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# Surface Electron Cyclotron Waves in Plasmas

Springer

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# Preface

This book has been written as a result of theoretical studies which were carried out during the last forty years. It contains results of comprehensive investigations of properties of surface waves which propagate across an external static magnetic field at harmonics of the electron cyclotron frequency. The main objective of the authors was to collect material devoted to studying different characteristics of these transverse waves, namely—their dispersion properties and their dependence on various design peculiarities of plasma waveguides; their damping due to interaction with the plasma surface (this is the kinetic channel of their power dissipation) and due to collisions between plasma particles (this is the Ohmic channel of their power dissipation); their interaction with flows of charged particles that move above the plasma surface; their parametric excitation due to the effect of an external radiofrequency (RF) field and some aspects of their power transfer for sustaining gas discharges.

Thus, the material collected in this book will be useful for postgraduate plasma physics students and for experts, who are interested in the field of kinetic theory of plasmas or in applications of surface electron cyclotron waves.

The strongest interest of scientists in the development of plasma physics observed during more than the last fifty years is explained by a desire of mankind to use the knowledge gained in the field of research on magnetically confined plasmas for clean energy generation by controlled thermonuclear fusion. During this time, there was a significant evolution in views of physicists on the main mechanism of plasma heating in fusion reactors. Namely, in early years it was planned to utilize Ohmic heating, then at the present time the main mechanism is neutral beam injection (NBI). An additional method of plasma heating that is required for sustaining an optimal heating regime is electron cyclotron resonance heating (ECRH). Improvement of the heating and plasma confining methods in various fusion devices has contributed as well to advances in allied branches of plasma science such as plasma electronics, physics of gas discharges and collective phenomena in solid-state plasmas.

This latter statement is especially valid for cyclotron waves since they are utilized for plasma heating, non-inductive current drive, plasma stabilization and plasma diagnostics in fusion devices and also in all the branches of applied plasma physics mentioned above. However, the features of plasmas which are studied in these fields of applied sciences are different, and the conditions for plasma production and confinement are also different. In addition, it should be mentioned that under laboratory conditions the plasma volume is always finite with boundaries. Restricted space of a plasma especially affects the dispersion properties and spatial field distribution of those waves which can propagate in the plasma.

So we can highlight two joint features of the material presented here. First, magnetoactive plasmas are bounded, and second, the electromagnetic waves which propagate in these plasmas have frequencies at harmonics of the electron cyclotron resonance. This means that all presented theoretical results are obtained in the framework of the kinetic description, and that for all considered problems solutions of the kinetic equation have been obtained using a definite model of interaction between plasma particles and plasma interface.

This monograph contains materials devoted to three types of polarization of surface electron cyclotron waves: TM-modes, X (extraordinary)-modes and O (ordinary)-modes. Unlike the case of propagation of bulk cyclotron waves, surface cyclotron modes are eigenwaves of different bounded plasma structures; therefore, their properties essentially depend on geometrical peculiarities of the studied plasma structure and its design features, and not only on plasma parameters like temperature, particle density and value of an external magnetic field.

The material presented in this monograph is the result of a comprehensive study of these surface cyclotron wave modes. The contents include studying their dispersion properties, calculating their damping rates caused by both the Ohmic and kinetic channel of power dissipation, investigating the interaction between these modes and charged particle beams, studying the parametric excitation of these surface cyclotron modes due to the effect of an external RF field including a non-monochromatic RF field, and mechanisms of power transfer from these surface cyclotron modes to gas discharges.

The start of theoretical studying these eigenwaves has been done by Prof. A. Kondratenko, who was a scientific advisor of V. O. Girka. Later definite support for the investigation of these waves was provided by the Science and Technology Center in Ukraine. Some results of this study of surface electron cyclotron waves have been presented at the Joint Workshops on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating and published in the proceedings of these meetings. Regrettably, V. O. Girka passed away on 3 November 2015, when three of the five chapters of this book had been finished.

I. O. Girka is indebted to the grant of DAAD that allowed him to take part in the final preparation of the text for publication as a book at the Karlsruhe Institute for Technology (KIT). He is also very grateful to Prof. J. Jelonnek and colleagues in the High-Power Microwave Division of the Institute for Pulsed-Power and

Microwave Technology (IHM) at KIT for a lot of fruitful discussions and their kind hospitality. The authors also thank Dr. I. Pavlenko for very fruitful discussions on several issues of this monograph.

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