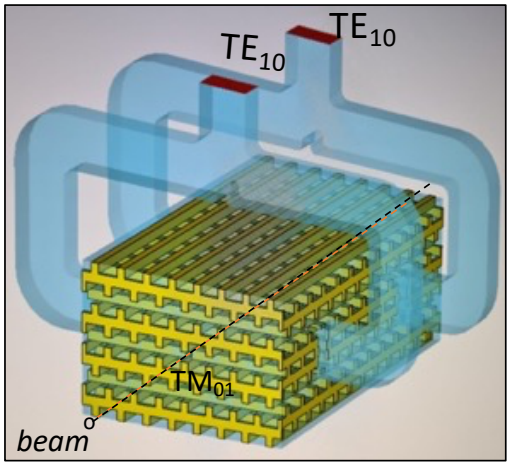
Photonic Crystal (PhC)-based Dielectric Laser Accelerator (DLA)



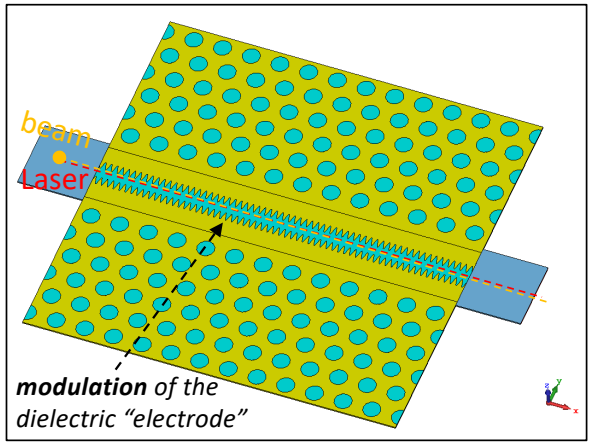
*DLA **high-Q photonic-crystal cavity***
[courtesy of C2N]

LoI Core Ideas:

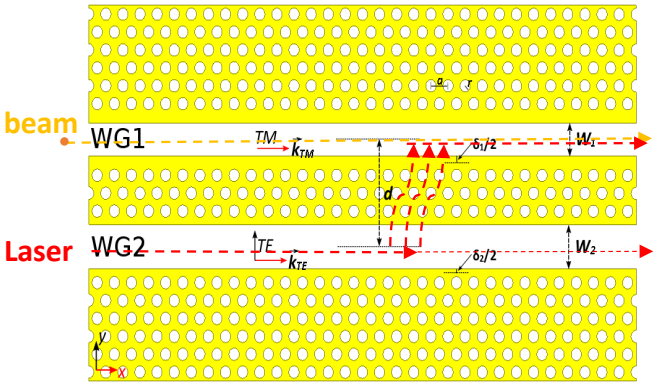
- **Hollow-core waveguides** for high power handling
- **High interaction impedance** Z_c and accelerating gradient
- **Continuous wave** (CW) laser operation (1-5 μm)
- **Collinear** co-propagating laser and beam
- Sub-wavelength features for **sub-relativistic particles**
- Integrated **nano-proton-source**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



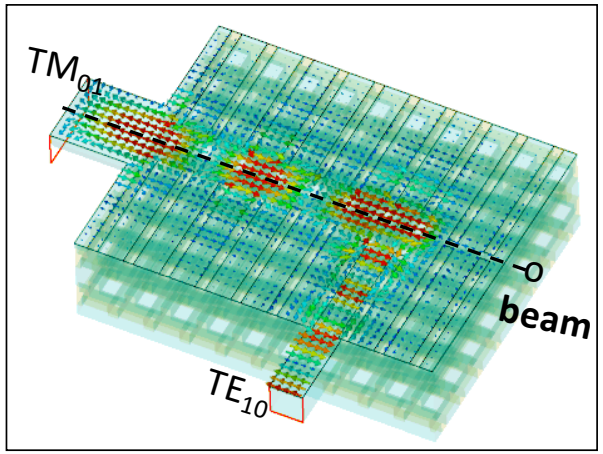
*3D Silicon **Woodpile mode launcher***



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



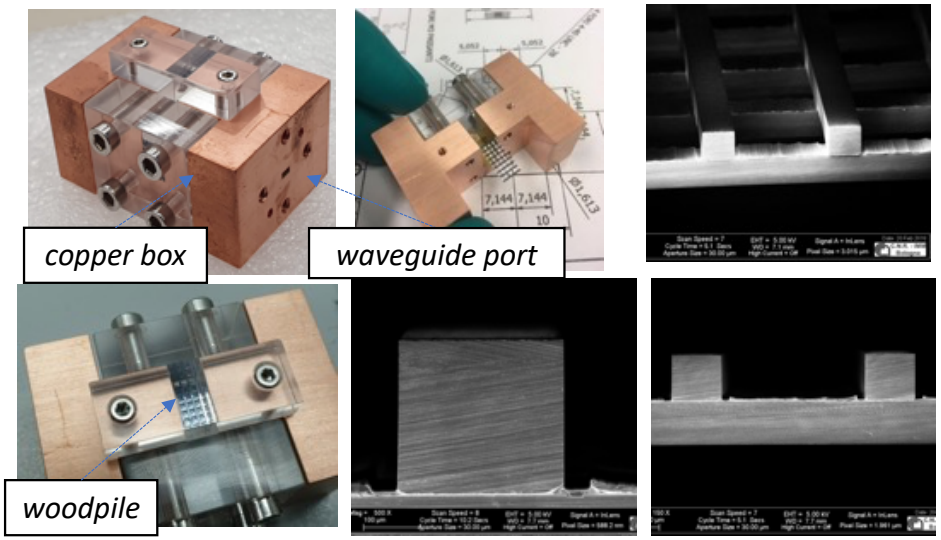
***2D** longitudinal Photonic Crystal*
Directional Coupler



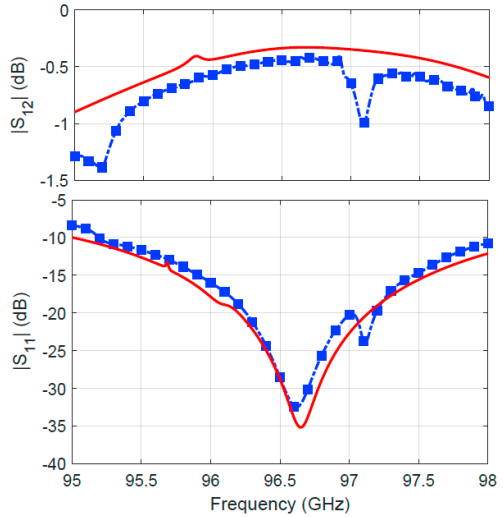
3D woodpile mode converter side-coupler

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**



Manufactured dielectric PhC woodpile structure



Simulated vs Experimental S-parameters

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

THANK YOU!!

LoI #142
(see also INFN position paper LoI #44)

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