Preface

Our knowledge of the properties of intensity-dependent beam instabilities has grown tremendously in the last several decades, owing to the introduction of more precise instrumentation and very much faster digital computers. Every few years, a new beam instability is discovered and an ingenious new method to cure an instability is proposed. Here, I am having the pleasure of introducing them to my readers and sharing with them my personal views and understanding.

The subject on intensity dependent instabilities is important in the field of accelerator physics. The thresholds and growth rates of these instabilities very often determine the upper limit of the particle beam intensity, the lower limit of the bunch sizes, the minimum aperture of the vacuum chamber, the smoothness of the chamber walls, and have a lot of influence on the design of all the beam-related elements such as diagnosis detectors, kickers, beam separators, beam collimators, etc. The understanding of how instabilities are generated and the various ways to contain them has become an essential part of operating an existing accelerator and in the design of future machines.

The first chapter is devoted to a review of the basic concept of wake potentials and coupling impedances in the vacuum chamber, which enables the formulation of the static and dynamic contributions to the equations of motion. Static solutions are then given, followed by the consequence of beam instabilities and the result of possible beam loss. The dynamic solutions lead to intensity-dependent instabilities, some of which are collective effects and some are not. While some of these instabilities exhibit thresholds, some do not. Special emphasis are made separately on proton and electron machines, because these two categories are so different in lattice design, in beam storage operation, and in beam structure. Other special topics of interest covered include Landau damping, Balakin–Novokhatsky–Smirnov damping, Sacherer's integral equations, Landau cavity, saw-tooth instability, Robinson stability criteria, beam loading, transition crossing, two-stream instabilities, and collective instability issues of isochronous rings.

The readers will find this book theory oriented, because the basic features of the instabilities are laid out by mathematics. However, we try every means to minimize the use of mathematics, especially at the beginning, so that the readers can grasp the mechanism of the instabilities rather than become lost in the jungle of formulas and equations. For example, Sacherer's integral equation is not introduced and derived until Chapter 8, while its formal solution in terms of orthogonal polynomials is delayed until Chapter 9. Except for some geometrical concepts that may be accepted intuitively, the presentation here is intended to be rigorous and self-contained. Nearly all the formulas and equations employed in the book are derived or given guidelines to be derived in the exercises at the end of each chapter. The introduction of an instability is mostly followed by a thorough description of one or more experimental observations together with different methods of cures.

This book is an outgrowth from the lecture notes of two courses "Physics of Collective Beam Instabilities" and "Physics of Intensity Dependent Instabilities" given in the 2000 and 2002 at the U.S. Particle Accelerator School. I wish to thank my colleagues and students for countless helpful remarks. The material in this book can serve as subject matter for a graduate physics course in accelerator physics. A preliminary background in classical electrodynamics and basic knowledge of accelerator physics will be required.

Because the book is composed of a number of lectures, there has been an initial intention of writing each chapter as independent as possible. Although such an intention does not materialize completely, however, I do have some formulas depicted more than once, some notations defined more than once, and some concepts construed more than once throughout the book. While some consider it long-winded, I consider it a merit, because the readers may find it convenient when they wish to jump into a chapter or a section without the necessity of starting from the first page of the book.

To conclude, I would like to express both regret and pleasure. The range of topics discussed and the pace of their development have made the writing of an adequate bibliography impossible. I have therefore chosen to refer primarily to those papers from which I happened to have learned certain things. Consequently, inadequate recognition is frequently given to the originators of certain ideas, fundamental or technical, and apologies are undoubtedly due to a number of my colleagues. Inevitably there will be errors in the manuscript coming both from careless typos and something beyond my present understanding. Comments and corrections are welcome and can be sent to NG@FNAL.GOV.

The pleasure comes from the opportunity to express appreciation to those contributed to the existence and final form of the book. My utmost thanks go to Dr. P. Colestock, Professor S.Y. Lee, and Dr. M. Syphers, who provided the necessary encouragement for the writing of the book. Particular appreciation goes to Dr. C. Ankenbrandt who carefully read the manuscripts of my 2000 lecture notes and 2002 lecture notes of the U.S. Accelerator School, which form the basis of this book. I am grateful to many of my colleagues for numerous discussions and final clarification of many ambiguities, paradoxes, and difficulties that popped up in the course of writing the book. To mention a few, they include Professor A. W. Chao, Professor R. Gluckstern, Dr. G. Lambertson, Dr. F. Ostiguy, Dr. T.S. Wang, Dr. B. Zotter, and many others. Ultimately, my greatest thanks go to my wife whose constant understanding, encouragement, and support have been essential to the completion of the book.

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