4th International Accelerator School for Linear Colliders

Course A : Particle Sources Home Work

1. We assume the following parameters for ILC electron gun.

- Cathode radius is 5mm.
- Anode-cathode voltage is 120kV.
- Anode-cathode distance is 50mm.

Answer the following questions.

a) Calculate the space charge limited current of the electron gun.

Space charge limited current is given by Child-Langmuir law. Substituting the given parameters, the current is calculated to be

$$I=2.33\times10^{-6}\frac{SV^{1.5}}{d^2}=2.33\times10^{-6}\frac{7.85\times10^{-5}\times(1.2\times10^5)^{1.5}}{0.05^2}=3.04(A)$$

b) There is another phenomena limiting emission current density from GaAs cathode. What is the name of the effect? What is the limitation on the current from ILC gun?

The name is Surface Charge Limit by Photo-voltage effect. The limitation is 5.0 A/cm^2, which corresponds to the current from ILC gun of

$$I=5.0\times0.785=3.93(A)$$

c) What is the possible real current density from the ILC gun?

The lowest limit gives the practical limit on the current. In this case, space charge limit is the lowest and gives the actual limit, 3.04A.

d) How much is the bunch length in time to extract ILC bunch (3.2nC)?

To extract 3.2nC, the time duration is

$$t_{bunch}=3.20/3.04=1.05\,ns$$

e) How much laser energy per bunch is needed to make such bunch? Please assume 1% quantum efficiency and 700nm laser wave length.

From a photo-cathode, laser energy E(μJ) to extract bunch charge Q(nC) is obtained as

$$E=124\frac{Q}{\eta\lambda}=\frac{124\times3.2}{700\times1.0}=0.57$$

The answer is 0.57μJ.

f) Is the bunch length acceptable for RF acceleration of 1.3 GHz? Explain the reason.

RF period of 1.3 Ghz frequency is 1/1.3E+9 = 770 ps (770E-12 s). The bunch length is longer than the period and it is impossible to accelerate the bunch with 1.3GHz RF.

g) If the bunch length has to be shorten before acceleration, we need bunch compression. What is aspect to choose RF frequency for bunch compression?

The bunching is made with velocity or energy modulation by RF. The modulation should be linear in a good approximation. The full bunch length should be even shorter than the half period.

h) Assuming 100MHz RF frequency for buncher cavity and 4m drift length. In linear approximation, what is the required voltage for the perfect bunching?

Gamma and beta of the 120kV beam is

$$\gamma = 1.0 + \frac{0.120}{0.511} = 1.24, \quad \beta = 1.0 - \frac{1}{\gamma^2} = 0.59$$

By substituting these numbers to the condition of the perfect bunching, we get

$$\frac{4.0}{3.0\times10^8\times1.24^2\times0.59^3}\frac{eV2\pi\times10^8}{0.631} = 1.0$$

from the equation, cavity voltage V is obtained as 23.8kV.

2. Please answer the following questions aboutpositron generation for ILC.

a) If the normalized positron yield by the electron driven scheme is 0.2 [$N_{e+}/N_{e-}E(GeV)$], how much bunch intensity (nC) do we need to obtain 3.2nC positron bunch charge? Assume 4.0GeV electron driver energy.

The yield with 4.0GeV driver is $0.2\times4.0 = 0.8\ (N_{e+}/N_{e-})$. To obtain 3.2nC e+, $N_{e-} = 3.2/0.8 = 4.0nC$.

b) How much beam energy for the undulator driver electron is required for positron generation? Please assume K value is 1.0 and 1.0 cm undulator period. 1st harmonic energy should be more than 10 MeV for positron generation.

Substituting the parameters, photon energy of 1^{st} harmonic from the undulator is

$$E_{ph} = 9.50\frac{1.0\times E^2}{0.01(1+1.0^2)}$$

To get E_{ph}=1E+7eV, E (beam energy in GeV) is 145 GeV.

c) How much beam energy for Compton driver electrons is required for positron generation? 1st harmonic energy should be more than 10 MeV for positron generation. Please assume 1.0µm laser wave length.

The energy of 1um wavelength laser photon i s

$$E_L = \hbar\omega = 1.055\times10^{-34}2\pi\frac{3.0\times10^8}{10^{-6}} = 1.99\times10^{-19}J = 1.24\,eV$$

If the photon energy from the laser Compton scattering is 10 MeV,

$$E_{ph} \sim 4.0\gamma^2\times1.24 = 1.0\times10^7$$

γ is 1.42E+3. The beam energy in eV is $E = 1.42\times10^3\times0.511 = 720\,MeV = 0.72\,GeV$.