

# Infrared and Millimeter Waves

VOLUME 5  
COHERENT SOURCES  
AND APPLICATIONS,  
Part I

*Edited by*  
***Kenneth J. Button***

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MILLIMETER WAVES**

**VOLUME 5 COHERENT SOURCES  
AND APPLICATIONS, PART I**

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*Edited by*      **KENNETH J. BUTTON**

NATIONAL MAGNET LABORATORY  
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# CONTENTS

LIST OF CONTRIBUTORS	vii
PREFACE	ix
CONTENTS OF OTHER VOLUMES	xi

## Chapter 1 Coherent Sources and Scientific Applications

*Benjamin Lax*

I. Introduction	1
II. Coherent Sources	2
III. Scientific Applications	9
IV. Conclusion	25
References	25

## Chapter 2 Molecular Spectroscopy by Far-Infrared Laser Emission

*J. O. Henningsen*

I. The Tools	29
II. CH <sub>3</sub> OH—A Case Story	57
References	124

## Chapter 3 Stark Spectroscopy and Frequency Tuning in Optically Pumped Far-Infrared Molecular Lasers

*F. Strumia and M. Inguscio*

I. Introduction	130
II. Stark Effect in Polar Molecules	133
III. Laser Gain Curves in the Presence of an Electric Field	139
IV. General Performances of Optically Pumped FIR Lasers	155
V. Experimental Results—dc Electric Fields	176
VI. Experimental Results—ac Electric Fields	204
VII. Conclusion	208
References	210

**Chapter 4 The GaAs TUNNETT Diodes***Jun-ichi Nishizawa*

I. Introduction	215
II. TUNNETT Diode	238
III. Future of TUNNETT	260
IV. Conclusion	264
References	265

**Chapter 5 Measured Performance of Gyrotron Oscillators and Amplifiers***V. L. Granatstein, M. E. Read, and L. R. Barnett*

I. Introduction	267
II. Gyrotron Traveling-Wave Tube Amplifiers	272
III. Gyromonotron Oscillators	281
Appendix. Measurement Methods	298
References	301

**Chapter 6 Distributed-Feedback Gas Lasers***F. K. Kneubühl and E. Affolter*

I. Introduction	305
II. Dispersion Relations Based on Hill's Equation	308
III. Resonance Conditions	311
IV. DFB in Periodic Metal Guides	314
V. DFB Gas Laser in Operation	322
VI. Future Developments	334
References	335

## LIST OF CONTRIBUTORS

Numbers in parentheses indicate the pages on which the authors' contributions begin.

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## PREFACE

The subject of sources of radiation will become a subset of volumes, consisting so far of Volume 1 (Sources of Radiation), Volume 5 (Coherent Sources and Applications, Part I), and Volume 7 (Coherent Sources and Applications, Part II). Volume 1 dealt with gyrotrons, free electron lasers, IMPATT devices, pulsed optically pumped lasers, backward wave oscillators, and the ledatron. This was far from complete, of course, so we have tried to arrange for complete coverage as quickly as possible. Professor Kneubühl and Professor Sturzenegger gave us “Electrically Excited Submillimeter-Wave Lasers” in time to be published as Chapter 5 in Volume 3. Now Professor Kneubühl and Professor Affolter have given us “Distributed-Feedback Gas Lasers” as Chapter 6 in this book. In Volume 4 (Millimeter Systems), N. Bruce Kramer gave us full coverage of traveling-wave tubes, IMPATT and Gunn diodes. We are still waiting for someone to write up the very important extended interaction oscillator and amplifier. We do have the GaAs TUNNETT diodes in this book (Chapter 4), written by Professor Nishizawa, who originally developed this device.

As we continue to develop this subset on sources of millimeter and far-infrared radiation, we have the space to include a broader treatment by dealing with *performance* and *applications*. The keynote of this book, Volume 5, is the opening chapter on coherent sources and their scientific applications by Professor Benjamin Lax. This is followed by a very comprehensive treatment of spectroscopy of molecules by far-infrared laser emission prepared by Professor J. O. Henningsen. A similarly comprehensive treatment of Stark spectroscopy and frequency tuning in optically pumped far-infrared molecular lasers is given by Professor F. Strumia and Professor M. Inguscio. Then we were quite fortunate to get a follow-up on gyrotron oscillators and amplifiers in the form of “Measured Performance of Gyrotron Oscillators and Amplifiers” (Chapter 5) by some of the leaders of the outstanding group at Naval Research Laboratory, Dr. V. L. Granatstein, Dr. M. E. Read, and Dr. L. R. Barnett.

Volume 7 (Coherent Sources and Applications, Part II), will open with “CW Optically Pumped Lasers” by Professor Thomas A. DeTemple and Dr. E. Danielewicz. Professor DeTemple had already published his contribution on pulsed optically pumped far-infrared lasers in Volume 1. This

will be followed by a chapter on mid-infrared optically pumped molecular lasers by Robert G. Harrison and Pradeep K. Gupta and a short chapter on the optimization of optically pumped far-infrared lasers by Dr. Konrad Walzer.

Dr. Philip Sprangle, who is also one of the leaders of the outstanding Plasma Physics Division of the Naval Research Laboratory, has contributed a chapter on free-electron lasers to Volume 7 as a complement to his theoretical chapter on the subject that appeared in Volume 1. Following this is a treatment of the oratron, originally known as the Smith–Purcell free-electron laser, which is a promising version of the FEL for generating coherent millimeter- and submillimeter-wave radiation. A definitive chapter describing this device has been prepared by Dr. Donald E. Wortman and Dr. Richard P. Leavitt to appear in Volume 7 (Coherent Sources and Applications, Part II). In this third book of the subset on sources, we shall have space to expand again into the applications with a chapter on high-frequency gyrotrons and applications to tokamak plasma heating by Kenneth E. Kreischer and Richard J. Temkin of the Plasma Fusion Center at M.I.T. This chapter was commissioned for the forthcoming volume on tokamak plasma diagnostics but its originality and the importance of its concepts earned it early publication in Coherent Sources and Applications, Part II. The subject of nonlinear frequency conversion in bulk crystals and semiconductor diodes will be developed by Dr. Dane D. Bicanic in “Generation of Tunable Laser Sidebands in the Terahertz Region by Frequency Mixing of the HCN Laser and a Microwave Source in a Metal–Semiconductor Diode”. The basic subject of metal–semiconductor junctions as frequency converters has been covered by Dr. Martin V. Schneider in Chapter 4 of Volume 6.

## CONTENTS OF OTHER VOLUMES

### **Volume 1: Sources of Radiation**

*J. L. Hirshfield*, Gyrotrons

*H. J. Kuno*, IMPATT Devices for Generation of Millimeter Waves

*Thomas A. DeTemple*, Pulsed Optically Pumped Far Infrared Lasers

*G. Kantorowicz and P. Palluel*, Backward Wave Oscillators

*K. Mizuno and S. Ono*, The Ledatron

*F. K. Kneubühl and E. Affolter*, Infrared and Submillimeter-Wave Waveguides

*P. Sprangle, Robert A. Smith, and V. L. Granatstein*, Free Electron Lasers and Stimulated Scattering from Relativistic Electron Beams

### **Volume 2: Instrumentation**

*N. C. Luhmann, Jr.*, Instrumentation and Techniques for Plasma Diagnostics: An Overview

*D. Véron*, Submillimeter Interferometry of High-Density Plasmas

*J. R. Birch and T. J. Parker*, Dispersive Fourier Transform Spectroscopy

*B. L. Bean and S. Perkowitz*, Far Infrared Submillimeter Spectroscopy with an Optically Pumped Laser

*Wallace M. Manheimer*, Electron Cyclotron Heating of Tokamaks

### **Volume 3: Submillimeter Techniques**

*T. G. Blaney*, Detection Techniques at Short Millimeter and Submillimeter Wavelengths: An Overview

*W. M. Kelley and G. T. Wrixon*, Optimization of Schottky-Barrier Diodes for Low-Noise, Low-Conversion Loss Operation at Near-Millimeter Wavelengths

*A. Hadni*, Pyroelectricity and Pyroelectric Detectors

*A. F. Gibson and M. F. Kimmitt*, Photon Drag Detection

*F. W. Kneubühl and Ch. Sturzenegger*, Electrically Excited Submillimeter-Wave Lasers

*Michael von Ortenberg*, Submillimeter Magnetospectroscopy of Charge Carriers in Semiconductors by Use of the Strip-Line Technique  
*Eizo Otsuka*, Cyclotron Resonance and Related Studies of Semiconductors in Off-Thermal Equilibrium

#### **Volume 4: Millimeter Systems**

*James C. Wiltse*, Introduction and Overview of Millimeter Waves  
*Edward K. Reedy and George W. Ewell*, Millimeter Radar  
*Charles R. Seashore*, Missile Guidance  
*N. Bruce Kramer*, Sources of Millimeter-Wave Radiation: Traveling-Wave Tube and Solid-State Sources  
*Tatsuo Itoh*, Dielectric Waveguide-Type Millimeter-Wave Integrated Circuits  
*M. Tsuji, H. Shigesawa, and K. Takiyama*, Submillimeter Guided Wave Experiments with Dielectric Waveguides  
*Gary A. Gordon, Richard L. Hartman, and Paul W. Kruse*, Imaging-Mode Operation of Active NMMW Systems --

#### **Volume 6: Systems and Components**

*J. E. Harries*, Infrared and Submillimeter Spectroscopy of the Atmosphere  
*D. H. Martin*, Polarizing (Martin–Puplett) Interferometric Spectrometers for the Near- and Submillimeter Spectra  
*P. L. Richards and L. T. Greenberg*, Infrared Detectors for Low Background Astronomy  
*M. V. Schneider*, Metal–Semiconductor Junctions as Frequency Converters  
*Paul F. Goldsmith*, Quasi-Optical Techniques at Millimeter and Submillimeter Wavelengths  
*G. D. Holah*, Far-Infrared and Submillimeter Wavelength Filters

#### **Volume 7: Coherent Sources and Applications, Part II**

*Thomas A. DeTemple and E. Danielewicz*, CW Optically Pumped Lasers  
*Robert G. Harrison and Pradeep K. Gupta*, Mid-Infrared Optically Pumped Molecular Gas Lasers  
*Konrad Walzer*, On the Optimization of Optically Pumped Far-Infrared Lasers  
*J. P. Pichamuthu*, Submillimeter Lasers with Electrical, Chemical, and Incoherent Optical Excitation.

*Dane D. Bicanic*, Generation of Tunable Laser Sidebands in the Terahertz Region by Frequency Mixing of the HCN Laser and a Microwave Source in a Metal–Semiconductor Diode

*Philip Sprangle*, Quasi-Optical Laser

*Donald E. Wortman and Richard P. Leavitt*, The Oratron

*Kenneth E. Kreischer and Richard J. Temkin*, High-Frequency Gyrotrons and Applications to Tokamak Plasma Heating

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**INFRARED AND  
MILLIMETER WAVES**

**VOLUME 5 COHERENT SOURCES  
AND APPLICATIONS, PART I**



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**CHAPTER 1**

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**Coherent Sources and Scientific Applications**

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I.	INTRODUCTION	1
II.	COHERENT SOURCES	2
	A. <i>Harmonic Generation and Nonlinear Mixing</i>	2
	B. <i>Optical Pumping</i>	5
	C. <i>Electronic Devices</i>	6
	D. <i>The Free-Electron Laser</i>	8
III.	SCIENTIFIC APPLICATIONS	9
	A. <i>Cyclotron Resonance</i>	9
	B. <i>Magneto-Optical Effects and the Spin-Flip Laser</i>	14
	C. <i>Raman Transitions in Submillimeter Lasers</i>	15
	D. <i>Plasma Diagnostics</i>	18
	E. <i>Motional Stark Spectroscopy</i>	21
IV.	CONCLUSION	25
	REFERENCES	25

**I. Introduction**

Coherent sources for resonance spectroscopy now extend from the microwave to the ultraviolet region. Pioneers in this area of research, such as Professor Gordy, began with microwave sources that were developed during World War II for radar. The challenges of spectroscopy demanded coherent sources at shorter wavelengths. One of the first techniques for this purpose was to use harmonic generation of a microwave source and a crystal multiplier to obtain 5-mm radiation (Beringer, 1946). Professor Gordy and his students adapted this technique to make tunable millimeter sources in 1948 to study a variety of molecules (Gordy, 1948). During subsequent years they made numerous such measurements of gaseous mole-

\* Supported by the National Science Foundation.