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102

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Nonlinear Plasma Dynamics at Laser Irradiation

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of Laser Physics, Institute of Applied Physics,
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editorial assistance of P. Schwarzenbach



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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 principle in 1916 was one of the milestones in physics of our century in the rank of Dirac's discovery of 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 appropriate formulation 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 wellcomed. 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 Committee for support by Grant Nr. 75/15538; 15-001-71.

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TABLE OF CONTENTS

Preface	V
1) Aim and Scope	1
2) Review of Phenomena	7
3) Elements of Microscopic Plasma Theorie	19
Plasma Frequency and Debye Length	21
Plasmons	26
Cyclotron Frequency	29
Collisions	31
4) Hydrodynamics	37
Euler's Equation of Motion	37
Bernoulli's stationary Solution	38
Equation of Continuity	39
Compressibility	40
Acoustic Waves	41
Equation of Energy	43
5) Self-Similarity Model	45
Hydrodynamic Deviation	46
Laser Irradiation with Varying Radius	49
Numerical Example	53
Application to Foils	55
6) Plasma Dynamics and Lorentz Theory	58
The Schlueter Equation of Motion	58
Electrodynamic Equations	59
Refractive Index of Plasma and its Relation to Absorption	64
Nonlinear and Relativistic Absorption	71
7) Waves in Inhomogeneous Plasma	76
WKB Solution for Perpendicular Incidence	77
Oblique Incidence and WKB Solution	79
The Rayleigh Profile	84
The Airy Profiles	94
8) Equation of Motion	96
Collisional Term of the Nonlinear Force	97
Equivalence to Maxwellian Stress Tensor	104
Obliquely Incident Plane Waves	108
Summary	111
9) Momentum Transfer and the Abraham-Minkowski Problem	113
Range of Predominance of the Nonlinear Force	114
Momentum Transfer to the Plasma Corona and Compression	117

VIII

Energy Transfer by Integration of the Nonlinear Force	120
Photon Momentum in Plasma (Abraham-Minkowski)	122
Summary	128
10) Numerical and Experimental Examples - Solitons	129
Thermokinetic Forces	129
Static Cases with Nonlinear Forces	134
Approximative Dynamic Cases - Cavitons	137
Experimental Examples	147
Acceleration of Thick Blocks and Solitons	150
Parametric Instabilities	163
11) Striated Motion and Resonance Absorption	165
Striated Motion	165
Resonance Absorption	179
12) Self-Focussing of Laser Beams in Plasma	189
Nonlinear-Force- (Ponderomotive) Self-Focussing	190
Relativistic Self-Focussing	193
Laser Beams in Tenuous Plasmas and Spontaneous Magnetic Fields	201
Conclusions for Medium Laser Intensities	204
Conclusions for Very High Laser Intensities	206
13) Laser Compression of Plasma for Nuclear Fusion	211
Results on Laser Fusion	211
Requirement for Laser Fusion	214
Laser Pellet Compression Schemes	215
Fusion Gain Calculations	219
Conclusions	222
Index (References, Names, Subjects)	223