Lecture Notes in Physics

102

Heinrich Hora

Nonlinear Plasma Dynamics at Laser Irradiation

Notes from lectures presented during the winter semester 1978/79 at the Department of Laser Physics, Institute of Applied Physics University Berne, Switzerland, written under editorial assistance of P. Schwarzenbach

Springer-Verlag
Berlin Heidelberg New York 1979

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ISBN 3-540-09502-0 Springer-Verlag Berlin Heidelberg New York
ISBN 0-387-09502-0 Springer-Verlag New York Heidelberg Berlin

Library of Congress Cataloging in Publication Data. Hora, Heinrich, 1931- Nonlinear plasma dynamics at laser irradiation. (Lecture notes in physics ; 102) Bibliography: p. Includes index. 1. Plasma dynamics. 2. Laser plasmas. 3. Nonlinear theories. I. Title. II. Series. QC718.5.D9H67 530.4'4 79-15466

Printing and binding: Beltz Offsetdruck, Hemsbach/Bergstr.
2153/3140-543210

PREFACE

Lecture notes, to which the author was invited by the publisher Springer, Heidelberg, are a very appropriate medium to distribute a synopsis of such a very fast moving field as the physical concepts of laser plasma interaction. The present effort of about 400 Mill Dollars spent per year in this field is stimulated by the goal of finding one possible way to solve the most challenging task of this century: low cost, safe, inexhaustive, and highly concentrated energy production by fusion using lasers. The laser technology is a spin-off of electronics engineering and plasma physics is a field of mechanical engineering of fluids. Compared with the presently dominating fields of physics, elementary particle physics and solid state physics, laser produced plasmas is considered not without restrictions as a field of physics, though Einsteins derivation of the laser priniciple in 1916 was one of the mile stones in physics of our century in the rank of Dirac's discovery or antimatter. Both results were not the intention of research and even could not be dreamed of before their theoretical discovery and ingenious interpretation.

The physics behind laser plasma dynamics does not need a development of new basic concepts. The existing hydrodynamics, Maxwell-Lorentz electrodynamic theory, quantum mechanics, and relativity is - at least at present - sufficient to describe the phenomena. Based on these theories, however, several new formulations were necessary for the high intensity laser plasma interaction. There was the need to extend the optical constants to a nonlinear dependence on the laser intensity and to include relativistic effects if the oscillation energy of the electrons in the laser field exceeded $m_e c^2$. These questions provided an access for rediscussing the black body radiation, for a physical argument to derive the fine structure constant, and to solve the Abraham-Minkowski dilemma - to mention some spin-offs in basic physics.

Coming back to the question of laser plasma interaction, the physics for the application of material treatment, or of plasma compression for laser fusion, or of generation of super-relativistic intensities for pair production or MeV heavy ion generation, required several new developments as the approriate formultion of the nonlinear equation of motion, modifications of the energy law, the development of a detailed knowledge of the propagation of waves in inhomogeneous media and the processes of self focussing. A lot of these problems have been solved. Other less solved problems are the solutions for time dependent processes

and several complications of the plasma and wave behaviour at oblique incidence of the radiation. Further complications arise from the generated static magnetic field induced by the interaction of small diameter laser beams with plasma - only to mention few of the futural problems.

The whole development is still at a fast motion. Nevertheless there are several facts which have been achieved now, which can be presented as settled standard knowledge in an introductory lecture including remarks - even remarks of some hypothetical nature - about unsolved aspects for stimulation of research into the one or other direction. The author is aware that despite of intensive work of the preparation of these notes, several misprints and less accurate formulations will have been overlooked. Helpful comments of the readers for a further preparation of a similar manuscript will be gratefully wellcommed. Encouraging comments of leading scientists in this field in the USA were the basis for the decision not to lose further time for the preparation of the notes and making them absolute.

It is a great pleasure to express my great thanks to Dipl.Phys.(ETH) P. Schwarzenbach for his intensive work in assisting the writing and correcting and clearing several formulations of the manuscript. His precise way of thinking as a well trained physicist improved several points of the text. Very strong work was done by Miss C. Weber in typing parts of the manuscripts and correcting and arranging the final version on a Vydec writer. The author is indebted to great thanks.

I gratefully acknowledge the very appreciable invitation by Professor H.P.Weber, Head of the Department of Laser Physics, University of Berne, to spend a sabbatical leave there and for stimulating discussions with him and his staff, especially with Dr.T.P.Donaldson, Dr.J.Balmer, Dr.E.Stürmer, Dipl.Phys. P.Laedrach and others. Thanks are due to Professor E. Schanda, Director of the Institute of Applied Physics,University of Berne, due to the University of New South Wales for granting Study Leave, Mr. Alfred and Mrs. Luella Slaner and Dr. G. Brumlik from the Slaner Foundation, New York, for support, Professor G.H.Miley, Chairman of the Nuclear Engineering Department of the University of Illinois for support, and the Australian Research Grant Commitee for support by Grant Nr. 75/15538; 15-001-71.

Berne, Febr. 1979. Heinrich Hora

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