

CONTENTS

Preface

xvii

PART I TUTORIAL

- 1 Energy and Momentum Conservation Requirements
for Electron Interactions with Electromagnetic
Radiation 1

R. H. Pantell

A tutorial presentation of energy and momentum conservation requirements for electron interactions with electromagnetic radiation.

- 2 Energy Exchange Between Free Electrons and an
Electromagnetic Field 15

*R. H. Pantell, W. D. Kimura, J. A.
Edighoffer, and M. A. Piestrup*

A tutorial presentation of energy exchange between free electrons and an electromagnetic field.

- 3 The Free-Electron Laser from a Laser-Physics
Perspective 31

*Frederic A. Hopf, Thomas G. Kuper, Gerald T.
Moore, and Marlan O. Scully*

A theory of FELs in non-collective regime is considered with special emphasis on the role of coherent transients in the Stanford experiment, and a theory of FEL behavior is presented with special emphasis on pulse propagation and coherent transient phenomena. It is found that coherent transient effects such as laser lethargy are crucial in understanding the Stanford experiments. The theory is extended to deal with high levels of saturation power.

- 4 Variable Parameter Free-Electron Laser 89

*N. M. Kroll, P. L. Morton, and M. N.
Rosenbluth*

By proper variation of wiggler parameters, it is possible to obtain tremendous improvement of a variable parameter wiggler over the constant parameter wiggler.

- 5 Enhanced Energy Extraction in Free-Electron
Lasers by Means of Adiabatic Decrease of
Resonant Energy 113
*Norman M. Kroll, Philip L. Morton, and
Marshall N. Rosenbluth*
A discussion of FEL oscillators and amplifiers
which make use of adiabatic decrease of resonant
energy (Chap. 4) to enhance electron efficiency.
- 6 Sideband Instabilities in Trapped Particle Free-
Electron Lasers 147
Norman M. Kroll and Marshall N. Rosenbluth
We find that in a low-gain FEL oscillator lower
sideband instabilities tend to grow.
- 7 A Tutorial Summary of the Theory of Variable
Wiggler Free-Electron Lasers as Well as a
Summary of Some Proposed Experiments 175
A. Szöke, V. K. Neil, and D. Prosnitz
A tutorial summary of the theory of variable
wiggler free-electron lasers, based mostly on
the original work of Kroll et al., in this volume.
- 8 The General Non-linear Theory of Free-Electron
Laser and Efficiency Enhancement 207
P. Sprangle, Cha-Mei Tang, and W. M. Manheimer
A general self-consistent nonlinear theory of the
FEL, including numerical and analytical results.
- 9 Cerenkov and Cerenkov-Raman Radiation Sources 255
John E. Walsh
A tutorial discussion of practical radiation
sources which make use of the stimulated as well
as spontaneous Cerenkov emission processes.
- 10 Cerenkov and Cerenkov-Raman Masers:
Experiments 301
*K. L. Felch, K. O. Busby, R. W. Layman,
and J. E. Walsh*
A description of Cerenkov radiation and Cerenkov-
Raman scattering experiments performed at Dartmouth
College.

PART II GENERAL INTEREST

- 11 Interaction of Electrons and Pump Fields at
Superluminal Electron Velocities 323
Stanley Schneider and Richard Spitzer
A discussion of potential advantages of combining
a superluminal drift velocity with an oscillatory
motion about that drift velocity.
- 12 Relativistic Synchrotron Radiation in a Medium
and Its Implications for SESR 355
Norman M. Kroll
The process referred to as stimulated electro-
magnetic shock radiation (SESR) is quantitatively
quite similar to Cerenkov radiation, and we find
no evidence to support claims of "much greater
intensity" or narrower band radiation.
- 13 The Free-Electron Laser: Maxwell's Equations
Driven by Single-Particle Currents 377
W. B. Colson and S. K. Ride
Single-particle dynamics are used to determine
the transverse current in Maxwell's equations.
This gives a self-consistent electron evolution
which is used to discuss effects of ultrashort
pulses. The method permits detailed comparison
with experimental results and leads to a FEL
phase transition analogy.
- 14 Synchrotron Radiation Problems in Storage Ring
Version of FEL 415
C. Pellegrini
Main properties of synchrotron radiation are
reviewed. A description is given of how synchro-
tron radiation determines beam emittance and af-
fects operation in a storage ring.

- 15 Numerical Calculation of the Evolution of the
Electron Distribution Function in the Free-
Electron Laser 429
Claudio G. Parazzoli and Robert P. Korechhoff
FEL performance is calculated using the coupled
Vlasov-Maxwell equations. The method includes
effects of electrostatic repulsion for low energy
electron beams and treats high energy operation.
The theory is cast in a form suitable for numeri-
cal analysis.
- 16 Electron Rebunching and Radiation Gain in Two-
Element Free-Electron Lasers 473
C. Shih and A. Yariv
Interaction between electrons and radiation in a
FEL leads to a shift and a spread of the electron
velocity distribution. The shift-spread ratio
determines efficiency of a FEL which recirculates
electrons. This efficiency can be increased by
introducing an adjustable drift distance between
two identical wigglers.
- 17 An Investigation of Efficiency Optimization in
Free-Electron Lasers 491
Thomas J. T. Kwan
From results of computer simulations it is shown
that efficiency of energy extraction maximizes at
a particular initial intensity. A criterion is
obtained which predicts accurately the optimum
intensity of the electromagnetic radiation.
- 18 The Collective Free-Electron Laser 509
D. B. McDermott and T. C. Marshall
Performance of a tunable FEL operated by Columbia-
NRL in the stimulated Raman scattering regime is
discussed.

- 19 Optimized Operation of a Free-Electron Laser,
 Spanning the Single Particle and Collective
 Regimes: Theory and Experiment 523

M. Zales Caponi, J. Munch, and H. Boehmer

A Vlasov-Maxwell FEL theory is given that spans the single and collective particle regimes. The theory is used to explain experiments at microwave wavelengths.

- 20 Particle Simulation of Free-Electron Laser 555

A. T. Lin and J. M. Dawson

It is proposed that, by properly varying the ripple strength of a FEL, the efficiency can be substantially increased, along with other benefits such as narrow bandwidth and shorter device length.

PART III VARIABLE WIGGLERS

- 21 One-Dimensional Computer Simulation of the
Variable Wiggler Free-Electron Laser 571

D. Prosnitz, A. Szöke, and V. K. Neil

The results of a one-dimensional computer simulation of a variable wiggler FEL amplifier are presented. The advantages of high current density operation are discussed.

- 22 Free-Electron Laser Interaction in a Variable Pitch Wiggler 589

S. A. Mani

We discuss the theory of FELs with variable pitch and variable magnetic field strengths and suggest a method of using a storage ring beam for overall efficiency of $\sim 10\%$.

23	Single-Particle Approach to Free-Electron Lasers with Tapered Wigglers	623
	<i>William H. Louisell, Cyrus D. Cantrell, and William A. Wegener</i>	
	A numerical method based on following the motion of representative particles is developed for the self-consistent, nonperturbative solution of Maxwell's equations and the electron equations of motion, including longitudinal variation of the wiggler magnetic field and both transverse and longitudinal variation of the laser electric field, but excluding effects of space charge.	
24	Variable Wiggler Optimization	647
	<i>Charles A. Brau and Richard K. Cooper</i>	
	The proposed LASL low-gain FEL experiment is described. Energy extraction efficiency of 5.3% is predicted.	
PART IV	RESEARCH INTERESTS	
25	Theoretical Considerations for FEL'S in the Far Infrared	665
	<i>E. D. Shaw and C. K. N. Patel</i>	
	Design considerations for an FEL oscillator to operate in the 100-400 μm range are discussed.	
26	X-Rays From a Free-Electron Laser	671
	<i>A. Lewis Licht</i>	
	It is shown that the FEL is potentially a rather strong source of x-rays if the electron recoil energy can be made much greater than the electron energy spread.	

- 27 Beam Heating Constraints on a Low-Voltage Free-Electron Laser with Visible Output 681

D. A. Reilly, M. S. Tekula, and R. M. Patrick

A scheme for a low-voltage FEL using an infrared laser pump is presented. Appropriate choice of parameter leads to efficient conversion and precludes plasma mode instabilities. A scaling law is presented.

- 28 A Free-Electron Laser Based on Periodic Longitudinal Electrostatic Bremsstrahlung 701

Avraham Gover

A laser mechanism is analyzed in which the electron beam is longitudinally modulated by a longitudinally electrostatic force, facilitating interaction of the electron beam with a regular superluminal TM electromagnetic waveguide mode.

- 29 Variable Period Free-Electron Laser Amplifier Simulation Studies 729

H. R. Hiddleston, S. B. Segall, and G. C. Catella

An initial parameter study to determine the fraction of the electron kinetic energy converted to photon energy and the resultant electron energy spread produced for a single-pass of an electron beam through an FEL amplifier with 99% trapping.

- 30 Equations of Motion for a Free-Electron Laser With a Transverse Gradient 741

John M. J. Madey and Robert C. Taber

Introduction of a transverse gradient in the periodic magnet field of a FEL couples transverse motion of the electrons to their energy and phase and can dramatically alter the gain and saturation characteristics. Equations of motion are derived, and effects of the gradient on laser operation are reviewed.

31	Stimulated Electromagnetic Shock Radiation (SESR) When the Angle Between the Electron Velocity and the External Field Direction is Arbitrary	779
	<i>W. W. Zachary</i>	
	Interaction between a plane electromagnetic wave and a charged particle travelling through a di- electric with velocity arbitrary in direction and greater than the velocity of light in the medium is considered.	
32	An X-Ray Relativistic Free-Electron Frequency Upconverter	789
	<i>Francesco De Martini</i>	
	Reduced gain at low frequencies may preclude future operation of FELs in the UV and x-ray regions. Alternatively, formation of a "coherent" array of electrons and the coherent scattering by this array of an incident radiation field is proposed.	
	Index	807