Enhanced γ-ray emission by using counter-propagating laser beams irradiating solid target

YUAN ZHAO

Supervisor: Guoxing Xia

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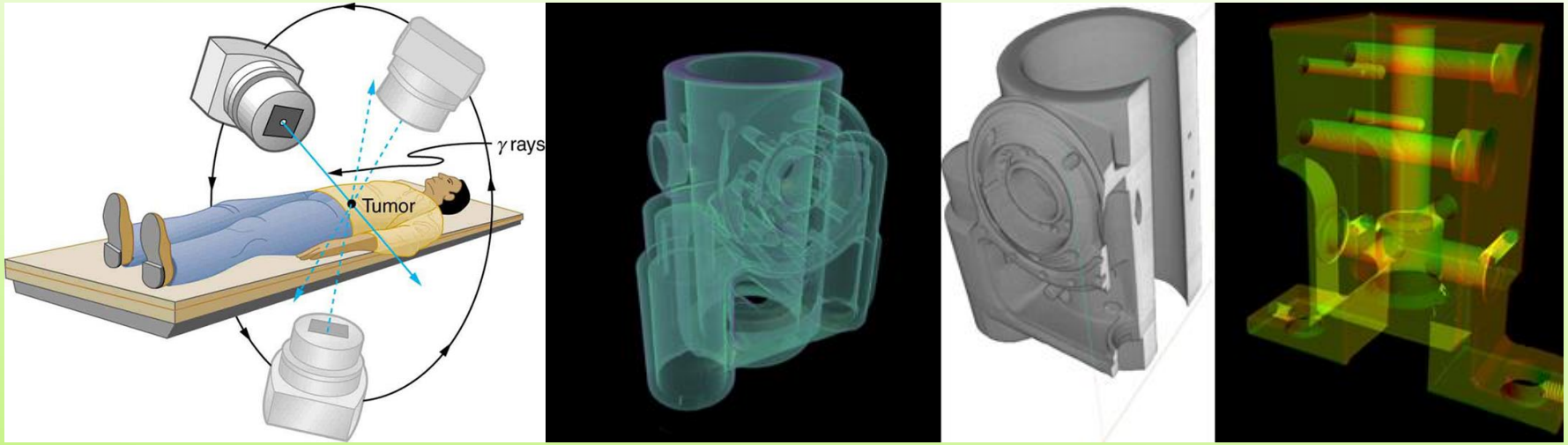
Outline

- Background of γ-ray sources
  - Applications
  - γ-ray sources based on laser-plasma interaction
- Simulation results
- Summary

▸ Applications : imaging



Denser matter⇒ higher energy and higher brightness

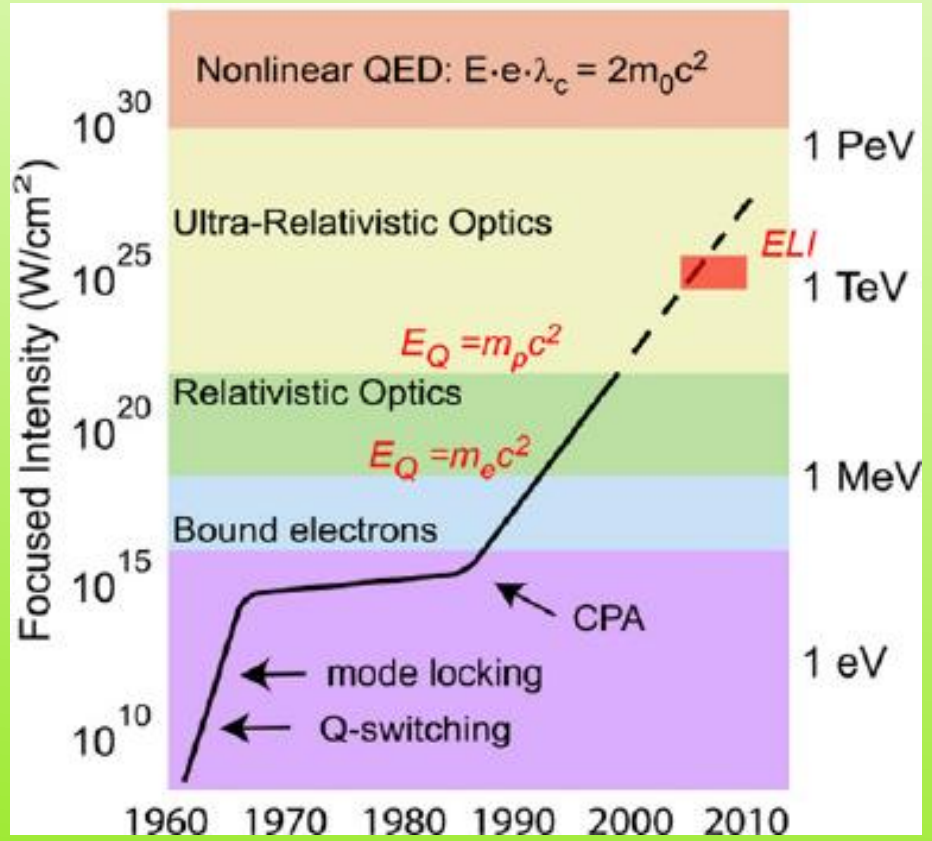
Ultrafast phenomenon ⇒ increasing resolution and shorter pulse duration

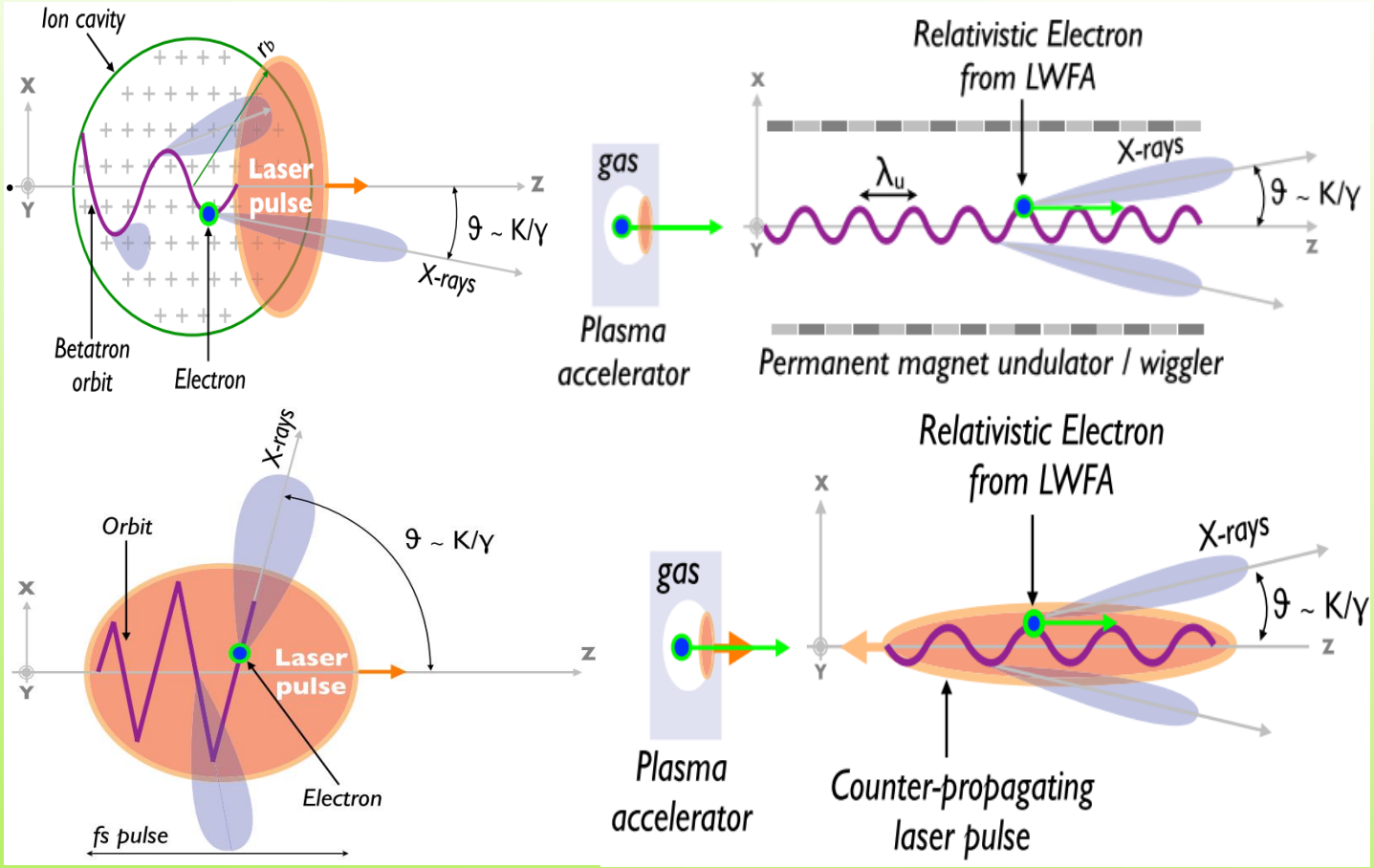
- **Conventional γ-ray sources**

Radioactive sources, and Compton scattering source based on conventional accelerator.

- **Novel γ-ray sources**

Produced by laser-plasma interaction (LPI).





Hwang S W, Lee H J. Journal of the Optical Society of Korea. 2009, 13(1):86-91.
S. Corde, et, al., Reviews of Modern Physics, 85 (2013) 1-48.

In quantum electrodynamics regimes

nonlinear Compton scattering

$a_0 \ll 1$ linear single photon absorbed

$a_0 \gg 1$ nonlinear multiple photon absorbed

Lower energy photons from laser

$e^- + m\omega_l \rightarrow e^- + \omega_\gamma$

relativistic electrons

- LWFA
- RPA
- PA

Electrons ~GeV
γ-ray range

$$\eta = \frac{e\hbar}{m_e^3 c^4}\left|F_{\mu\nu}p^\upsilon\right| \approx \frac{\gamma}{E_s}\left|\overrightarrow{E_\perp} + \vec{v}\times\vec{B}\right|$$

Possibility: η

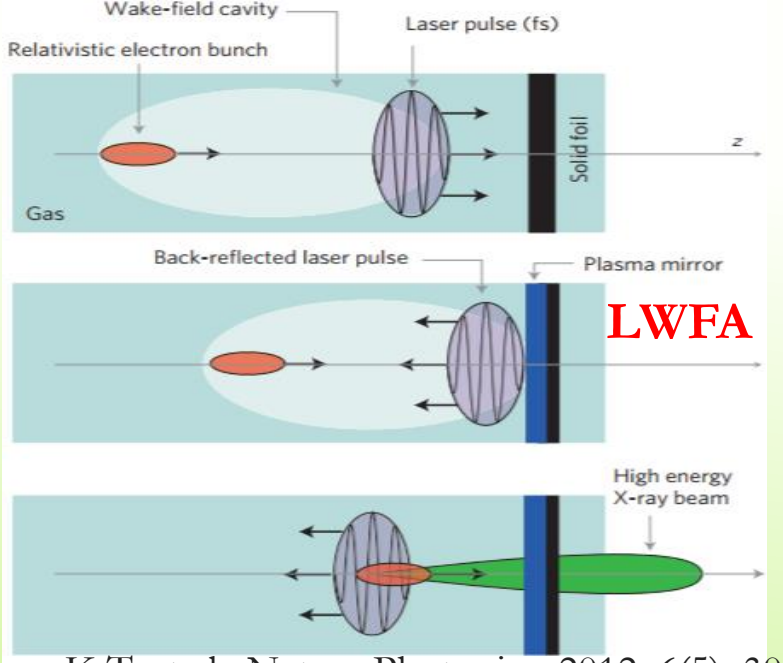
In counter-propagating laser field: $\eta = \frac{2\gamma E_L}{E_s}$

Problems:

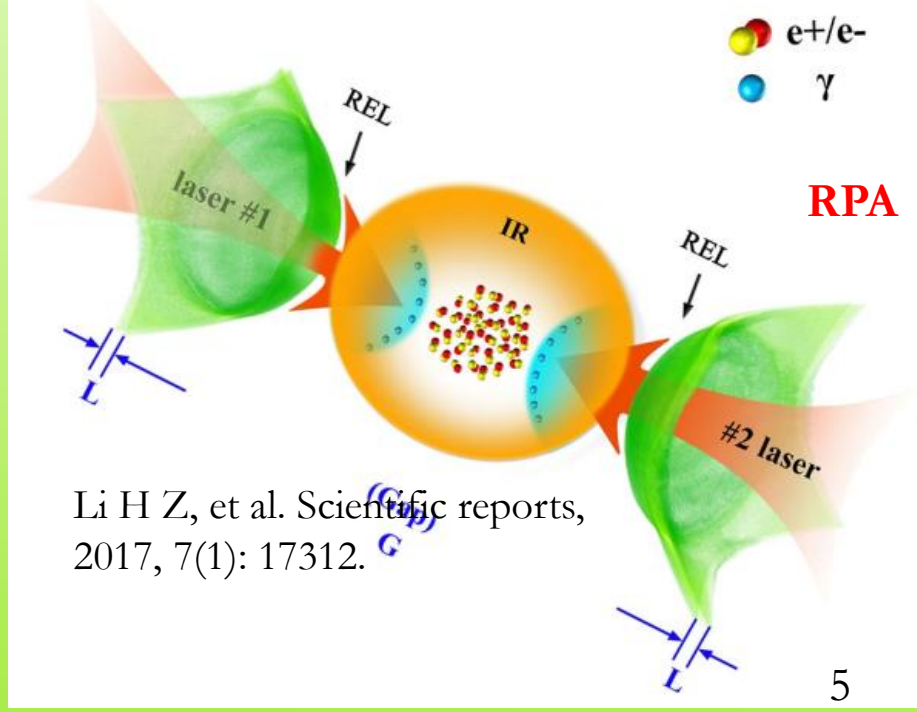
High intensity laser facility

Number of electrons participated

Energy conversion efficiency

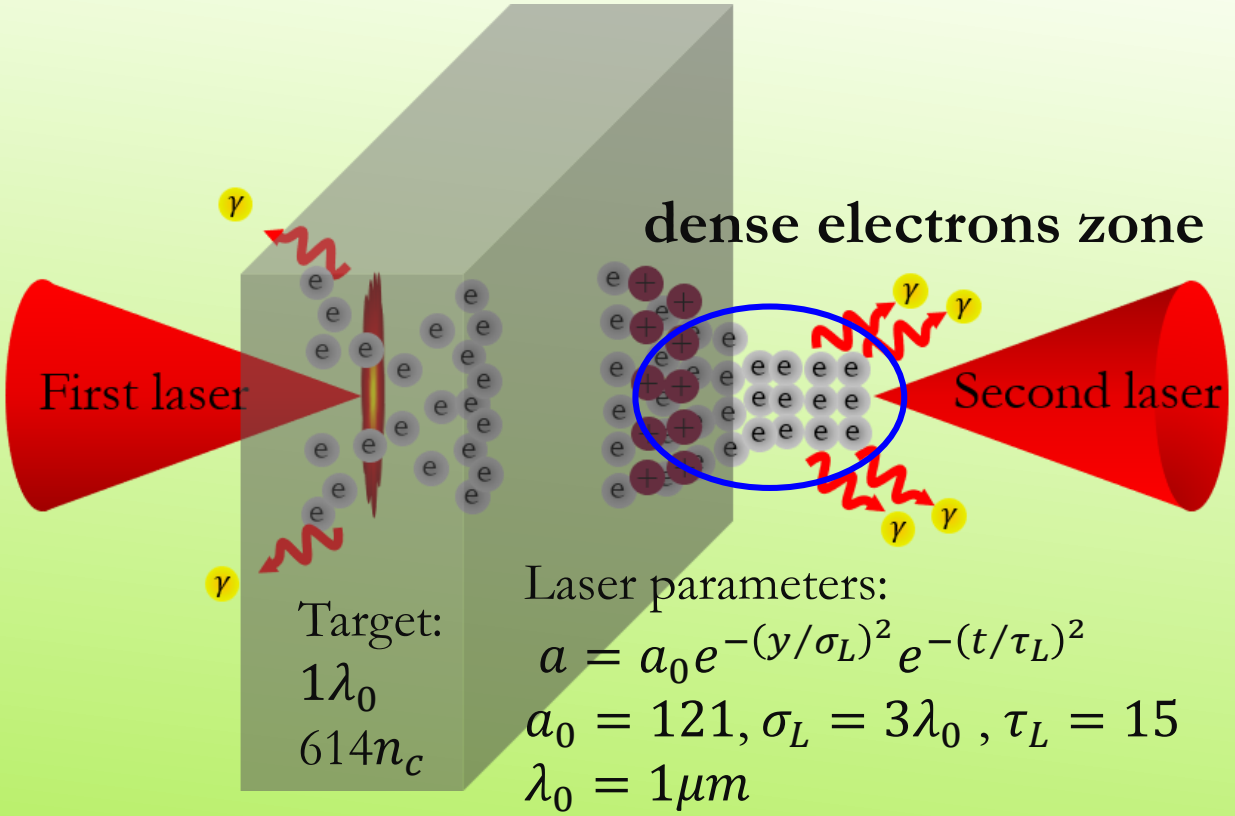


Phuoc K T, et al., Nature Photonics, 2012, 6(5): 308.



Li H Z, et al. Scientific reports, 2017, 7(1): 17312.

▸ Delayed counter-propagating laser beams irradiating solid target



Code: EPOCH-QED
open source code;
Simulation sources:
SCARF cluster.

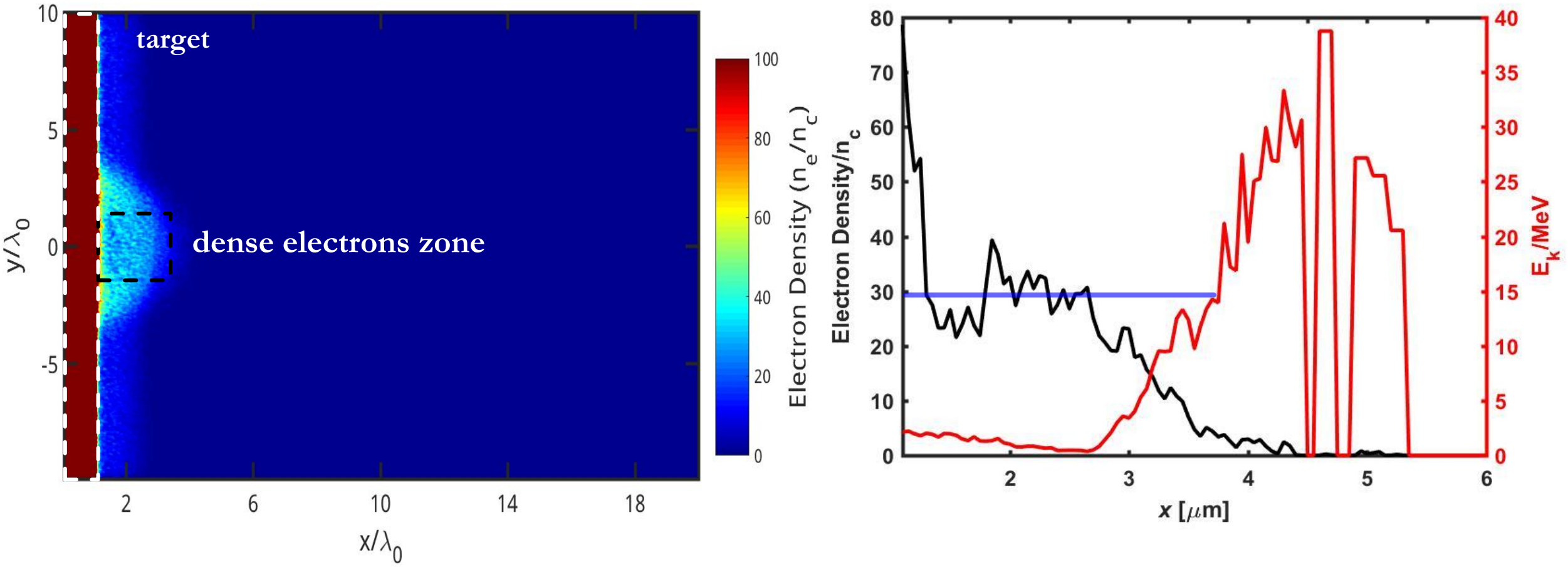
Four stages:
First laser irradiating,
Second laser approaching the dense electrons zone,
Second laser arrives at the rear surface,
Second laser reflected.

Three kinds radiation regimes:
Direct radiating; corresponding to the peak of photons emission
Nonlinear Compton scattering[1]:
$\omega'_{max} = \frac{\epsilon+p}{1-\cos(\theta)}$ determines the maximum of the photons energy
Radiation from oscillating electrons:
$\omega = \omega_e / (1-\beta) \simeq 2\gamma^2 \omega_e$

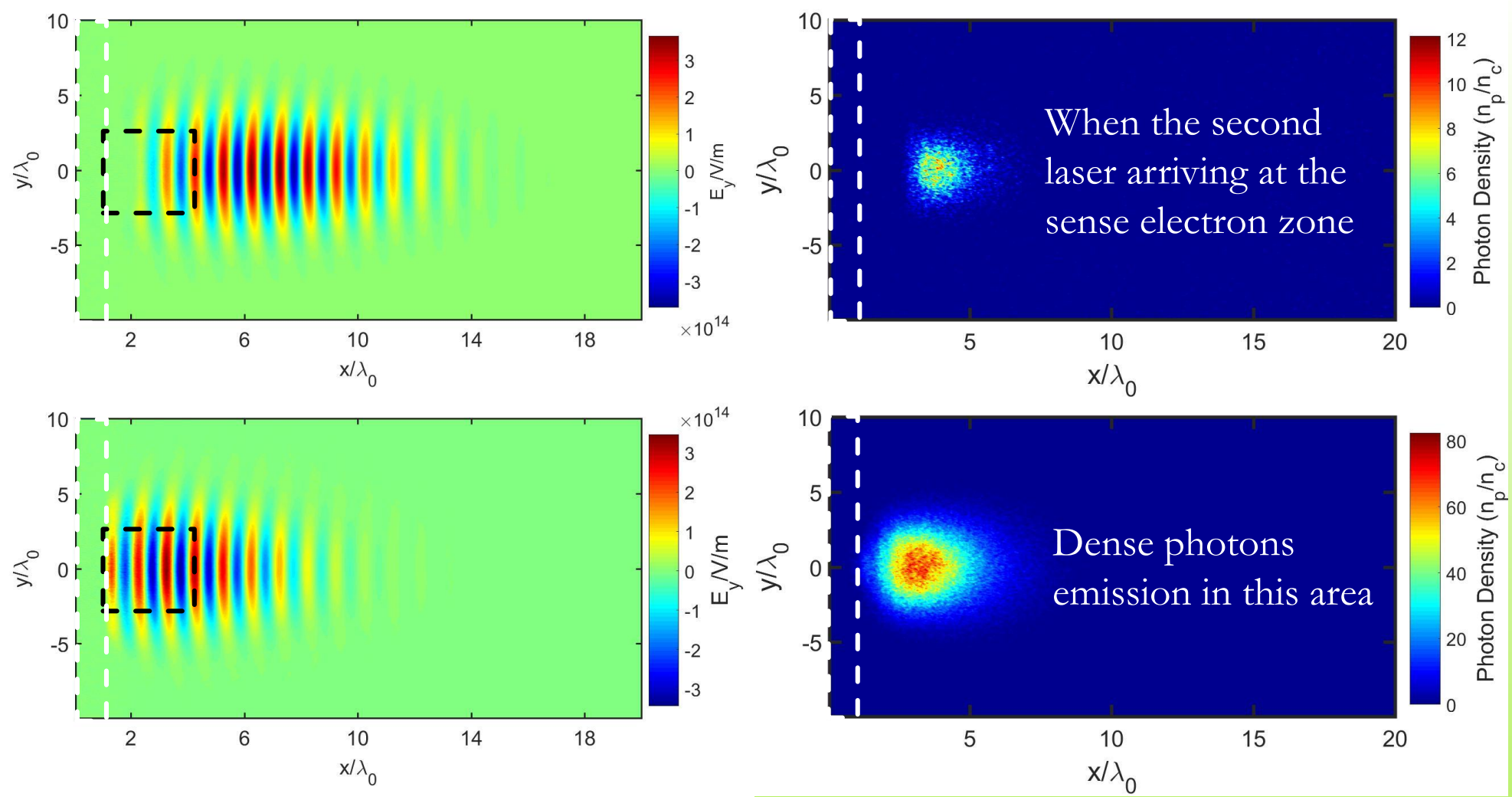
[1]Mackenroth F, Di Piazza A. Physical Review A, 2011,83(3): 032106.

▸ Simulation results

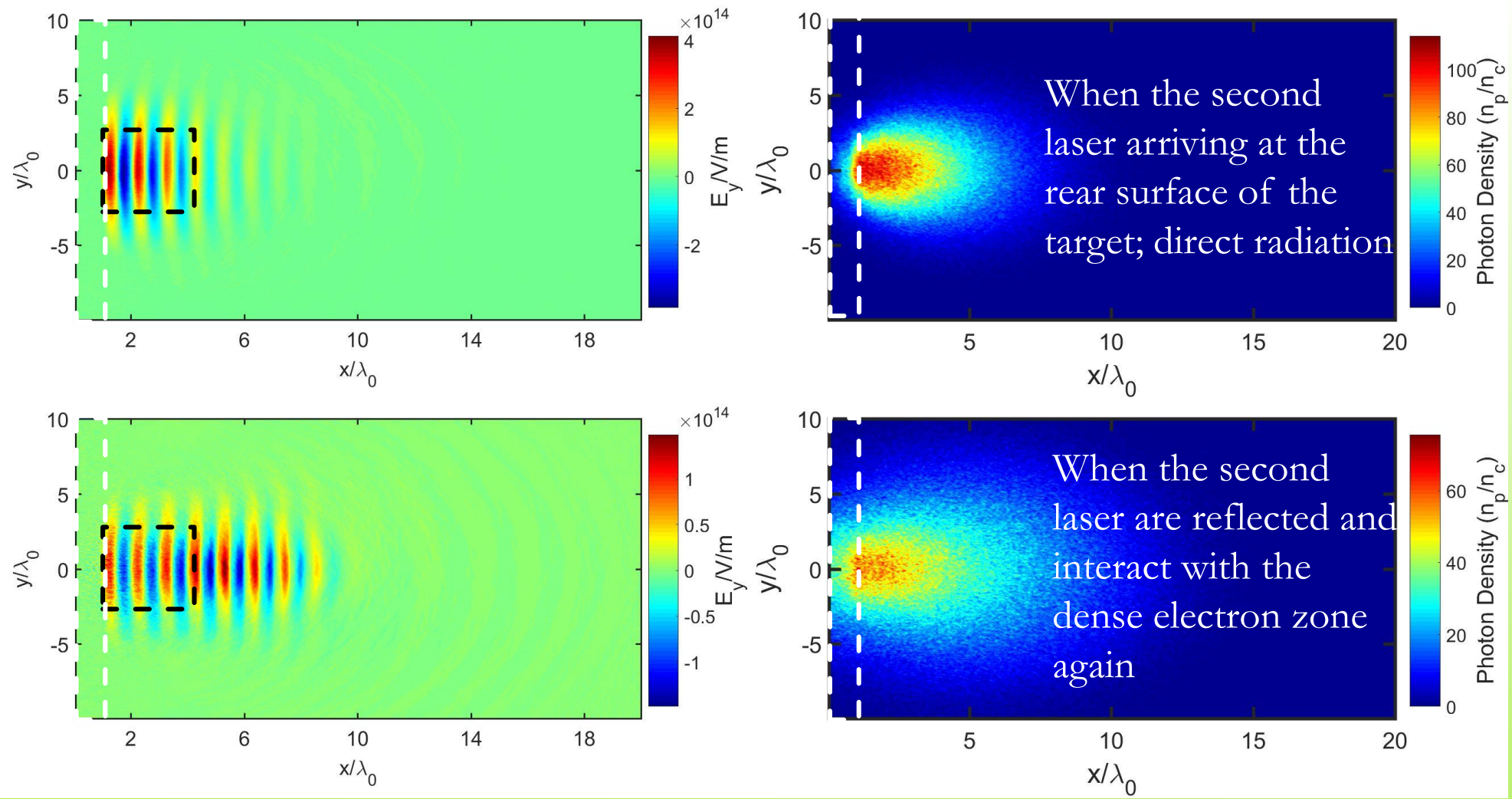
After the first laser irradiating ⟶ dense electrons zone forming



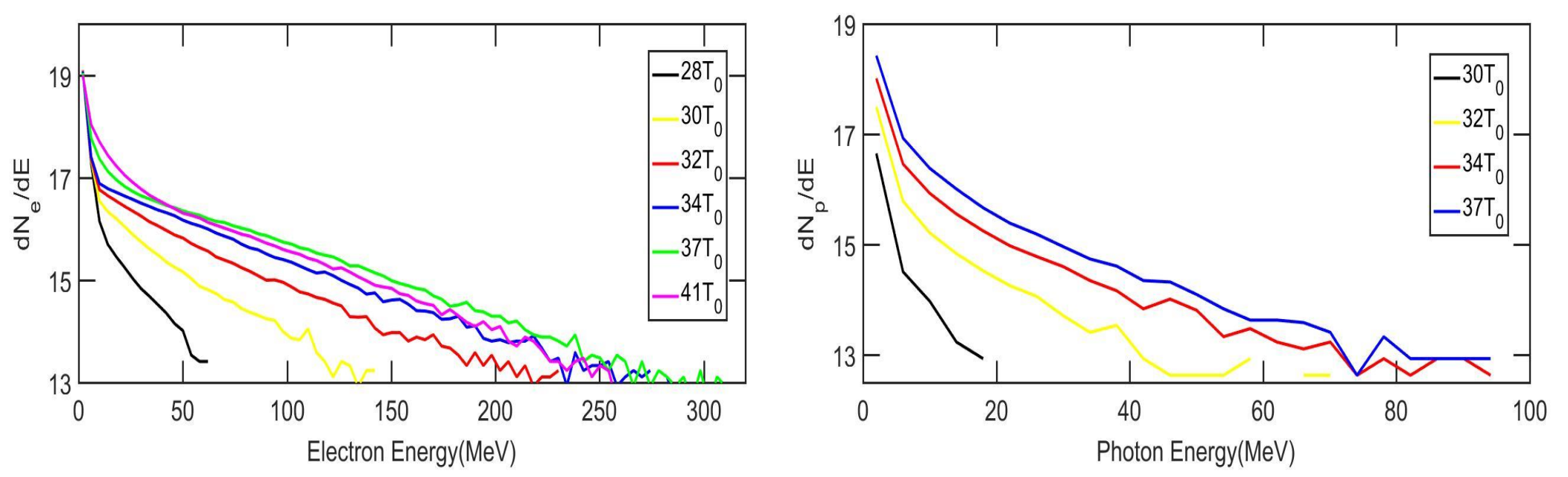
▸ Second laser interacts with the dense electron zone



▸ Direct radiation and reflected laser interacts with dense electron zone



▸ Spectra

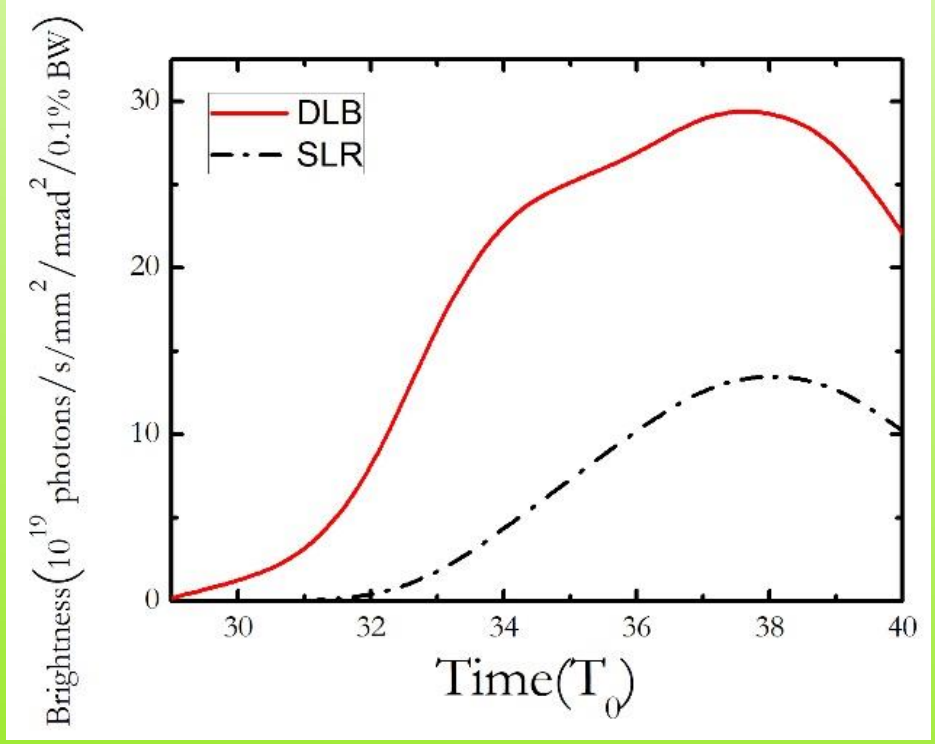

dN_e/dE
19
17
15
13
0
50
100
150
200
250
300
Electron Energy(MeV)
28T_0
30T_0
32T_0
34T_0
37T_0
41T_0
dN_p/dE
19
17
15
13
0
20
40
60
80
100
Photon Energy(MeV)
30T_0
32T_0
34T_0
37T_0

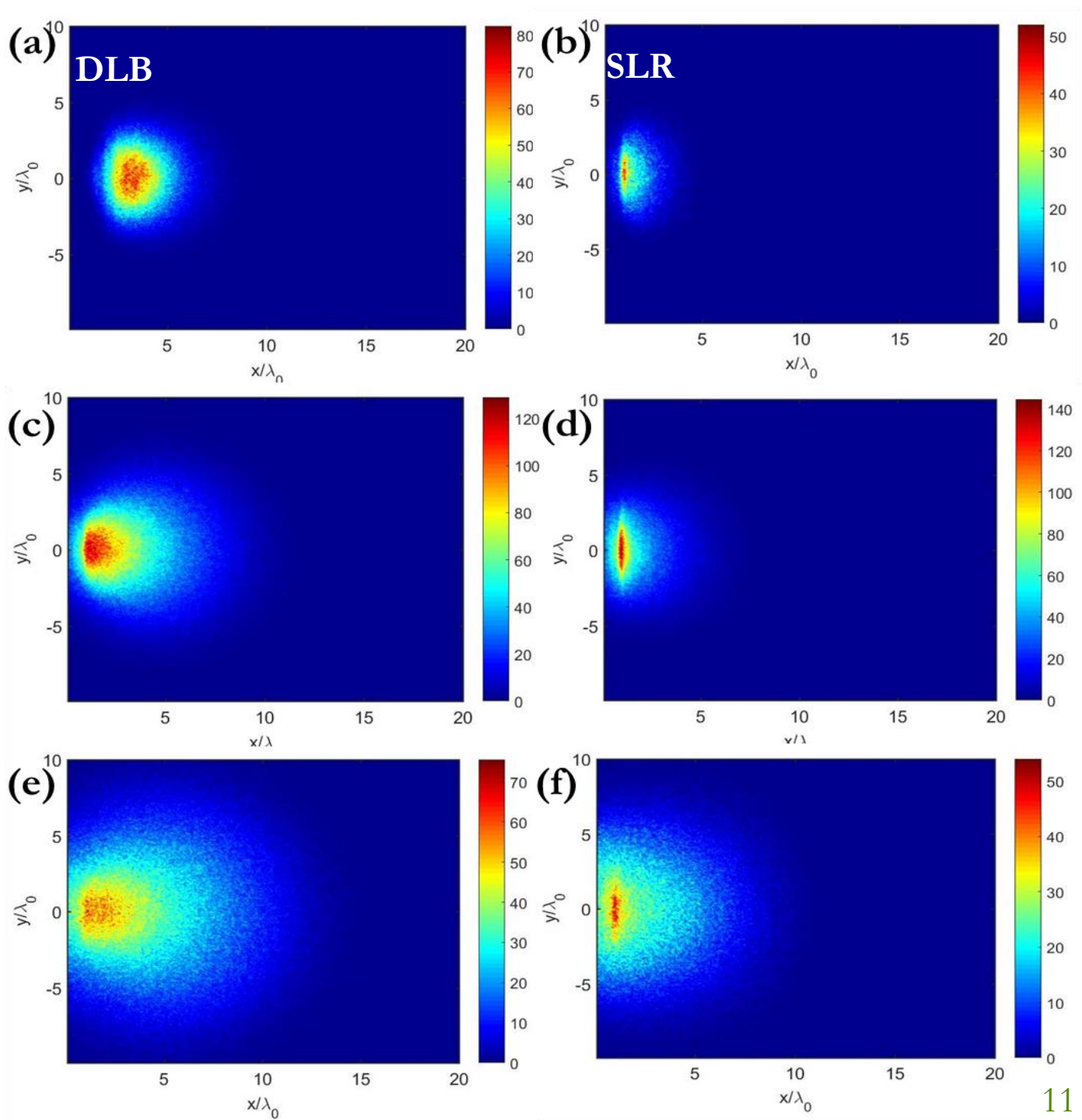
▸ Discussion

Analyze the function of the first laser

Model	Electric field maximum	Peak photon density/n_c
DLB	4.126e14	129
SLR	5.171e14	160

SLR: Single Laser from Right side;
DLB: Double Laser from Both sides

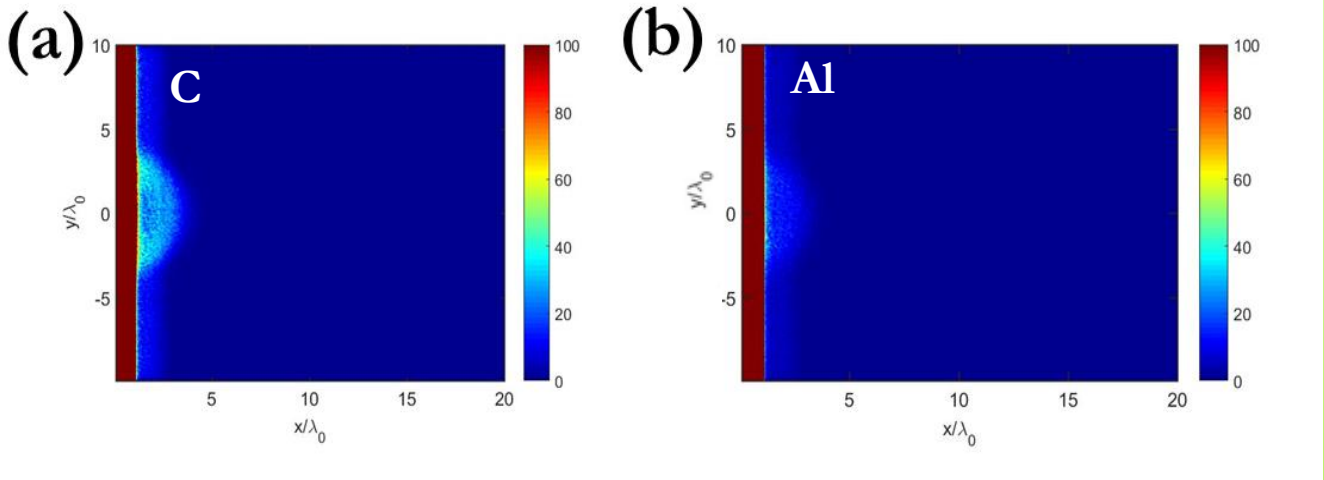


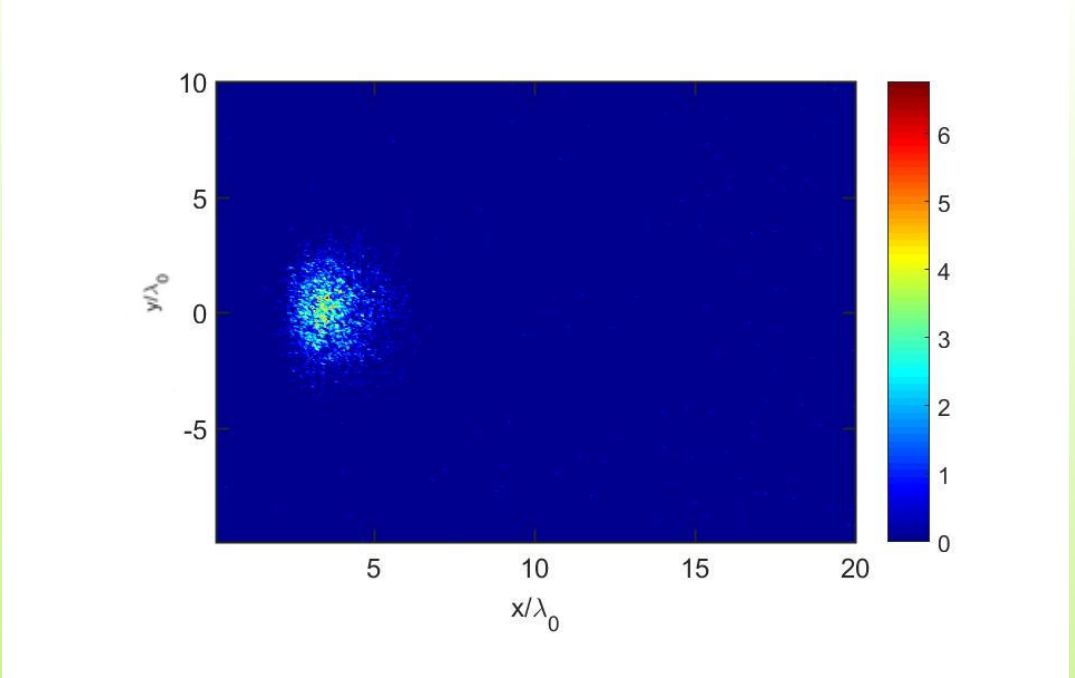


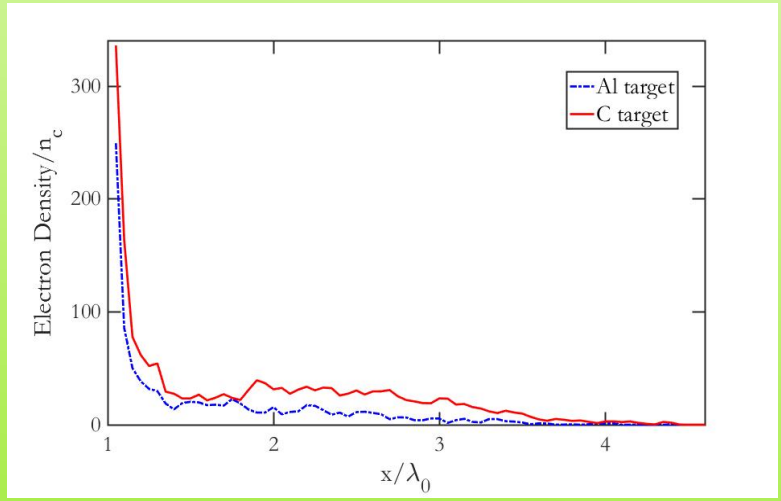
▸ Discussion

Materials

Material	C	Al
Peak photon density/n_c	129	139
Electric field maximum	4.126e14	5.309e14







▸ Summary

- **Proposed to use delayed counter-propagating laser beams to irradiate the solid. After the first laser irradiating, there will form a dense electron zone in the rear side of the target. The dense electron zone are larger than $2\lambda_0$ with averaged density of $\sim 30 n_c$;**

- **The second laser interacts with the dense electron zone from the time when the laser arriving this area to the time when the reflected laser leave this area. This increases the duration of laser-electron interaction and thus enhances the photons emission.**

- **This delayed counter-propagating lasers model can enhance the brightness of γ-ray source significantly.**

Thanks for your attention!