

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE  
V. N. KARAZIN KHARKIV NATIONAL UNIVERSITY

**FORMATION AND SELECTION  
OF TRANSVERSE MODES  
IN LASER CAVITIES**

Monograph

Kharkiv – 2021

УДК 621.373.826  
F 75

**Reviewers:**

**P. N. Melezhik** – Academician of NASU, Dr. Sci. (Physics & Mathematics), Director of O. Ya. Usikov Institute for Radiophysics and Electronics, National Academy of Sciences of Ukraine;

**O. O. Shmatko** – Dr. Sci. (Physics & Mathematics), Professor of Microwave Frequencies Physics Department, V. N. Karazin Kharkiv National University;

**M. G. Kokodii** – Dr. Sci. (Physics & Mathematics), Professor of Physics Department, National University of Pharmacy.

*Approved for publication by the decision on the Academic Council  
of V. N. Karazin Kharkiv National University  
(Protocol № 4 of March 29, 2021)*

F 75 Formation and selection of transverse modes in laser cavities :  
monograph / A. V. Degtyarev, V. O. Maslov, V. A. Svich, O. M. Topkov. –  
Kharkiv : V. N. Karazin Kharkiv National University, 2021. – 180 p.

ISBN 978-966-285-707-8

The monograph summarizes the results of studies on the development and implementation of methods for shaping wave beams of a specified profile in open and waveguide resonators of infrared and terahertz gas lasers. Methods are described that allow the angular selection of modes during the tuning of laser cavities containing open and waveguide sections.

The monograph is intended for a wide range of scientists and engineers specializing in the field of laser physics and technology. The book will also be useful to teachers, graduate students and senior students of radiophysical and physical specialties studying the theory and practical methods of constructing optical systems and diffraction problems.

**УДК 621.373.826**

ISBN 978-966-285-707-8

© V. N. Karazin Kharkiv National University, 2021

© Degtyarev A. V., Maslov V. O.,

Svich V. A., Topkov O. M., 2021

© Chorna O. D., design of cover, 2021

# CONTENTS

<b>List of notations</b> .....	5
<b>Preface</b> .....	6
<b>Introduction</b> .....	8
<b>CHAPTER 1 Spatial Fourier-filtration Method for Mode Formation with a Specified Output Radiation Profile in Laser Resonators</b> .....	13
1.1 Fourier-mode Formation in Open Two-mirror Resonators .....	14
1.1.1 Integral Equations of Open Resonators in Terms of Fourier Optics. Analytical Substantiation of Fourier Mode Existence with Uniform Output Radiation Profile.....	14
1.1.2 Numerical Solution of Integral Equation for Two-mirror Resonator with Fundamental Type of Oscillations in Form of a Fourier Mode .....	17
1.2 Integral Equations of Generalized Confocal Resonators in Terms of Fourier Optics .....	23
1.2.1 Resonators with Rectangular Plane Mirrors.....	23
1.2.2 Resonators with Circular Spherical Mirrors.....	28
1.3 Numerical Solution of the Integral Equation for Laser Resonator .....	33
1.3.1 Equations of Electromagnetic Field and Features of Active Media of Gas Lasers. Stability Criterion for Generated Modes .....	33
1.3.2 Numerical Algorithm of Integral Equation Calculation for a Resonator with an Active Medium.....	38
1.4 Selective Excitation of Gaussian Modes of Higher Types in Generalized Confocal Resonator.....	43
<b>CHAPTER 2 Formation of a Mode with a Quasi-uniform Profile of Output Radiation in a CW CO<sub>2</sub> Lasers</b> .....	48
2.1 CO <sub>2</sub> Laser with an Amplitude-stepped Mirror .....	49
2.1.1 Calculated Characteristics of Fourier Mode in Passive Resonator .....	49
2.1.2 Comparison of Experimental and Calculated Data for Resonator with an Active Medium .....	58
2.2 CO <sub>2</sub> Laser with a Phase-stepped Mirror.....	68
2.2.1 Calculated Characteristics of Fourier Mode in Passive Resonator .....	68
2.2.2 Comparison of Experimental and Calculated Data for Resonator with an Active Medium.....	75

<b>CHAPTER 3 Formation of a Mode with a Quasi-uniform Profile of Output Radiation in a CW Waveguide Gas Lasers .....</b>	<b>81</b>
3.1 Waveguide CO <sub>2</sub> laser .....	82
3.1.1 Undistorted Transmission of Infrared Beams with a Non-Uniform Field Profile of the Form of the Super-Gauss and Sombbrero Functions in Hollow Dielectric Waveguides .....	82
3.1.2 Matrix Model of a Passive Waveguide Resonator with an Inhomogeneous Mirror .....	89
3.1.3 Influence of a Cavity Geometry and Nonuniform Mirror Parameters on the Characteristics of the Fourier Mode.....	94
3.1.4 Experimental Setup. Comparison of Experimental and Numerical Results .....	101
3.2 Waveguide Optically Pumped THz laser .....	105
3.2.1 Waveguide Folding Resonator .....	105
3.2.2 Theoretical Model and Experimental Setup .....	109
3.2.3 Comparison of Experimental and Calculated Data for Resonator with an Active Medium.....	114
3.3 Waveguide Resonators of a CO <sub>2</sub> and THz Lasers with Spherical and Aspherical Mirrors .....	120
3.3.1 Calculated Mode Characteristics of the Resonators.....	120
3.3.1.1 Resonators with Spherical Reflector.....	120
3.3.1.2 Resonator with Aspherical Reflector .....	126
3.3.2 Comparison of Experimental and Numerical Results .....	130
<b>CHAPTER 4 Selection of Transverse Modes in Quasi-optical Waveguide Resonators .....</b>	<b>134</b>
4.1 Calculation Procedure of Waveguide Resonators with Mode Selectors.....	135
4.1.1 Selection of Lower Transverse Types of Oscillations.....	135
4.1.2 Structure of the Transverse Modes of Higher Orders in the Far Zone .....	141
4.2 Calculation Results of the Characteristics of Selected Transverse Modes.....	142
4.2.1 Method of Selection with Iris Diaphragm.....	142
4.2.1.1 Resonators with Coupling Holes in Reflectors .....	145
4.2.2 Method of Selection by a Section of Free Space.....	147
4.2.3 Selective Excitation of Individual Higher Transverse Types of Oscillations .....	149
4.3 Comparison of Experimental and Numerical Results .....	155
<b>Conclusion.....</b>	<b>167</b>
<b>References .....</b>	<b>169</b>
<b>Appendix.....</b>	<b>177</b>