



VCSELS

# Vertical-Cavity Surface-Emitting Laser

# Vertical Cavity Surface Emitting Lasers

**Connie J. Chang-Hasnain**



## **Vertical Cavity Surface Emitting Lasers:**

*Vertical-Cavity Surface-Emitting Lasers* Carl W. Wilmsen, Henryk Temkin, Larry A. Coldren, 2001-11-12 One of the key advances in photonic technology in recent years is the development of vertical cavity surface emitting lasers or VCSELs. These devices have a huge range of potential applications in areas such as communications, printing, and optical switching. This book, first published in 1999, provides a clear insight into the physics of VCSELs as well as describing details of their fabrication and applications. All of the book's contributors are at the forefront of VCSEL research and development. Together they provide complete and coherent coverage of the current state of the art. The opening chapters cover VCSEL design, emission from microcavities, growth, fabrication, and characterization. These are followed by chapters on long and short wavelength VCSELs, optical data links, and free space optical processing. The book will be of great interest to graduate students and researchers in electrical engineering, applied physics, and materials science. It will also be an excellent reference volume for practising engineers in the photonics industry.

**Vertical-Cavity Surface-Emitting Lasers** Julian Cheng, Niloy K. Dutta, 2000-07-06 Since first coming into existence in the early 90s, the vertical cavity surface emitting laser VCSEL has made several quantum leaps in performance. The performance of VCSELs now exceeds that of edge emitting lasers in many respects and offers a superior optical beam and much easier monolithic integrability. As the VCSEL technology improves further,

*Vertical-Cavity Surface-Emitting Lasers* Julian Cheng, Niloy K. Dutta, 2000-07-06 Since first coming into existence in the early 90s, the vertical cavity surface emitting laser VCSEL has made several quantum leaps in performance. The performance of VCSELs now exceeds that of edge emitting lasers in many respects and offers a superior optical beam and much easier monolithic integrability. As the VCSEL technology improves further and their number and variety multiply, their potential applications will likely expand at a rapid pace. *Vertical Cavity Surface Emitting Lasers: Technology and Applications* addresses two main objectives. It provides the researcher and device engineer with a reference guide to understanding the physical principles as well as the practical design concepts of VCSELs. Furthermore, it provides the system designer or application engineer with a review of the properties of VCSELs and an overview of some of the applications in which the VCSEL has already played an important role. This book features contributions from prominent researchers in the field.

Vertical Cavity Surface Emitting Lasers Terence Edward Sale, 1995 Starting from basic principles, this book provides coverage of the operation and design of Vertical Cavity Surface Emitting Lasers VCSELs. It includes original experimental work backed up by calculations and theoretical analysis and reviews work already done in the field.

Vertical-Cavity Surface-Emitting Laser Devices Herbert Li, Kenichi Iga, 2002-10-22 Explains in detail the basic theory, design, fabrication, and operation of vertical cavity surface emitting lasers. All the chapters are written by pioneers and key experts who have exclusive access to the most up-to-date innovations in the respective fields.

**VCSELs** Rainer Michalzik, 2012-10-16 The huge progress which has been achieved in the field is covered here in the first comprehensive monograph on vertical cavity surface emitting lasers VCSELs.

since eight years Apart from chapters reviewing the research field and the laser fundamentals there are comprehensive updates on red and blue emitting VCSELs telecommunication VCSELs optical transceivers and parallel optical links for computer interconnects Entirely new contributions are made to the fields of vectorial three dimensional optical modeling single mode VCSELs polarization control polarization dynamics very high speed design high power emission use of high contrast gratings GaInNAsSb long wavelength VCSELs optical video links VCSELs for optical mice and sensing as well as VCSEL based laser printing The book appeals to researchers optical engineers and graduate students

**Analysis and Design of Vertical Cavity Surface Emitting Lasers** S. F. Yu,2003-09-04 A practical hands on guidebook for the efficient modeling of VCSELs Vertical Cavity Surface Emitting Lasers VCSELs are a unique type of semiconductor laser whose optical output is vertically emitted from the surface as opposed to conventional edge emitting semiconductor lasers Complex in design and expensive to produce VCSELs nevertheless represent an already widely used laser technology that promises to have even more significant applications in the future Although the research has accelerated there have been relatively few books written on this important topic Analysis and Design of Vertical Cavity Surface Emitting Lasers seeks to encapsulate this growing body of knowledge into a single comprehensive reference that will be of equal value for both professionals and academics in the field The author a recognized expert in the field of VCSELs attempts to clarify often conflicting assumptions in order to help readers achieve the simplest and most efficient VCSEL models for any given problem Highlights of the text include A clear and comprehensive theoretical treatment of VCSELs Detailed derivations for understanding the operational principles of VCSELs Mathematical models for the investigation of electrical optical and thermal properties of VCSELs Case studies on the mathematical modeling of VCSELs and the implementation of simulation programs

Vertical-cavity Surface-emitting Lasers ,2001 Current Trends in Vertical Cavity Surface Emitting Lasers Tien-Pei Lee,1995 With significant progress made in recent years vertical cavity surface emitting lasers VCSELs have emerged as potential lightwave sources with a variety of applications including high speed optical interconnects parallel data links optical recording 2 D scanning and optical signal processing This volume which contains a collection of articles by outstanding experts on this topic encompasses a broad discussion of the current trends in the development of VCSELs Discussions include material growths structure designs processing methods performance analysis improvement strategies and future prospects The collection provides a comprehensive overview that may help newcomers to this field as well as engineers and researchers who are engaged in the research and development of this new exciting device family

**Vertical-cavity Surface-emitting Laser Device** ,1999 A vertical cavity surface emitting laser device The vertical cavity surface emitting laser VCSEL device comprises one or more VCSELs with each VCSEL having a mode control region thereabout with the mode control region forming an optical cavity with an effective cavity length different from the effective cavity length within each VCSEL Embodiments of the present invention can be formed as single VCSELs and as one or two dimensional arrays of VCSELs with

either an index guided mode of operation or an index anti guided mode of operation being defined by a sign of the difference in the two effective cavity lengths

Vertical External Cavity Surface Emitting Lasers Michael Jetter, Peter Michler, 2021-09-16 Vertical External Cavity Surface Emitting Lasers Provides comprehensive coverage of the advancement of vertical external cavity surface emitting lasers Vertical external cavity surface emitting lasers VECSELS emit coherent light from the infrared to the visible spectral range with high power output Recent years have seen new device developments such as the mode locked integrated MIXSEL and the membrane external cavity surface emitting laser MECSEL expand the application of VECSELS to include laser cooling spectroscopy telecommunications biophotonics and laser based displays and projectors In Vertical External Cavity Surface Emitting Lasers VECSEL Technology and Applications leading international research groups provide a comprehensive fully up to date account of all fundamental and technological aspects of vertical external cavity surface emitting lasers This unique book reviews the physics and technology of optically pumped disk lasers and discusses the latest developments of VECSEL devices in different wavelength ranges Topics include OP VECSEL physics continuous wave CW lasers frequency doubling carrier dynamics in SESAMs and characterization of nonlinear lensing in VECSEL gain samples This authoritative volume Summarizes new concepts of DBR free and MECSEL lasers for the first time Covers the mode locking concept and its application Provides an overview of the emerging concept of self mode locking Describes the development of next generation OPS laser products Vertical External Cavity Surface Emitting Lasers VECSEL Technology and Applications is an invaluable resource for laser specialists semiconductor physicists optical industry professionals spectroscopists telecommunications engineers and industrial physicists

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*Lithographic Vertical-cavity Surface-emitting Lasers* Guowei Zhao, 2012 Remarkable improvements in vertical cavity surface emitting lasers VCSELS have been made by the introduction of mode and current confining oxide optical aperture now used commercially However the oxide aperture blocks heat flow inside the device causing a larger thermal resistance and the internal strain caused by the oxide can degrade device reliability also the diffusion process used for the oxide formation can limit device uniformity and scalability Oxide free lithographic VCSELS are introduced to overcome these device limitations with both the mode and current confined within the lithographically defined intracavity mesa scaling and mass production of small size device could be possible The 3  $\mu\text{m}$  diameter lithographic VCSEL shows a threshold current of 260  $\mu\text{A}$  differential quantum efficiency of 60% and maximum output power density of 65  $\text{kW cm}^2$  and shows single mode single polarization operation with side mode suppression ratio over 25 dB at output power up to 1 mW The device also shows reliable operation during 1000 hours stress test with high injection current density of 142  $\text{kA cm}^2$  The lithographic VCSELS have much lower thermal resistance than oxide confined

VCSELs due to elimination of the oxide aperture The improved thermal property allows the device to have wide operating temperature range of up to 190 C heat sink temperature high output power density especially in small device high rollover current density and high rollover cavity temperature Research is still underway to reduce the operating voltage of lithographic VCSELs for high wall plug efficiency and the voltage of 6  $\mu\text{m}$  device at injection current density of 10  $\text{kA cm}^2$  is reduces to 1.83 V with optimized mesa and DBR mirror structure The lithographic VCSELs are promising to become the next generation VCSEL technology

**Vertical-Cavity Surface-Emitting Lasers XVIII.** , *Vertical Cavity Surface Emitting Lasers (VCSELs) and VCSEL Arrays for Communication and Sensing* Nasibeh Haghighi,2022 *Advances in Vertical Cavity Surface Emitting Lasers* Connie J. Chang-Hasnain,1997 *Vertical-cavity Surface-emitting Laser Diodes* Mark Alfred Hadley,1994

**Design and Epitaxial Growth of Vertical Cavity Surface-emitting Lasers (VCSEL) Emitting at Ultraviolet Wavelength** Mohamed Abid,2013 One of the key advances in photonic technology in recent decades was the development of a new type of diode lasers emitting in the visible and infrared region These vertical cavity surface emitting lasers VCSELs emerged from a laboratory curiosity in 1977 13 to an object of industrial mass production 14 and are currently used in many applications The applications include communication printing and absorption spectroscopy 15 Their rise in credibility has largely been motivated by the rapid evolution of their performance the more sweeping recognition of their compatibility with low cost wafer scale fabrication and their possible formation into specific arrays with no change in the fabrication procedure Various applications such as advanced chemical sensors and high density optical storage require coherent and small size ultraviolet emitting devices below 400nm Therefore to extend the VCSEL emission to the ultraviolet UV region intensive efforts have been made in the VCSEL technology However the achievement of such UV VCSEL is very challenging because of the various limitations and issues The issues noticeably include the carrier injection optical confinement and highly reflective distributed Bragg reflectors DBR structures with a broad bandwidth operating in the UV region 16 In this context motivated by the reported large refractive index induced by boron incorporation 7 we propose to introduce the boron based material systems  $\text{BaInGaN}$  as an innovative solution to address some of the encountered difficulties The objective of the proposed research is to investigate and optimize new wide bandgap  $\text{BaInGaN}$  material systems and illustrate their incorporation into the building blocks of vertical cavity surface emitting laser structures for operation in the UV spectral range

**Studies on Vertical-cavity Surface-emitting Lasers (VCSELs) and Their Application in Remote Sensing** Pierpaolo Andrea Porta,2002 **Aspects of the Numerical Modeling of Vertical Cavity Surface Emitting Lasers (VCSEL's)** Gregory Leon Bates,1993

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