

Plasma Physics

Alexander Piel

Plasma Physics

An Introduction to Laboratory, Space,
and Fusion Plasmas

 Springer

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*To Hannemarie,
Christoph and Johannes*

Preface

This book is an outgrowth of courses in plasma physics which I have taught at Kiel University for many years. During this time I have tried to convince my students that plasmas as different as gas discharges, fusion plasmas and space plasmas can be described in a unified way by simple models.

The challenge in teaching plasma physics is its apparent complexity. The wealth of plasma phenomena found in so diverse fields makes it quite different from atomic physics, where atomic structure, spectral lines and chemical binding can all be derived from a single equation—the Schrödinger equation. I positively accept the variety of plasmas and refrain from subdividing plasma physics into the traditional, but artificially separated fields, of hot, cold and space plasmas. This is why I like to confront my students, and the readers of this book, with examples from so many fields. By this approach, I believe, they will be able to become discoverers who can see the commonality between a falling apple and planetary motion.

As an experimentalist, I am convinced that plasma physics can be best understood from a bottom-up approach with many illustrating examples that give the students confidence in their understanding of plasma processes. The theoretical framework of plasma physics can then be introduced in several steps of refinement. In the end, the student (or reader) will see that there is something like the Schrödinger equation, namely the Vlasov-Maxwell model of plasmas, from which nearly all phenomena in collisionless plasmas can be derived.

My second credo as experimentalist is that there is a lack of plasma diagnostics in many textbooks. We humans have only an indirect experience of plasmas, we cannot touch, hear, smell or taste plasma. Even the visual impression of a plasma is only the radiation from embedded atoms. Therefore, we must use indirect evidence to deduce plasma properties, like density, temperature and motion. Each time my students have grasped the principle of a plasma process, I ask what we can learn about the plasma by studying this process.

In preparing this book, I have been supported by many colleagues. My special thanks go to John Goree, Thomas Klinger and André Melzer for many fruitful discussions which led to the concept of this book and for critically reading selected chapters. Holger Kersten commented on Chap. 11 and permitted photographing some of his gas discharges. Many examples in this book were taken from papers published together with my PhD students and Post-Docs, which I

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Acronyms

ac	alternating current
ADC	analog to digital converter
AGM	anode glow mode
CCD	charge coupled device
CME	coronal mass ejection
CRI	color rendering index
DAC	digital to analog converter
DAW	dust acoustic wave
dc	direct current
DDW	dust density wave
DIAW	dust ion-acoustic wave
DL	double layer
DS1	Deep Space-1
D-T	deuterium-tritium
EEDF	electron energy distribution function
EEPF	electron energy probability function
ES-1	electrostatic code 1
FCC	Federal Communications Committee
ICF	inertial confinement fusion
ICP	inductively coupled plasma
IRC	internal reflective coating
IRI	International Reference Ionosphere
ITER	International Thermonuclear Experimental Reactor
JET	Joint European Torus
LASCO	Large-Angle Spectrometric COronograph
MHD	magnetohydrodynamics
NASA	National Aeronautics and Space Administration
NIF	National Ignition Facility
NSTAR	NASA solar electric propulsion technology application readiness
PDP1	plasma device planar code
PIC	particle-in-cell
OML	orbital motion limit

rf	radio frequency
RIE	reactive ion etching
SMART-1	Small Missions for Advanced Research in Technology
STEREO	Solar TERrestrial RELations Observatory
SWOOPS	Solar Wind Observations Over the Poles of the Sun
TEXTOR	Tokamak Experiment for Technology Oriented Research
TFTR	Tokamak Fusion Test Reactor
TLM	temperature limited mode
TNT	trinitrotoluene
UV	ultraviolet
VCR	video cassette recorder
WIIa	Wendelstein IIa stellarator
W7-A	Wendelstein 7-A stellarator
W7-AS	Wendelstein 7 advanced stellarator
W7-X	Wendelstein 7-X stellarator