Pair-Plasma Creation on kJ-class High-Intensity Lasers

OMEGA EP beam

Relativistic pair plasma

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Summary

Positron–electron pair creation will be significant on OMEGA EP, possibly generating a relativistic pair plasma

- This paves the way for the laboratory investigation of relativistic pair plasmas
  - basic physics, astrophysical phenomena
- Pair yields and spectra have been optimized and are consistent with recent LLNL experiments (TITAN)
- Of the order of $10^{12}$ positrons can be made on OMEGA EP, assuming a total laser energy of 2.5 kJ
- High pair density is required for plasma creation
- Pair production rates as high as $10^{23}$ pairs per second
- External magnetic fields can increase the pair density
Very encouraging positron production results have recently been obtained at LLNL (May 2008)

LLNL TITAN positron experimental setup

Large numbers of $e^-$ and $e^+$ were created

The TITAN results are in agreement with a model that computes the yields based on the photo-production of pairs:

- Trident <10% of B–H
- Two steps: first bremsstrahlung, then pair production
- Conversion into x rays can be very efficient of high-Z materials
- Gold (Z = 79) is a good choice
- Exponential energy spectrum for hot electrons ($T_{\text{hot}}$)

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J. Myatt et al., submitted to Phys. Rev. E
The same model predicts the energy spectrum of the pairs as a function of laser intensity

- Knowledge of spectrum allows optimization of target thickness
- Useful for future computations of pair expansion

![Pair energy spectrum](image)

![Ponderomotive scaling](image)
The positron–electron cloud may not achieve sufficient density if the pairs are allowed to expand freely.

- The goal is to optimize pair density and not just the total number.
- Production rate is important:
  \[
  L_n/\lambda_D = 1.6 \left( \frac{\dot{N}_+/10^{12} \text{ ps}^{-1}}{\langle T+/\gamma \rangle/1 \text{ MeV}^{1/2}} \right)^{1/2} (E/1 \text{ kJ})^{1/2}
  \]
- Spherical expansion
- Rate is increased most effectively by increasing laser energy (OMEGA EP)

![Diagram showing Debye length and relevant temperature range]
Externally applied magnetic fields can be used to increase the pair density to the required value.

- The pairs are emitted in a jet along the direction of the imposed field.

\[ B_0 = 0 \]
\[ B_0 = 4 \text{ MG} \]

\[ n_+ \times 10^{16} \text{ cm}^{-3} \]
\[ n_+ \times 10^{20} \text{ cm}^{-3} \]

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