Number of gamma-ray photons

$$N_\gamma = L\sigma$$

Cross section

$$\sigma = \int \mathrm{d}\Omega \frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}$$

It assumes that cross section is equal to Thomson scattering cross section, $8/3\pi r_0^2$, even if Laguerre Gaussian (LG) beam injects.

Luminosity

Bunched electron + CW laser

$$L = N_e \lambda_p 2cf \cos^2\phi \int \mathrm{d}x\mathrm{d}y\mathrm{d}z\mathrm{d}t\, f_e(x,y,z,t) f_p(x,y,z)$$

Bunched electron + pulsed laser

$$L = N_e N_p 2cf \cos^2\phi \int \mathrm{d}x\mathrm{d}y\mathrm{d}z\mathrm{d}t\, f_e(x,y,z,t) f_p(x,y,z,t)$$

Ne: Number of electrons

Np: Number of photons, λp: Line intensity distribution of photons

f: Collision frequency, $\phi=\alpha/2$ (α is the crossing angle)

T. Suzuki, KEK Report, KEK-76-3, (1976).

Bunched electron + CW laser ($\alpha \neq 0$)

Density distribution function

Electron: three dimensional Gaussian distribution

$$f_e(x,y,z,t) = \frac{1}{(2\pi)^{3/2}} \frac{1}{\sigma_{xe}\sigma_{ye}\sigma_{ze}} \exp\left\{ -\frac{1}{2}\left(\frac{x^2}{\sigma_{xe}^2} + \frac{y^2}{\sigma_{ye}^2} + \frac{(z-ct)^2}{\sigma_{ze}^2} \right) \right\}$$

Photon: Laguerre Gaussian in x-y plane

$$f_p(x,y,z) = \frac{1}{2\pi} \frac{1}{\sigma_p^2 |m|!} \left(\frac{r^2}{2\sigma_p^2} \right)^{|m|} \exp\left\{ -\frac{1}{2}\left(\frac{x^2}{\sigma_p^2} + \frac{y^2}{\sigma_p^2} \right) \right\}$$

$$L = N_e \lambda_p f \sqrt{\frac{2}{\pi}} \frac{\sigma_p}{\sigma_e} \frac{(\sigma_e^2)^{|m|+1}}{(\sigma_e^2 + \sigma_p^2)^{|m|+3/2}} \sqrt{\frac{1}{\phi^2} \left\{ 1 - \exp\left(-\frac{\phi^2}{2} \frac{\sigma_e^2 + \sigma_p^2}{\sigma_e^2 \sigma_p^2} L^2 \right) \right\}}$$

$\sigma_p \approx \sigma_e$ $\phi << 1$ **Cavity length = 2L**

Bunched electron + CW laser ($\alpha = 0$)

$$L = N_e \lambda_p \frac{f}{\pi} \frac{\left(\sigma_e^2\right)^{|m|}}{\left(\sigma_e^2 + \sigma_p^2\right)^{|m|+1}} 2L$$

Interaction length = 2L

Bunched electron + pulased laser (α << 1)

Density distribution function

Electron: three dimensional Gaussian distribution

$$f_e(x,y,z,t)=\frac{1}{(2\pi)^{3/2}}\frac{1}{\sigma_{xe}\sigma_{ye}\sigma_{ze}}\exp\left\{-\frac{1}{2}\left(\frac{x^2}{\sigma_{xe}^2}+\frac{y^2}{\sigma_{ye}^2}+\frac{(z-ct)^2}{\sigma_{ze}^2}\right)\right\}$$

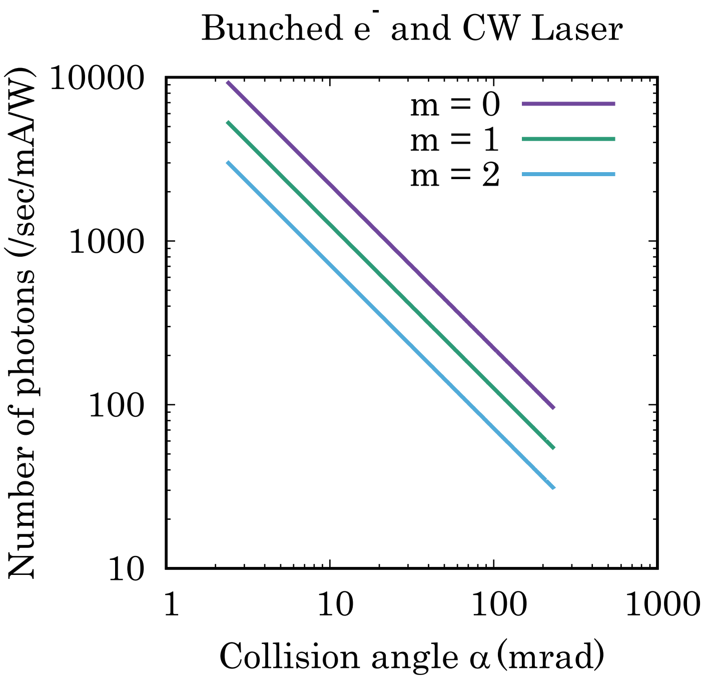
Photon: Laguerre Gaussian in x-y plane and Gaussian along z axis

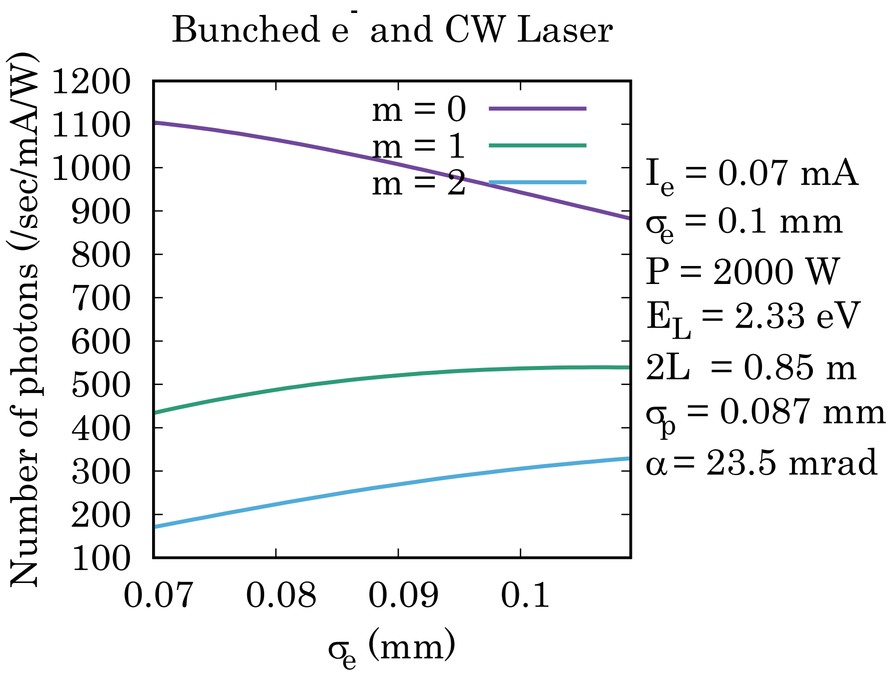
$$f_p(x,y,z,t)=\frac{1}{(2\pi)^{3/2}}\frac{1}{\sigma_p^2\sigma_{zp}|m|!}\left(\frac{r^2}{2\sigma^2}\right)^{|m|}\exp\left\{-\frac{1}{2}\left(\frac{x^2}{\sigma_p^2}+\frac{y^2}{\sigma_p^2}+\frac{(z+ct)^2}{\sigma_{zp}^2}\right)\right\}$$

$$L=N_eN_p\frac{f}{2\pi}\sqrt{\frac{\sigma_e^2+\sigma_p^2}{\sigma_e^2+\sigma_p^2+(\sigma_{ze}^2+\sigma_{zp}^2)\phi^2}}\frac{(\sigma_e^2)^{|m|}}{(\sigma_e^2+\sigma_p^2)^{|m|+1}}$$

$$\phi<<1$$

Bunched electron + CW laser ($\alpha \neq 0$)





$N\gamma$ produced by LG beam (m = 1) is half of a normal Gaussian laser.

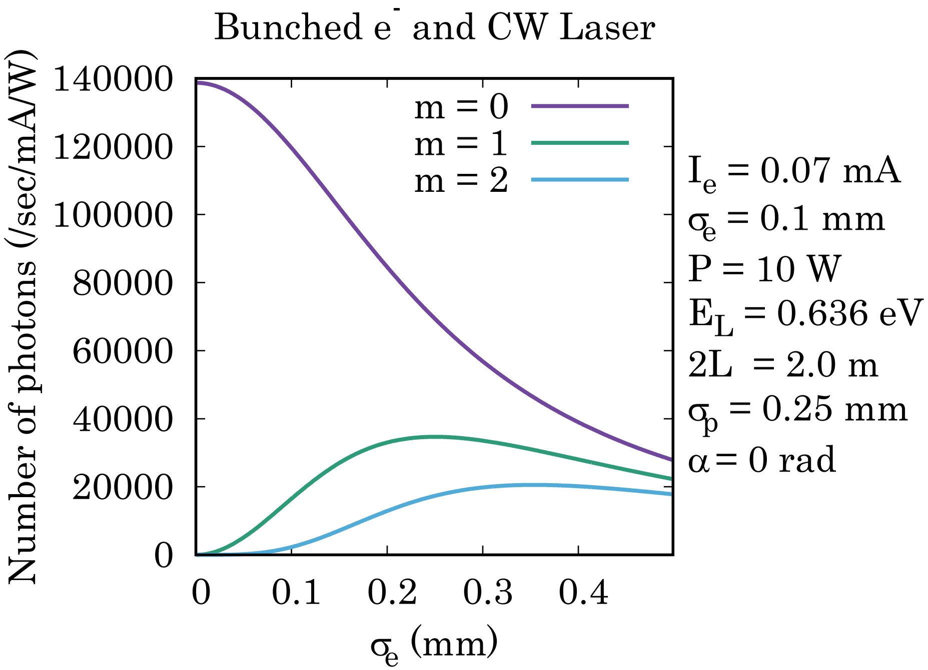
Number of gamma-ray photons: 8×10^4 photons/sec (m = 1)

Bunched electron + CW laser (α = 0)

Cavity method

A through hole for the electron is necessary

Single pass using high power fiber laser (e.g. AdValue Photonics, AP-CW1)

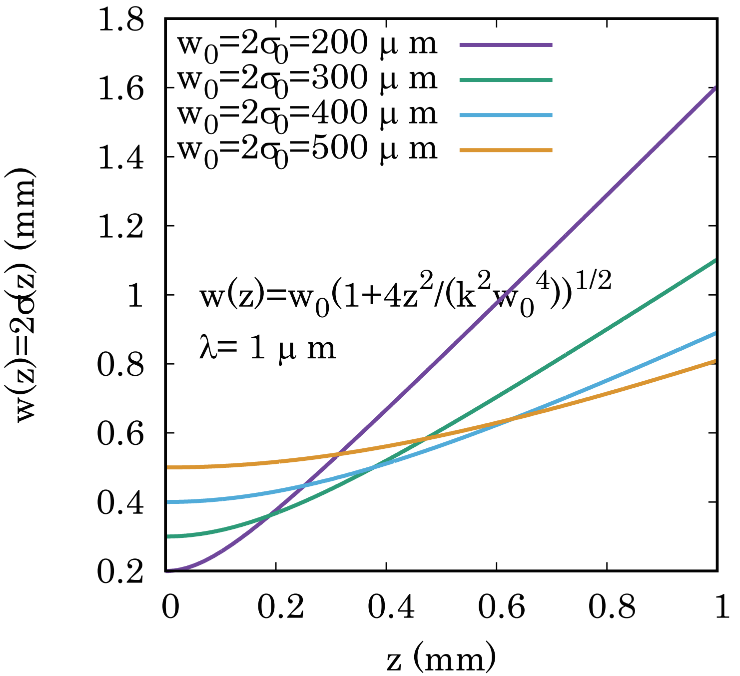


Number of gamma-ray photons:
2×10^4 photons/sec (m = 1)

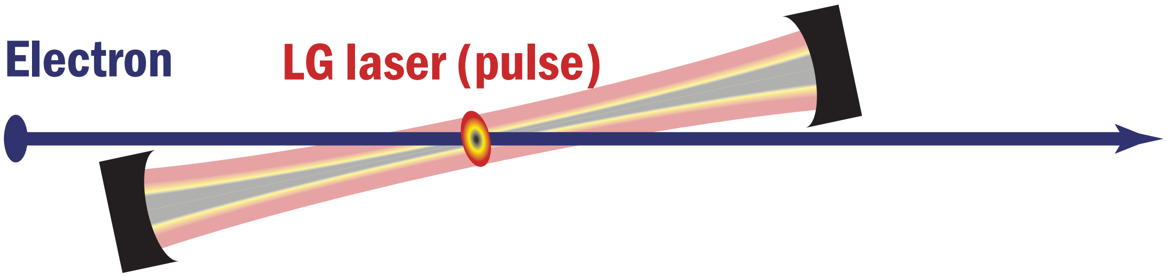
Probrem of the head-on collision

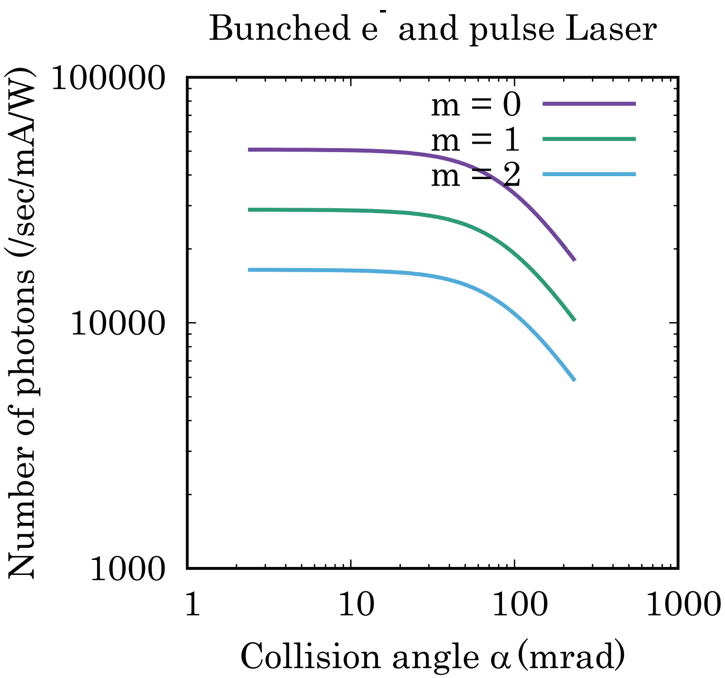
1. Source points of the gamma-ray expands few meter along z-axis.
   Electrons hit the laser photons everywhere.
   -> Smearing out of the spatial distribution of the gamma-ray??

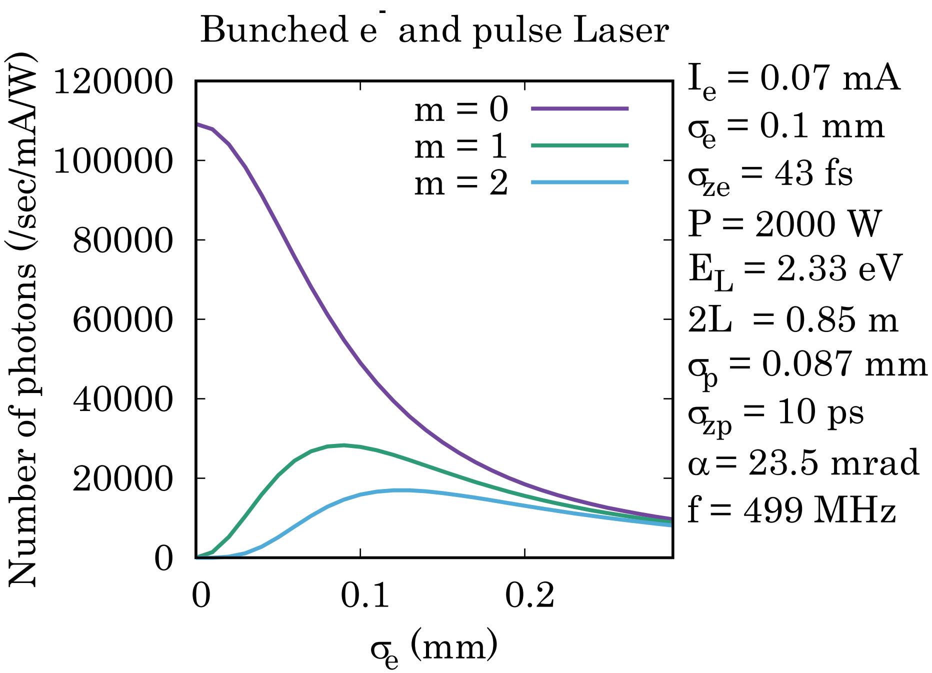
2. Transverse laser size is varied along z-axis.
   To keep the laser size constant, initial laser size should be large.



Bunched electron + pulased laser (α << 1)







Number of gamma-ray photons: 4 x 10^6 photons/sec (m = 1)

Summary

1. When the LG laser power is equal to normal Guassian laser, number of gamma-ray photons produced from the LG laser is half of that produced from the normal Gaussian laser.

2. We can obtain the number of gamma-ray photons as much as cavity method by using a head-on collision with a commercially available fiber laser.
But, some probrems exist.

3. The most intense gamma-rays will be obtained by the cavity method using a “pulsed” LG laser.
$N\gamma$ is increased 100 times.
Single source point and small source size of the gamma-ray.