BOOK REVIEW

Plasma Scattering of Electromagnetic Radiation: Theory and Measurement Techniques

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Reviewer Tony J. H. Donné

This book is the second edition of the original book by John Sheffield, published in 1975, which for a long time has been a standard textbook and reference book for graduate students and researchers. The book has been thoroughly modernized with many new and actual examples. New material on industrial and warm dense matter plasmas has been added. Also, much emphasis is given to energetic particle measurements and instrumentation, like ion collective Thomson scattering, while the discussion on relativistic theory has been expanded. The book covers many of the new developments in the field of scattering needed in order to diagnose and understand the future burning plasma reactors like ITER, and therefore, I do expect that it will be an excellent and useful textbook and reference book for the coming decade.

The first chapter of the book is an introduction (30 pages) to the basic properties of plasma as well as to the interaction of radiation with plasma. First, the scattering by an individual charged particle is discussed, and it is demonstrated that the scattering is essentially only from electrons. Accordingly, the cases of noncollective and collective scattering are discussed.

Chapter 2 (14 pages) focuses on the general relationship between the scattered power spectrum and plasma density fluctuations and introduces the spectral density function. In Chapter 3 (24 pages) the general scattered spectrum for unmagnetized plasmas is derived including also the effect of collisions. In both chapters the focus is on the theory.

In Chapter 4 (34 pages), a derivation is given of the noncollective spectrum for a magnetized plasma, followed by modern applications of noncollective Thomson scattering for measuring the electron temperature and density in the plasma as well as measuring the magnetic field direction from the fine structure that occurs in the spectrum under specific scattering geometries due to the cyclotron motion of the electrons.

Chapter 5 (40 pages) focuses on scattering in the collective regime. After a general theoretical introduction to the subject and a discussion of the Salpeter approximation, modern applications of collective scattering are discussed. Emphasis is given among other topics discussed on electron plasma waves, ion acoustic waves, and the measurement of ion temperature.

Chapter 6 (42 pages) is completely focused on the constraints on scattering experiments related to the choice of source, scattering angle, and geometry; to the signal-to-noise ratio; and to the background arising from bremsstrahlung. Also, the effect of the incident beam on the plasma is treated.

Chapter 7 (40 pages) gives an overview of the various optical elements used in scattering systems, including various types of spectrometers. It also discusses calibration (Rayleigh and Raman scattering) and alignment. Since the book covers scattering over a very wide frequency range, from X-rays to microwaves, attention is also devoted to cutoffs by electron cyclotron emission and calibration of collective scattering systems for microturbulence.

In Chapter 8 (26 pages), a number of interesting applications of scattering are discussed to illustrate the versatile use of scattering. This includes discussions of far-forward scattering, phase-contrast imaging, phase scintillation imaging, Thomson scattering from driven waves, direct forward and (ω, k)-resolved Thomson scattering, sub-ps time-resolved Thomson scattering of stimulated Raman scattering, and multiple ion-acoustic Thomson scattering.

Chapter 9 (26 pages) deals first with applications in industrial and other low-temperature plasmas and then concentrates on scattering from energetic ions and applications of ion collective Thomson scattering. This is an important addition to the book in view of the upcoming era of burning fusion plasmas.

Chapter 10 (32 pages) mainly presents a theoretical treatment of the scattering from a magnetized plasma. The subject of Chapter 11 (26 pages) is X-ray Thomson scattering for probing warm dense matter and dense plasmas and shows examples of scattering in the Compton and plasmon regimes. Work on scattering from unstable plasmas is reviewed in Chapter 12 (44 pages), including scattering from enhanced fluctuations driven by plasma wave turbulence or laser-plasma interaction.

The book has a total of six rather comprehensive appendixes. In Appendix A (18 pages), relevant mathematical techniques are reviewed. Appendix B (24 pages) presents the plasma kinetic theory in a concise way. The derivation of the general hot plasma dispersion relation is summarized in Appendix C (12 pages). A brief discussion of computational techniques used to calculate the Thomson scattering spectrum is given in Appendix D (8 pages), along with a simple computational method for solving the scattering spectrum. Appendix E (16 pages) presents a brief historical review on scattering of radiation from plasmas. Finally, Appendix F (4 pages) contains a list of physical constants and significant formulas, including a list of various scattered spectra obtained under different approximations. An extensive bibliography (32 pages) is added to direct the reader to the original literature sources.

Each of the main chapters of the book is followed by a list of problems for students along with their solutions. The book is printed in two tones (black and blue). The blue is mainly used in the figures, for paragraph numbering, and as background color for tables and contents.

I expect that this revised version of the original John Sheffield book will be used as a standard textbook for students and for researchers (especially diagnosticians) in a very wide field of plasma applications (going from low-temperature industrial plasmas via high-temperature fusion plasmas to ultradense plasmas used in inertial fusion). The balance between theory (and the accompanying mathematics) and description of experimental applications is very good. I enjoyed reading the book (but did not have time yet to solve all the problems on my own without sneaking in the solutions). I will certainly use the book in my courses for Master and Graduate students, and I warmly recommend it to anyone working in the field of scattering of radiation in plasmas.

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