Driving positron beam acceleration with coherent transition radiation

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Outline

1. Background

2. positron beam acceleration with coherent transition radiation
The experiment platform for “Ultrafast Sub-atomic Physics” at SULF is now in operation, where 10 PW laser is used.
We are preparing for the experiment of electron acceleration, hoping to produce the electron beam of energy more than 10GeV.
We use a gas cell with several sections to change the plasma density along the laser propagation.

Meng Wen, Baifei Shen et al., NEW JOURNAL OF PHYSICS 12, 045010 (2010)
In 2001, we studied positron production by laser foil interaction.

**Pair and $\gamma$-photon production from a thin foil confined by two laser pulses**

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Electron-positron and $\gamma$-photon production by high-intensity laser pulses is investigated for a special target geometry, in which two pulses irradiate a very thin foil (10–100 nm $<$ skin depth) with same intensity from opposite sides. A stationary solution is derived describing foil compression between the two pulses. Circular polarization is chosen such that all electrons and positrons rotate in the plane of the foil. We discuss the laser and target parameters required in order to optimize the $\gamma$ photon and pair production rate. We find a $\gamma$-photon intensity of $7 \times 10^{27}$/sr s and a positron density of $5 \times 10^{22}$/cm$^3$ when using two 330 fs, $7 \times 10^{21}$ W/cm$^2$ laser pulses.
Due to the compression of two intense laser pulses, the plasma density could be very high. Therefore, here the main scheme of positron production is the trident process.

Baifei Shen et al., PHYSICAL REVIEW E 65, 016405(2001)
Positron acceleration driven by proton beam

Proton beam could drive a wake field for positron acceleration. But the defocusing field in transverse prevents the positron acceleration in a long distance.

Laser and Particle Beams, 2013. doi:10.1017/S0263034613000293
Positron acceleration in a hollow channel driven by proton beam
The positron beam can be well accelerated in the proton driven wake field. There is a weak focusing field near the channel wall, but no transversal field in the middle of the channel. Therefore, the radiation loss of the positron is quite small.
In 2016, we succeeded to produce positrons with femtosecond laser. At first, we accelerated electrons with laser gas interaction. Then the energetic electrons produced gamma photons with bremsstrahlung. The gamma photons produced the positrons with the BH process.

Tongjun Xu, Baifei Shen et al., *Phys. Plasmas* 23, 033109 (2016)
Outline

1. Background

2. positron beam acceleration with coherent transition radiation
In our experiments, we found there was a mono energetic positron peak when the charge number of the driving electron beam is high (>1nC).

The positrons move together with the electrons. Due to relativistic effect, the longitudinal field of the electron beam becomes small, not enough to accelerate the positron.
When the electron beam goes through the back surface, strong coherent transition radiation of frequency several THz is generated, due to the small size and large charge number of the electron beam.
In simulation, with a 5 PW 45 fs laser, a positron beam of 10 pC is accelerated from 25 MeV to 500 MeV within a distance of 40 cm.
Positron density and focusing force in transverse.

Acceleration field and positron distribution in phase space.

Two dimensional acceleration field.

Two dimensional transversal force

The THz radiation is of radial polarization.

External magnetic field

Simulation shows that it is good for positron acceleration.

The magnetic field suppresses the spread of the electron which may guide the propagation of the THz wave.
The efficiency of the acceleration

1. During the propagation of particles and the radiation, the positrons get energy while the electrons lose energy. Therefore, in principle the radiation energy could keep unchanged. And the electron energy is gradually transferred to the positron energy. The efficiency could be high.

2. At present, the main limitation is the diffraction of the Thz radiation and the spreading of the electron beam.
The most important thing is that the electron beam should be compressed in time and in transversal size. Since the good collimation of the electron beam, the external magnetic field may not be required.
Short electron beam produce coherent transition radiation of high frequency short pulse duration and high intensity.

The charge of the electron beam is important to the intensity of the acceleration field.
Conclusions

1. In experiment, we observed monoenergetic positron peak.

2. We proposed the new scheme to accelerate positrons with coherent transition radiation.

3. We discussed the possibility to use the new scheme for conventional accelerator.

4. Many more things should be done for the new scheme.
Thank you for your attention!