

Room-Temperature Color Center Lasers

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(Invited Paper)

Abstract—A survey of results is presented on the development of room temperature tunable lasers using color centers in ionic crystals and on using color center crystals as nonlinear filters and passive Q-switches for neodymium lasers.

I. INTRODUCTION

LASERS using color centers (CC's) in ionic crystals, developed over the last 10 years, have become a new class of sources of coherent radiation with smoothly tunable wavelengths [1]–[12]. They possess an array of unique characteristics, such as 1) the practically important wavelength tuning region ranging from 0.5 to 4 μm , 2) high wavelength stability, and 3) an extremely narrow output spectral width, achievable virtually without power loss while preserving a continuous wide region of tuning (up to 2500 cm^{-1}) due to quasi-homogeneous broadening of their gain transitions.

The superb characteristics obtained by available and simple laser techniques, and the capability of color-center lasers (CCL's) to operate efficiently in all the known temporal modes (continuous to subpicosecond pulse) make them most promising tools for experimental physics. They confidently compete with semiconductor lasers, notable for their high resolution in the near IR region, and essentially surpass them in peak and average power, low radiation divergence, and region of continuous wavelength tuning. Color-center lasers also do not yield to parametric light oscillators in output power in nano- and picosecond operating modes and surpass them in quasi-continuous and CW regimes. Due to their high gain, the CCL features a considerably narrower oscillation spectrum, as well as a low sensitivity to the quality of the cavity optical elements and to the spatial-angular and spectral characteristics of the pump radiation.

The aim of this paper is to give a review of the present status of research in the field of development and application of room temperature CCL's.

The idea of making lasers using electron-vibrational transitions of color centers was first discussed as far back as 1961, soon after the first laser was demonstrated. B. Fritz and E. Menke [13] were the first in 1965 to attain oscillation with a color center using a pulsed flashlamp to pump a KCL-Li crystal with $F_2(\text{H})$ centers, cooled to

liquid nitrogen temperature. In the following decade, CCL's virtually fell outside active research interests. Considerable effort was devoted during this period to the development of tunable lasers using solutions of organic dyes. The availability of dyes, and the simplicity of creating an active volume, prompted a wide range of tunable dye laser research efforts. However, as early as the mid-1970's, when new application opportunities and requirements arose, and the merits and shortcomings of the dye lasers were clearly determined, an interest in tunable CCL's was renewed. Also by that time, the major techniques for narrowing laser radiation and for wavelength tuning across broad-electron-vibrational amplification bands using different types of dispersive cavities had been elaborated.

One of the first among those returning to the problem of making CCL's was a Bell Telephone group (U.S.A.). In 1974 they demonstrated [1], [6], [12] high monochromaticity and a wide tuning range of a KCL-Li laser with an $F_2(\text{H})$ CC, operating at nitrogen temperature (77 K) and laser pumped [14], [15]. This group [1], [6], [12] engaged in a search for new CCL media and the achievement of different operating modes of cryogenic CCL's.

Later on, another group [16]–[18] from the Institute of Thermo-Physics of the U.S.S.R. Academy of Sciences achieved room temperature oscillation on new quasi-molecular aggregate CC (F_2^- , F_2^+ , and F_2^0) in LiF and NaF crystals and showed them to be promising for producing tunable radiation in the spectral range 0.7–1.4 μm .

A group [19], [20] from the Hannover Technological University (West Germany) was the first to make a cryogenic ($T = 77\text{ K}$) $F_2(\text{H})$ CCL. They developed the techniques for attaining super stable narrow-band CC oscillation.

Scientists from the Irkutsk State University (U.S.S.R.) proposed the technique of optical stabilization of thermally unstable F_2^+ centers by doping the crystals with different impurities, and obtained oscillation using these impurity-vacancy centers at room temperature [2], [21], [22].

Oscillation on impurity-vacancy (F_2)₄ CC's in Na-doped CaF and SrF₂ was attained at $T = 300\text{ K}$ by researchers [23], [24] at the State Optical Institute (U.S.S.R.).

Scientists [25]–[29] of the General Physics Institute of the U.S.S.R. Academy of Sciences proposed new schemes for attaining tunable radiation using thermo- and photo-unstable CC's at room temperature, developed the tech-

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Marvin J. Weber



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Handbook of Laser Wavelengths Marvin J. Weber, 2018-10-08 This volume represents the most complete up to date compilation of wavelengths of lasers in all media Divided by type solid liquid and gas and listed in order of increasing wavelength Handbook of Laser Wavelengths includes crystalline paramagnetic ion lasers glass lasers color center lasers semiconductor lasers polymer lasers liquid and solid state dye lasers rare earth liquid lasers neutral atom ion and molecular gas lasers extreme ultraviolet and soft X ray lasers free electron lasers nuclear pumped lasers lasers in nature lasers without inversion Brief descriptions of each type of laser are presented followed by tables listing the laser wavelength lasing element or medium host transition and primary literature citations A special section on commercial lasers is an added featured Handbook of Laser Wavelengths singularly serves as the essential reference for scientists and engineers searching for laser sources for specific applications as well as a survey of the developments that have occurred since the advent of the laser

Selected Papers on Color-center Lasers Kenneth James Teegarden, 2003 A collection of papers dealing with the colour center laser The first section deals with fundamental research that preceded the colour center laser the second covers the discovery and development of several types of laser and the final section contains examples of applications of the laser

Solid-State Mid-Infrared Laser Sources Irina T. Sorokina, Konstantin L. Vodopyanov, 2003-07-10 The book describes the most advanced techniques for generating coherent light in the mid infrared region of the spectrum These techniques represent diverse areas of photonics and include heterojunction semiconductor lasers quantum cascade lasers tunable crystalline lasers fiber lasers Raman lasers and optical parametric laser sources Offering authoritative reviews by internationally recognized experts the book provides a wealth of information on the essential principles and methods of the generation of coherent mid infrared light and on some of its applications The instructive nature of the book makes it an

excellent text for physicists and practicing engineers who want to use mid infrared laser sources in spectroscopy medicine remote sensing and other fields and for researchers in various disciplines requiring a broad introduction to the subject

Handbook of Laser Technology and Applications Chunlei Guo,2021-06-24 This comprehensive handbook gives a fully updated guide to lasers and laser systems including the complete range of their technical applications The first volume outlines the fundamental components of lasers their properties and working principles The second volume gives exhaustive coverage of all major categories of lasers from solid state and semiconductor diode to fiber waveguide gas chemical and dye lasers The third volume covers modern applications in engineering and technology including all new and updated case studies spanning telecommunications and data storage to medicine optical measurement defense and security nanomaterials processing and characterization Handbook of Laser Technology and Applications Colin Webb,Julian D.C.

Jones,2020-09-29 The invention of the laser was one of the towering achievements of the twentieth century At the opening of the twenty first century we are witnessing the burgeoning of the myriad technical innovations to which that invention has led The Handbook of Laser Technology and Applications is a practical and long lasting reference source for scientists and engineers who work with lasers The Handbook provides a comprehensive guide to the current status of lasers and laser systems it is accessible to science or engineering graduates needing no more than standard undergraduate knowledge of optics Whilst being a self contained reference work the Handbook provides extensive references to contemporary work and is a basis for studying the professional journal literature on the subject It covers applications through detailed case studies and is therefore well suited to readers who wish to use it to solve specific problems of their own The first of the three volumes comprises an introduction to the basic scientific principles of lasers laser beams and non linear optics The second volume describes the mechanisms and operating characteristics of specific types of laser including crystalline solid state lasers semiconductor diode lasers fibre lasers gas lasers chemical lasers dye lasers and many others as well as detailing the optical and electronic components which tailor the laser s performance and beam delivery systems The third volume is devoted to case studies of applications in a wide range of subjects including materials processing optical measurement techniques medicine telecommunications data storage spectroscopy earth sciences and astronomy and plasma fusion research This vast compendium of knowledge on laser science and technology is the work of over 130 international experts many of whom are recognised as the world leaders in their respective fields Whether the reader is engaged in the science technology industrial or medical applications of lasers or is researching the subject as a manager or investor in technical enterprises they cannot fail to be informed and enlightened by the wide range of information the Handbook supplies Laser Induced Damage in Optical Materials ,1996 **Handbook of Laser Technology and Applications: Principles** Colin E. Webb,Julian D. C. Jones,2004 Solid-State Lasers and Applications Alphan Sennaroglu,2017-12-19 Because of the favorable characteristics of solid state lasers they have become the preferred candidates for a wide range of applications in science and technology

including spectroscopy atmospheric monitoring micromachining and precision metrology Presenting the most recent developments in the field Solid State Lasers and Applications focuses on the design and applications of solid state laser systems With contributions from leading international experts the book explores the latest research results and applications of solid state lasers as well as various laser systems The beginning chapters discuss current developments and applications of new solid state gain media in different wavelength regions including cerium doped lasers in the ultraviolet range ytterbium lasers near 1 μ m rare earth ion doped lasers in the eye safe region and tunable Cr²⁺ ZnSe lasers in the mid infrared range The remaining chapters study specific modes of operation of solid state laser systems such as pulsed microchip lasers high power neodymium lasers ultrafast solid state lasers amplification of femtosecond pulses with optical parametric amplifiers and noise characteristics of solid state lasers Solid State Lasers and Applications covers the most important aspects of the field to provide current comprehensive coverage of solid state lasers *Laser/Optoelektronik in der Technik / Laser/Optoelectronics in Engineering* W. Waidele, 2012-12-06 [Nonlinear Optics and Solid-State Lasers](#) Jianquan Yao, Yuyue Wang, 2012-01-14

This book covers the complete spectrum of nonlinear optics and all solid state lasers The book integrates theory calculations and practical design technology experimental schemes and applications With the expansion and further development of Laser technology the wavelength spectrum of Lasers had to be enlarged even to be tunable which requires the use of nonlinear optical and Laser tunable technology It systematically summarizes and integrates the analysis of international achievements within the last 20 years in this field It will be helpful for university teachers graduate students as well as engineers *Laser Beam Shaping Applications* Fred M. Dickey, Todd E. Lizotte, Scott C. Holswade, David L. Shealy, 2018-10-03 The practice of shaping the irradiance profile of laser beams goes back more than three decades and the applications of beam shaping are as diverse as they are numerous However until Dickey and Holswade's groundbreaking and highly popular Laser Beam Shaping Theory and Techniques was published there was no single detailed treatment available on the underlying theory and basic techniques of beam shaping Building on the foundations of this previous work these esteemed editors have teamed with recognized expert David L. Shealy to produce the first in depth account of beam shaping applications and design Laser Beam Shaping Applications details the important features of beam shaping and exposes the subtleties of the theory and techniques that are best demonstrated through proven applications In chapters contributed by prominent active leaders in their respective specialties the book discusses applications in lithography laser printing optical data storage stable isotope separation adaptive mirrors and spatially dispersive lasers The contributors share major insights knowledge and experience reveal the advantages of the technologies and include extensive references to the literature The book concludes with a summary of beam shaping theory and techniques as well as the history of the field Providing practical expertise Laser Beam Shaping Applications is an extremely helpful guide to improving current laser processes optimizing application specific technologies and advancing future development in the field [Advance Elements of Laser Circuits and Systems](#) Ofer

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Materials Charles W. Struck, Kailash C. Mishra, Baldassare Di Bartolo, 1999 **CLEO '96** Optical Society of America, 1996

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