Polarization of Incoherent Thomson Scattering in Burning Plasmas

V. V. Mirnov, E. Parke, D. J. Den Hartog

Abstract

Incoherent Thomson scattering (ITS) is a useful tool for plasma density measurement, and it is also used to probe the spatial and temporal evolution of plasma density. ITS has been widely used to measure electron temperature in various plasma environments, including burning plasmas. ITS is a non-invasive diagnostic technique that can be used to study the plasma parameters in a wide range of plasma environments. ITS is a powerful tool for studying the plasma parameters in a wide range of plasma environments.

Outline

• Full relativistic description of the polarization is analyzed as a function of:
  - q (electron momentum)
  - p (electron polarization vector)
  - v (electron velocity)
  - k (scattered radiation vector)
  - θ (angle of incident polarization)
  - φ (scattering angle)

• The work is motivated by the proposal by F. Orsiolo, N. Tartamella, Rev. Sci. Instrum. 2000, with some important corrections and results of similar works.

• Our approach allows us to identify a mechanism of loss of polarization in the process of Thomson scattering in hot plasmas.

• The degree of polarization and intensity of the scattered laser light is consistent with direct free-electron quadrature combination with quadrature-splitted ELA.

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• The degree of polarization is determined by the reduced expression:

μ = (1/2) (κ + τ) + (κ - τ) / (κ + τ).

• The use of different reference frames in these two cases allows us to derive precise expressions valid in a wide range of electron temperatures.

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Mueller matrix for scattering by a single electron

• Vector r is decomposed along perpendicular and parallel to the scattering plane directions, i.e., r = r⊥ + r∥.

• Components (e, p) are obtained from the scattering plane directions, i.e., r⊥ and r∥.

• The relationship between these two is given by:

r⊥ = r e e + r p p, r∥ = r e e - r p p.

Relating the Stokes parameters of the incident and scattered waves

• Mueller matrix (4 x 4) links Stokes parameters of the incident and scattered waves.

• Two methods for finding scattering field components:
  - Direct integration over t.
  - Equivalent to integration of the power spectrum over one and frequency over time.

• Relativistic kinematics for finding r⊥.

Spectral density of degree of depolarization 1-μ vs Ω at T_e = 50 MeV, 5 MeV, 500 keV, 100 keV, 100 keV, at w = w₀.

Depolarization factor accounts for relativistic effects in spectrum power of Thomson scattering.

• Depolarization factor is the ratio of the energy flux to the flux at w₀, which is given by the first term in the expression for scattered electric field.

• The energy flux is proportional to Ω²-1 (1 - 4 Ω²-1).

• Degree of polarization of the scattered beam is a function of power flux in polarized component to the total power flux.

• Degree of depolarization is determined by the reduced expression:

μ = (1/2) (κ + τ) + (κ - τ) / (κ + τ).

Integration over electron distribution function

• Averaging of the incoherent scattering over electron distribution makes scattered wave partially polarized.

• Elements of the Mueller matrix after integration over distribution function.

• Spectral density of degree of depolarization 1-μ vs Ω at T_e = 50 MeV, 5 MeV, 500 keV, 100 keV, 100 keV, at w = w₀.

Summary

• The phase of polarization and intensity of the scattered laser light are consistent with direct free-electron quadrature combination with quadrature-splitted ELA.

• The use of different reference frames in these two cases allows us to derive precise expressions valid in a wide range of electron temperatures.

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• Correct treatment of a function singularity leads to Mueller matrix and results of integration over velocity space different from similar calculations by J.E. Siegel, Y. Zozua, Phys. 2000.