COPROPAGATING SCHEMES FOR DIELECTRIC LASER ACCELERATORS (DLAS)

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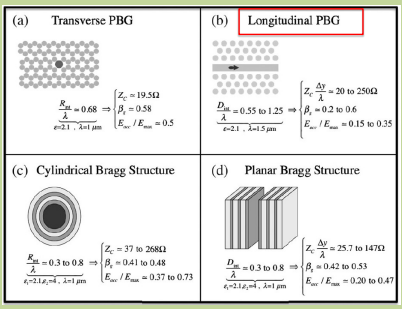
INTRODUCTION AND MOTIVATION

Dielectric Laser Accelerators (DLA)

- Dielectrics are characterized by larger damage threshold (multi-GV/m) with respect to metals.
- Reduction of cost and size.

Parameter	SLAC [Peralta 2013]	MPQ/FAU [Breuer 2013]	Stanford [Leedle 2015a]	FAU/Stanford [Kozak 2016]	SLAC [Wootton 2016]
Material	Fused Silica	Fused Silica	Silicon	Silicon	Fused Silica
Incident Beam Energy	60 MeV	28 keV	96.3 keV	28 keV	60 MeV
Particle Velocity (v/c)	0.9996	0.32	0.54	0.32	0.9996
Laser Wavelength	800 nm	790 nm	907 nm	1800 nm	800 nm
Laser Repetition Rate	10 Hz	2.7 MHz	76 MHz	100 kHz	10 Hz
Laser Pulse Energy	330 μJ	160 nJ	5.2 nJ	50 nJ	128 μJ
Pulse Duration	1.24 ps	110 fs	130 fs	20 fs	64 fs
Interaction Length	450 μm	11 μm	5.6 μm	1.8 μm	16.3 μm
Max. Energy Gain	120 keV	275 eV	2.05 keV	0.3 keV	24 keV
Max.Gradient	310 MeV/m	25 MeV/m	370 MeV/m	210 MeV/m	690 MeV/m

DLA Experimental Results



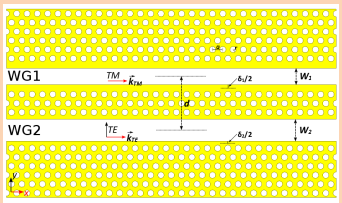
PC DLAs geometries: [R.J. England et al., *Dielectric laser accelerators*, Rev. Mod. Phys., 2014]

Photonic crystal (PC) based accelerators:

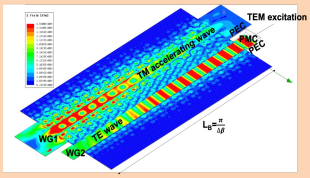
- Dielectric structures with advanced light manipulation capabilities.
- Hollow-core guiding with strong field confinement.
- Phase velocity control for synchronous acceleration.
- High intensity of the accelerating (longitudinal) field.
- Group velocity and timing control large Interaction length.
- Suppression of higher-order modes.

NUMERICAL RESULTS

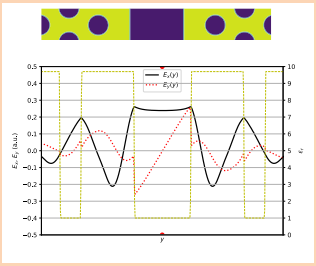
2D PHOTONIC CRYSTAL MODE



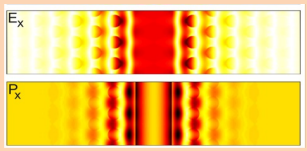
Geometry of a 2D PHc coupler 1. Here r = 0.3a and a = 6.6 mm.



CST MWS simulated Electric field intensity distribution

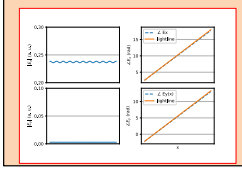


Electric fields components Ex and Ey and refractive index r at x = 0 (top graph).



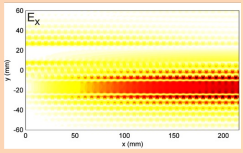
The accelerating mode E_x:

- is a surface mode: transverse field E_y and longitudinal Poynting vector P_x are confined at the PC - air interface;
- is rather intense and uniform along the air channel where light and particles travel in a synchronous fashion.

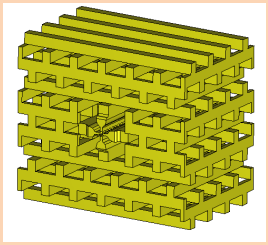


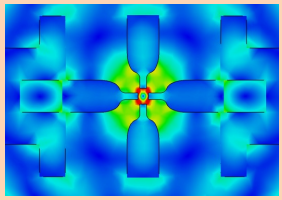
Figures of merit of the designed PC accelerator:

$$Z_c = 1.39\ \Omega$$
$$f_D = 1/1.39$$
$$Z = 10.22\ M\Omega/m$$

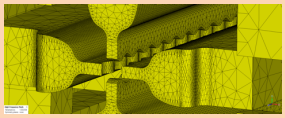


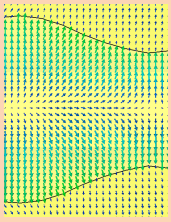
3D WOODPILE RFQ

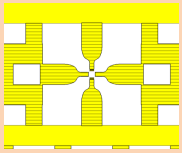


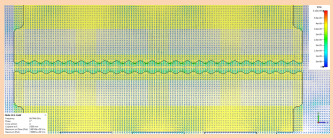


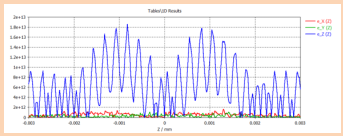
- Mode frequency = 59.7475 THz
- β = 0.05
- β λ = 0.2 μm



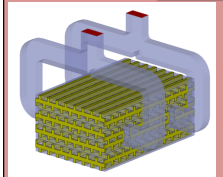


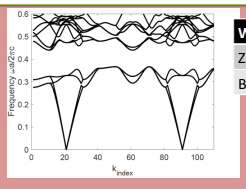






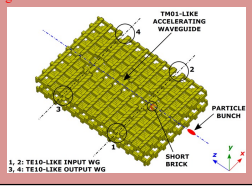
3D HOLLOW-CORE WOODPILE COUPLER





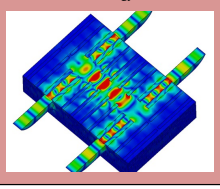
Woodpile	Slotted waveguide
Zc = 11.4 kΩ	Zc=1.5 kΩ
Beta = 1	0.4<Beta<0.75

- Wave is injected (and extracted) into the woodpile coupler by using two waveguide **splitters** (or optical fibers at optical frequencies).
- The bunch of particles is accelerated by the travelling wave along the hollow-core accelerating waveguide.

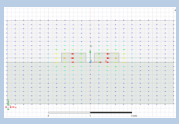


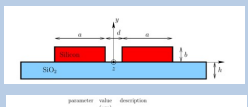
- The side-coupler consists of:

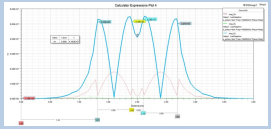
1. a **right-angled bend mode converter,** from **TE10-like launch mode** to **TM01-like mode** suitable **for particle acceleration;**
2. an **accelerating waveguide** whose length can be tuned in order to obtain the final energy.

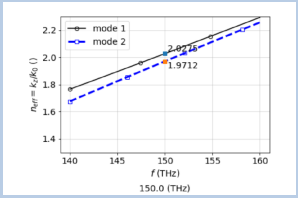


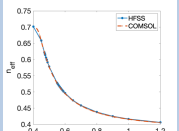
3D SLOTTED WAVEGUIDE











Simulators	$n_{eff,mode1}$	$n_{eff,mode2}$
COMSOL	2.04	1.99
HFSS	2.0275	1.9712
MATLAB(Full vector)	2.155726	2.106516

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