Fibre Laser Based Dielectric Gratings Accelerator

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Abstract

Dielectric laser accelerators (DLA) have great potential for applications, since they can generate acceleration gradients in the range of GeV/m and produce attosecond electron bunches. We numerically investigated the optimum structure dimensions of a dual-gratings accelerator structure made of silicon, the standard material for photolithography fabrication process. We analytically estimated the laser requirements and propose a suitable power source. Finally, we proposed a new scheme for better beam confinement.

Acceleration mechanism

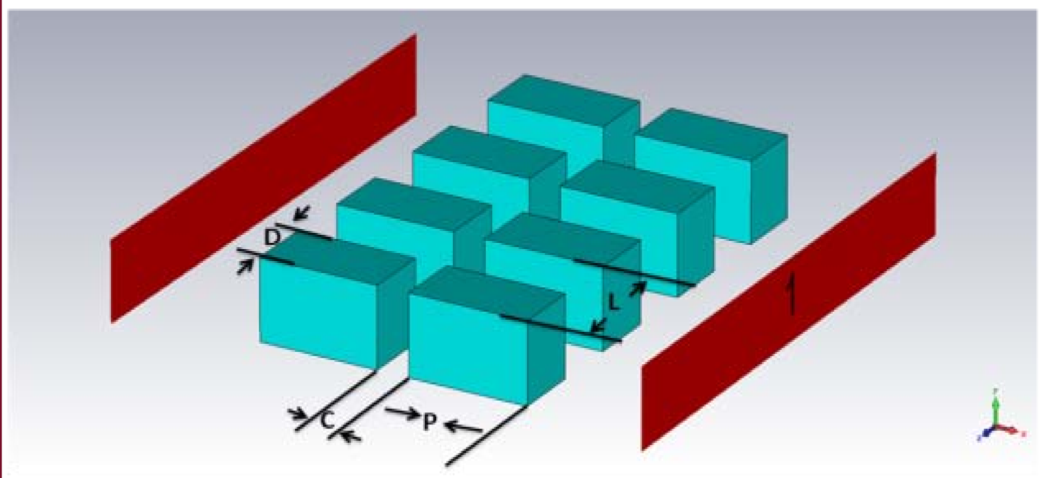
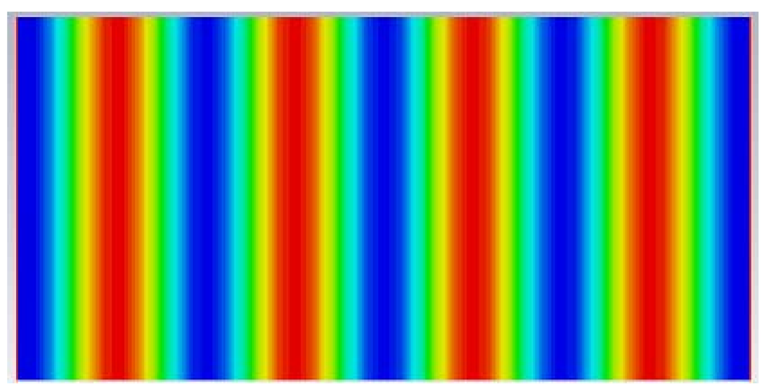
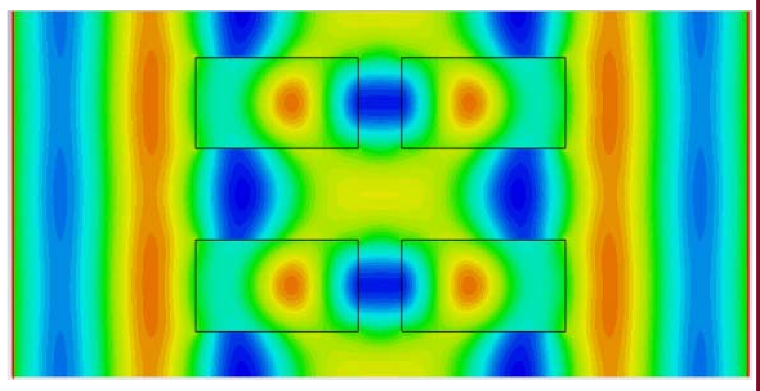


Illustration of dual-gratings structure.

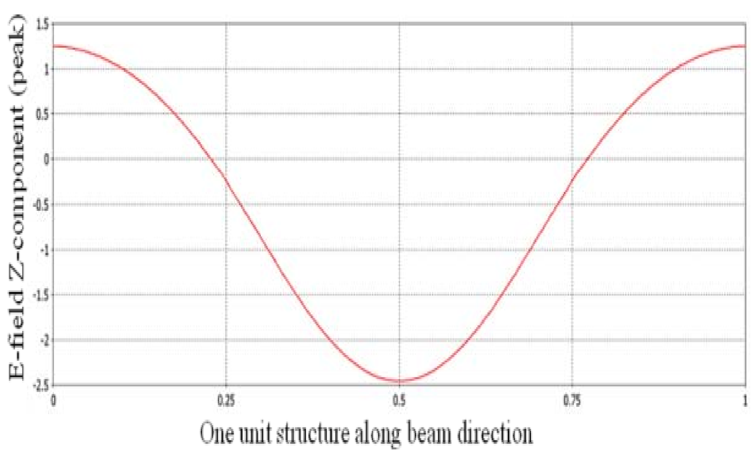
The basic working principle of dual-grating structures is based on decreasing the phase velocity of the electric field, thereby synchronizing it with non-relativistic and relativistic electrons [1].



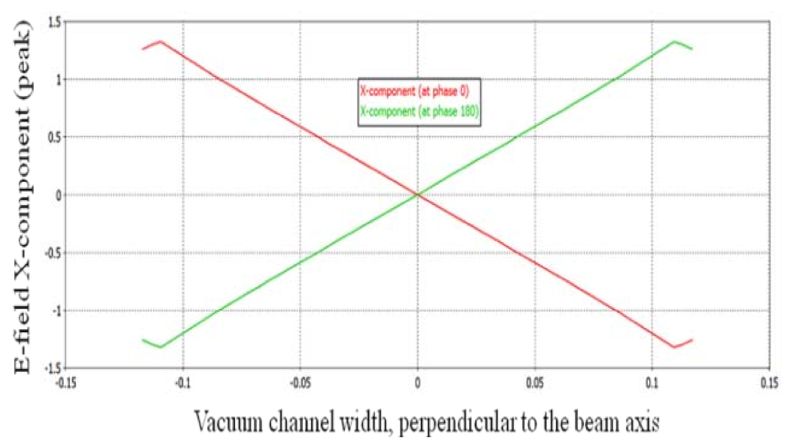
Laser field in vacuum



Simulated laser field in structure



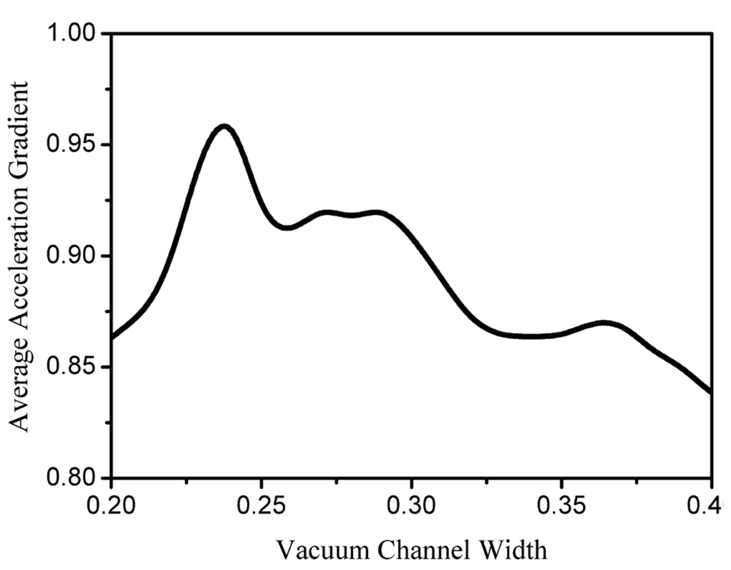
Z-component of the electric field (peak) distribution.



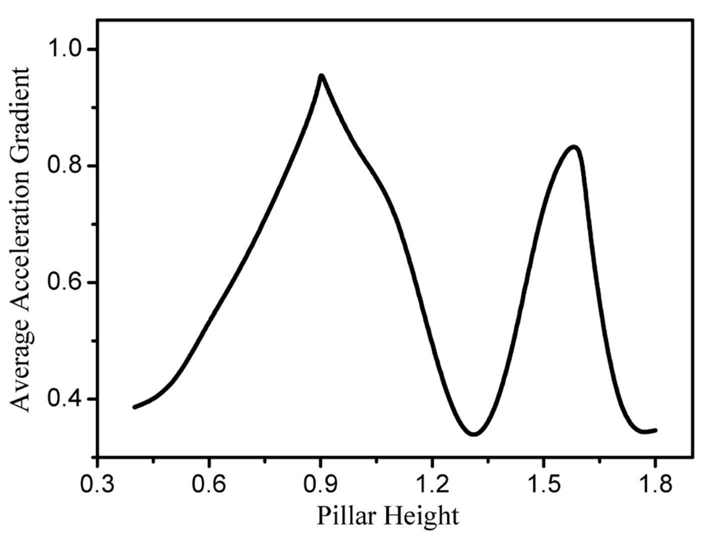
x-component of the electric field (peak) distribution

Optimized structure dimensions

We have determined the acceleration field gradient by particle track simulation using CST PATICLE STUDIO.



Optimum vacuum channel width



Optimum pillar height

References

[1] T. Plettner, P. P. Lu, and R. L. Byer, Phys. Rev. ST Accel. Beams 9, 111301 (2006)
[2] B. C. Stuart, M. D. Feit, S. Herman, A. M. Rubenchik, B.W. Shore, and M. D. Perry, J. Opt. Soc. Am. B **13,** 459 (1996)

Proposed new structure for better beam confinement

When electrons travel along the channel, the space charge effect scatters the beam. The charges collected on the wall then provide a Coulomb force on the beam which pushes the charges back to the axis. Field distributions calculated by CST Microwave Studio.

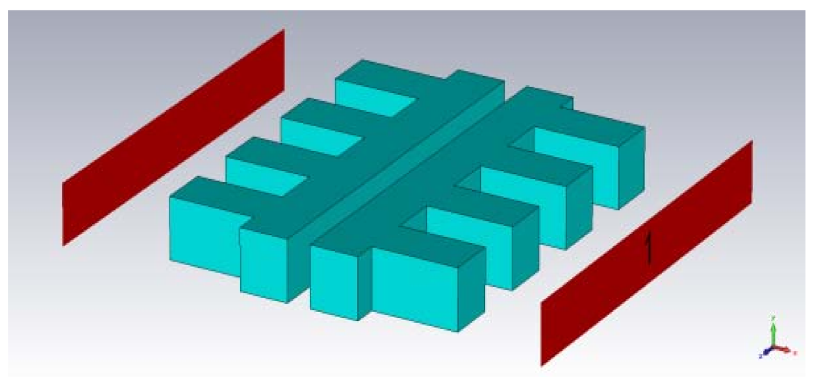
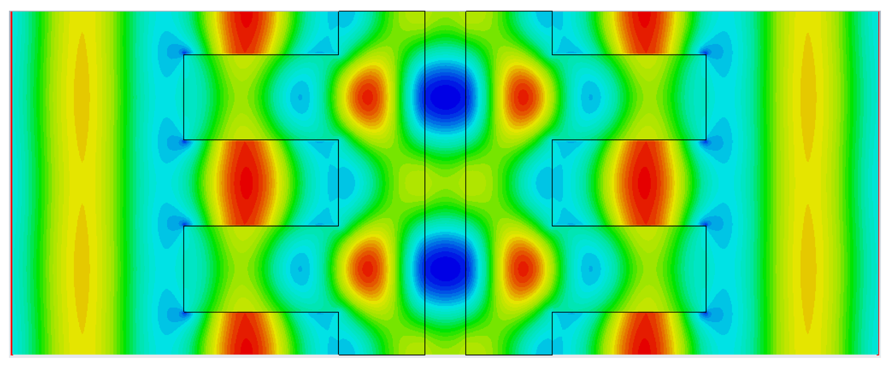
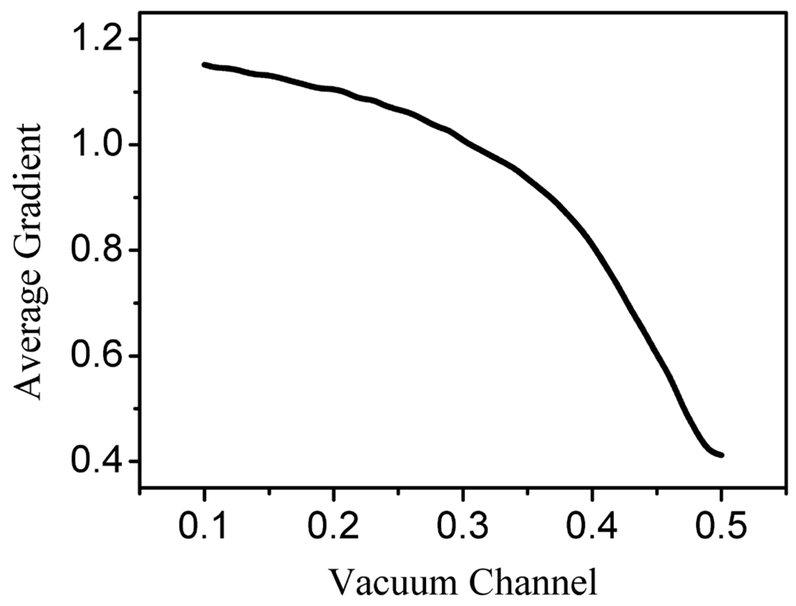


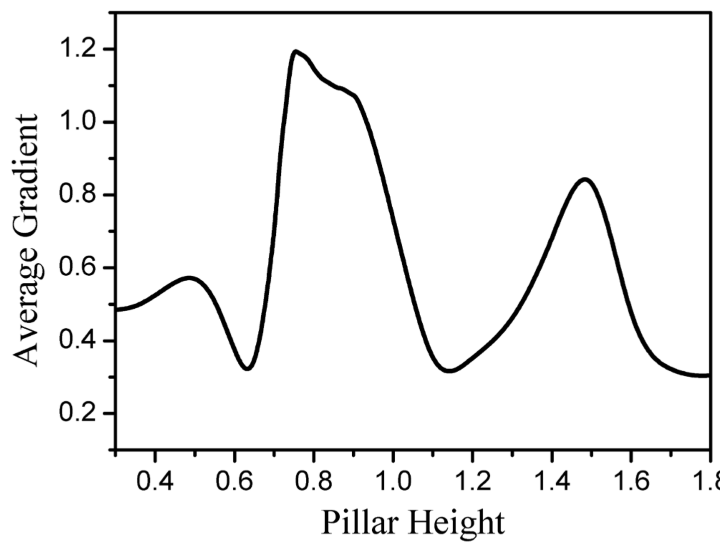
Illustration of dual-gratings structure with walls.



Simulated laser field in structure



Optimum vacuum channel width; For this simulation, wall thickness and pillar height are chosen 0.5 and 0.9 laser wavelength, respectively



Optimum pillar height ; For this simulation, wall thickness and vacuum channel width are chosen 0.5 and 0.24 laser wavelength, respectively

Laser parameters

Laser requirements to get 30 MeV energy (1cm long structure, laser and electron bunch coupling efficiency is assumed 100%):

Pulse energy: 20 μJ;
Average power: 2.0 kW;
Pulse width: 100 fs;
Repetition rate: 100 MHz.

Acceleration gradient is **3.0 GeV/m** for an unloaded field of 9.8 GV/m.

Damage threshold value is 2 J/cm^2 [2].

Future prospects and challenges

(1) Accelerate low energy electrons:
Note minimum requirement for particle beam's initial energy.
(2) Multi-stage acceleration scheme:
Design of entire structure is under investigation.
(3) Beam loading:
Focus and inject particles in hundreds-nm-wide vacuum cavity is a future challenge.
(4) Code benchmarking
Compare CST output with results from Tech-X Vorpal code.

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