Design of Laser Driven Dielectric Accelerator for Basic Radiation Biology Researches

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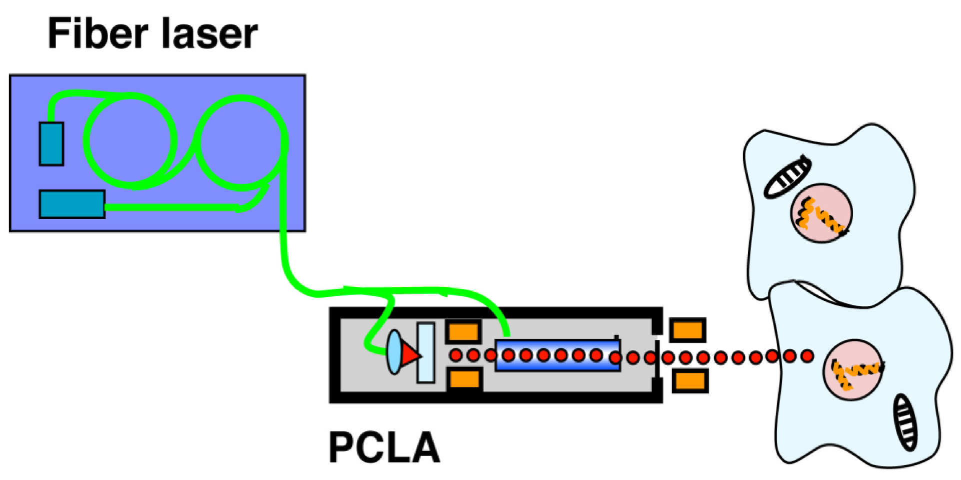
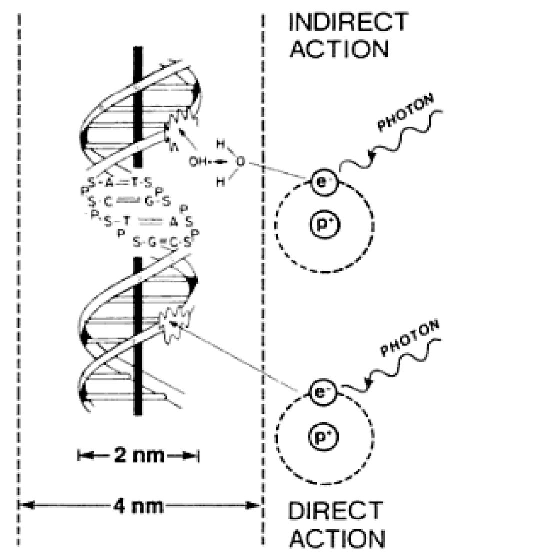
Motivation and objectives

- In order to investigate fundamental processes of radiation effect and evaluate risks of manifestation of secondary cancer after the radiation therapy, well defined ultra-short beam pulses are required.
- Beams can be manipulated under optical microscopes.
  - Electron bunch or X-ray pulse
  - Several hundreds keV
  - Sub-micron, sub-femtosecond





Direct and indirect DNA damage

Acceleration mechanism

No net energy gain in vacuum using optical fields [1]. Optic micro cavity in structure based laser accelerators prevents the infinite interaction region and no wall or boundaries present conditions.

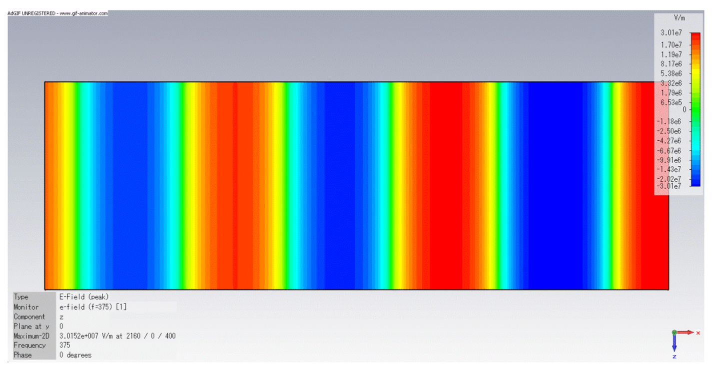


Figure 1. Laser field in vacuum

Dual gratings are used to synchronize phase velocity to the relativistic particle speed [2]. Structure material is quarters; refractive index is n=2.36; laser wavelength is 800 nm.

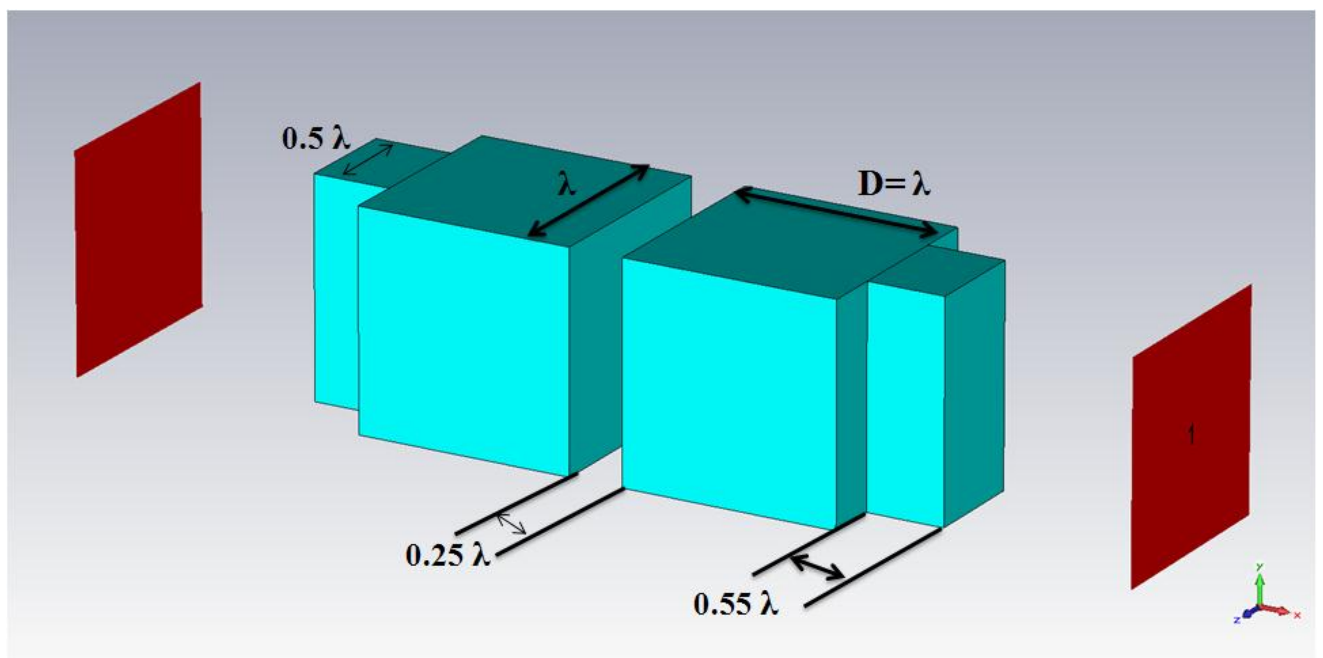


Figure 2. Structure dimensions; λ the wavelength of operating laser, driving laser lights are fed from the two outer surfaces (the red surfaces), electrons move in the vacuum channel perpendicular to the laser traveling direction.

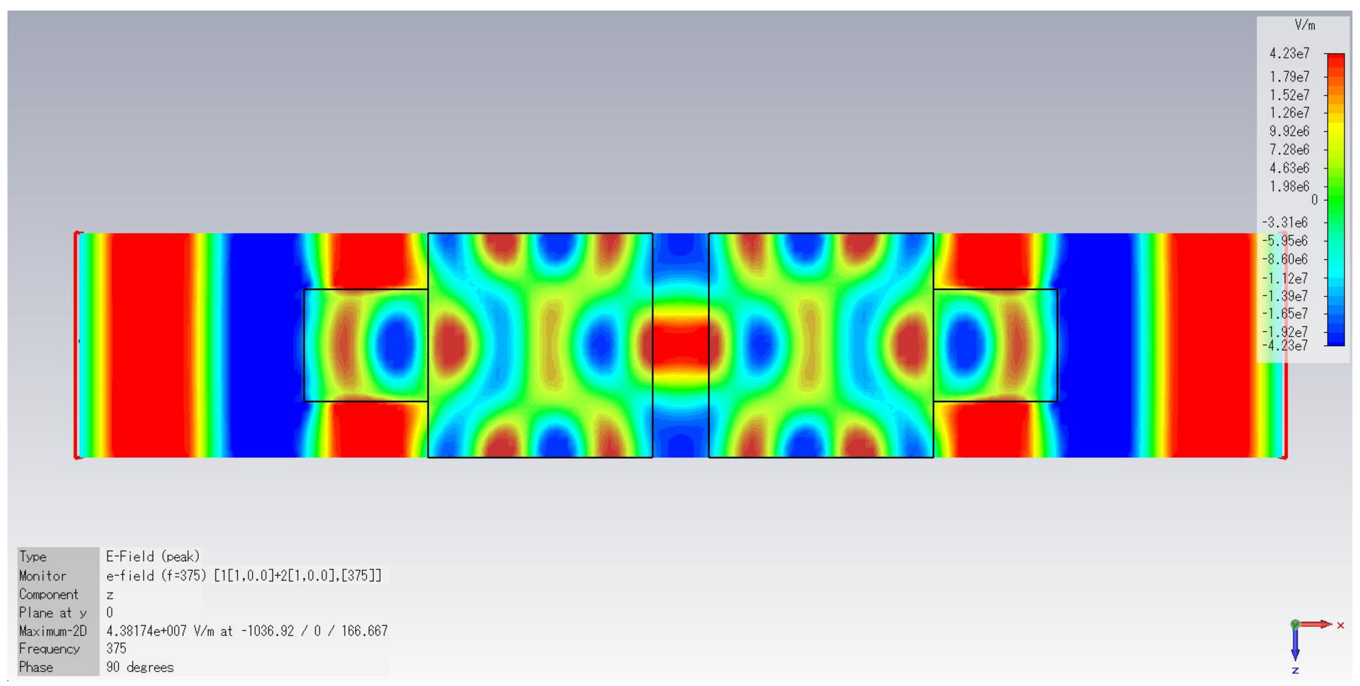


Figure 3. E-field (peak) Z component distribution

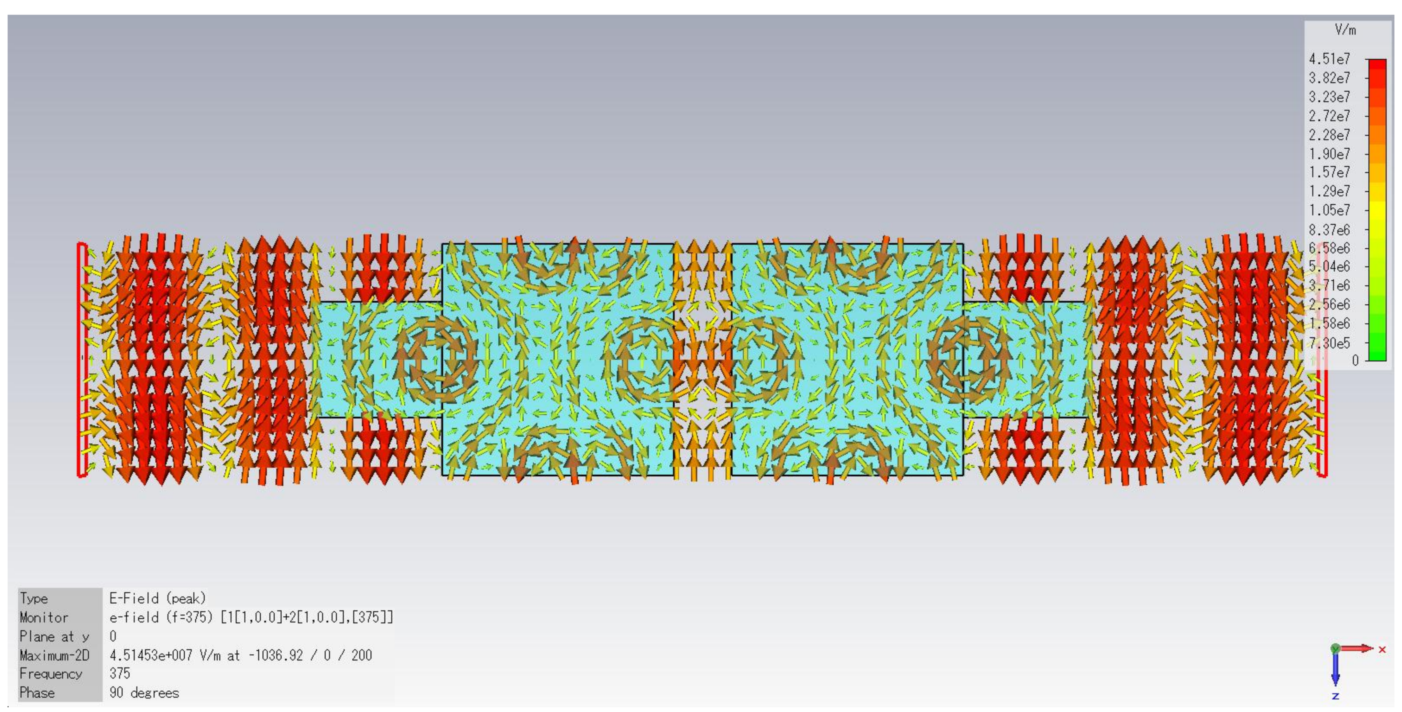


Figure 4. Vector view of E-field distribution

Structure optimum parameters and laser requirements

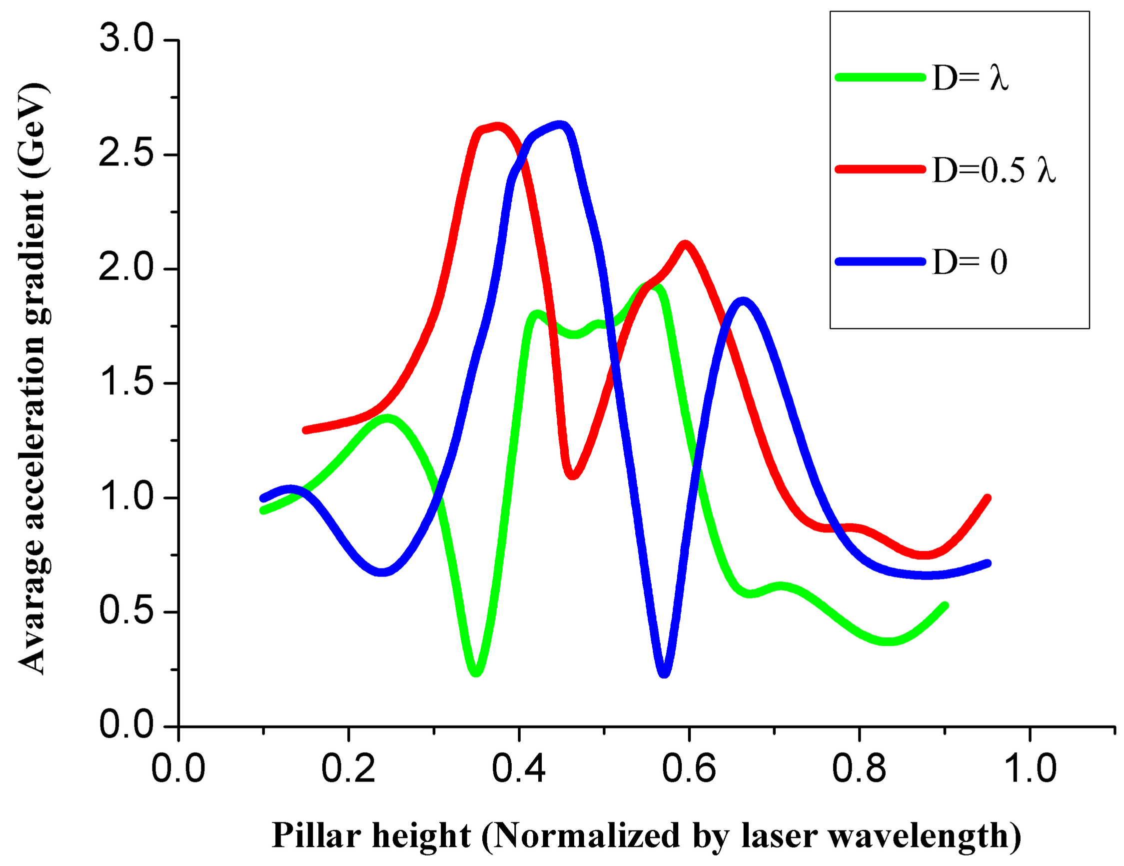


Figure 5. Average acceleration gradient; different color represents different thickness of channel wall; the transverse width of the vacuum channel is a quarter laser wavelength for all three cases.

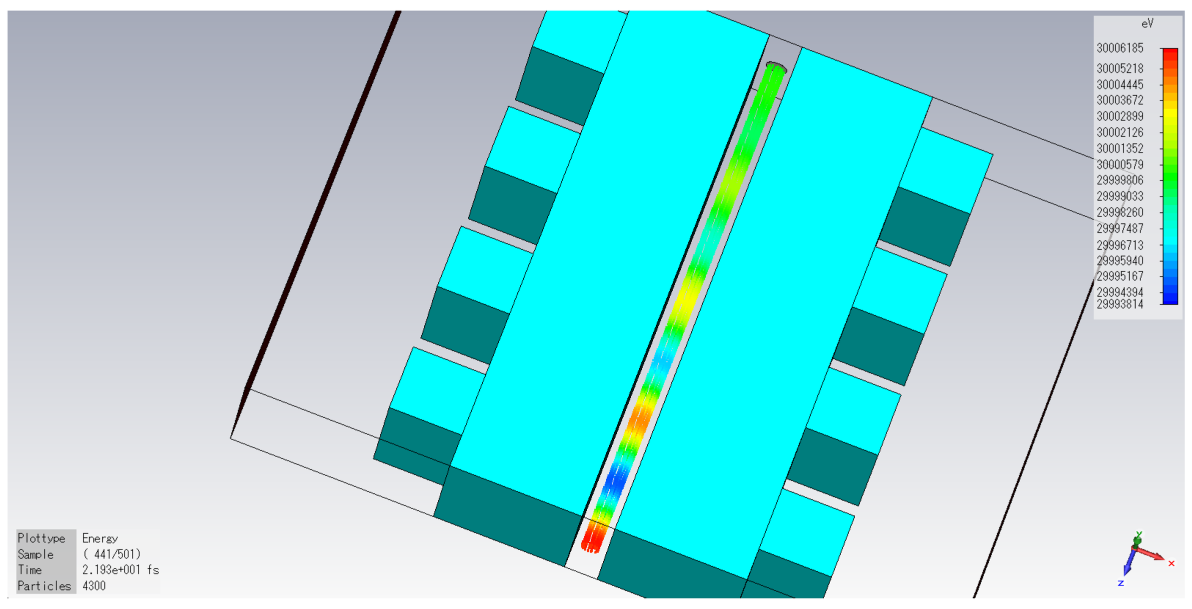


Figure 6. Particle track simulation. Initial particle energy is 30 MeV. Beam diameter is 128 nm, current is 50 mA.

Acceleration gradient is **2.5 GeV/m** for an unloaded field 7.9 GV/m. Damage threshold value is 2 J/cm^2 [3].

Laser requirements to get 25 MeV energy (1 cm long and 800nm wide structure):

Pulse energy: 15 μJ;
Average power: 1.5 kW;
Pulse width: 100 fs;
Repetition rate: 100 MHz.

Future prospects and challenges

(1) Accelerate low energy electrons;
There is a minimum requirement for particle 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 tough work.

References

[1] J.D. Lawson, IEEE Trans. Nucl. Sci. NS-26, 4217 (1979)
[2] T. Plettner, P. P. Lu, and R. L. Byer, Phys. Rev. ST Accel. Beams 9, 111301 (2006)
[3] 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)

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