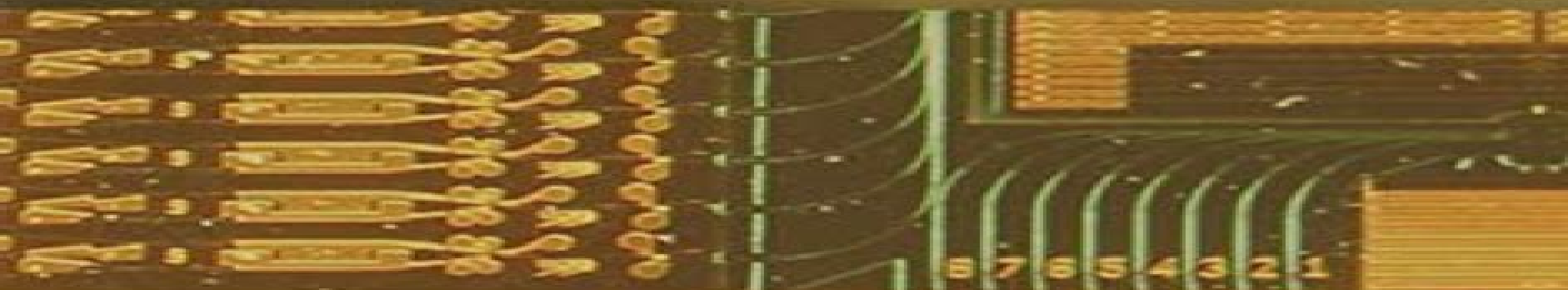


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# Diode Lasers and Photonic Integrated Circuits



SECOND EDITION

Larry A. Coldren  
Scott W. Corzine  
Milan L. Mašanović



 WILEY

# Diode Lasers And Photonic Integrated Circuits

**Chunlei Guo**



## **Diode Lasers And Photonic Integrated Circuits:**

**Diode Lasers and Photonic Integrated Circuits** Larry A. Coldren, Scott W. Corzine, Milan L. Mashanovitch, 2012-03-20 Diode Lasers and Photonic Integrated Circuits Second Edition provides a comprehensive treatment of optical communication technology its principles and theory treating students as well as experienced engineers to an in depth exploration of this field Diode lasers are still of significant importance in the areas of optical communication storage and sensing Using the the same well received theoretical foundations of the first edition the Second Edition now introduces timely updates in the technology and in focus of the book After 15 years of development in the field this book will offer brand new and updated material on GaN based and quantum dot lasers photonic IC technology detectors modulators and SOAs DVDs and storage eye diagrams and BER concepts and DFB lasers Appendices will also be expanded to include quantum dot issues and more on the relation between spontaneous emission and gain Diode Lasers and Photonic Integrated Circuits Larry A. Coldren, Scott W. Corzine, Milan L. Mashanovitch, 2012-03-02 Diode Lasers and Photonic Integrated Circuits Second Edition provides a comprehensive treatment of optical communication technology its principles and theory treating students as well as experienced engineers to an in depth exploration of this field Diode lasers are still of significant importance in the areas of optical communication storage and sensing Using the the same well received theoretical foundations of the first edition the Second Edition now introduces timely updates in the technology and in focus of the book After 15 years of development in the field this book will offer brand new and updated material on GaN based and quantum dot lasers photonic IC technology detectors modulators and SOAs DVDs and storage eye diagrams and BER concepts and DFB lasers Appendices will also be expanded to include quantum dot issues and more on the relation between spontaneous emission and gain 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 **Problem Solutions for Diode Lasers and Photonic in Tegrated Circuits** JOHN WILEY & SONS INC, Larry A. Coldren, 1998-03-01 **Grundlagen der Photonik** Bahaa E. A. Saleh, Malvin Carl Teich, 2008-05-05 Schon die erste Auflage des englischen Lehrbuchs Fundamentals of Photonics zeichnete sich durch seine ausgewogene

Mischung von Theorie und Praxis aus und deckte in detaillierter Darstellung die grundlegenden Theorien des Lichts ab Es umfasste sowohl die Themen Strahlenoptik Wellenoptik elektromagnetische Optik Photonik sowie die Wechselwirkung von Licht und Materie als auch die Theorie der optischen Eigenschaften von Halbleitern Die Photonik Technologie hat eine rasante Entwicklung genommen seit der Publikation der ersten Ausgabe von Fundamentals of Photonics vor 15 Jahren Die nun vorliegende Zweite Auflage des Marksteins auf dem Gebiet der Photonik tr gt mit zwei neuen und zus tzlichen Kapiteln den neuesten technologischen Fortschritten Rechnung Photonische Kristalle sowie Ultrakurzpuls Optik Zudem wurden alle Kapitel gr ndlich bearbeitet und viele Abschnitte hinzugef gt so z B ber Laguerre Gauss Strahlen die Sellmeier Gleichung Photonenkristall Wellenleiter photonische Kristallfasern Mikrosph ren Resonatoren Optische Koh renz Tomographie Bahndrehimpuls des Photons Bohrsche Theorie Raman Verst rker rauscharme Avalanche Photodioden Abstimmkurven und Dispersions Management

**Semiconductor Laser Fundamentals** Toshiaki Suhara,2004-03-16 Ranging from fundamental theoretical concepts to advanced device technologies this reference text explores the engineering characteristics and performance of specific semiconductor lasers It defines key principles in electromagnetics optoelectronics and laser implementation for novel applications in optical communications storage processing measurement and sensing This text prepares students for advanced experimental and theoretical research in semiconductor laser technology and provides the only comprehensive systematic and concise description of semiconductor lasers available for an understanding of the physics and parameters of laser operation and function

**Halbleiterlaser** Henning Fouckhardt,2011-07-27 Dieses Buch bietet eine fundierte Einf hrung in das Gebiet der Halbleiterlaser Ausgehend von den wellenoptischen Grundlagen bis hin zu Hochleistungs Halbleiterlasern vermittelt das Buch kompakt und verst ndlich die Grundlagen dieses spannenden Gebietes Bei der Darstellung wird gro er Wert auf das Verst ndnis der Fourier optischen Denkweisen und die Bez ge zur Optoelektronik gelegt

*Epitaxial Design Optimizations for Increased Efficiency in GaAs-Based High Power Diode Lasers* Thorben Kaul,2021-04-09 This work presents progress in the root cause analysis of power saturation mechanisms in continuous wave CW driven GaAs based high power broad area diode lasers operated at 935 nm Target is to increase efficiency at high optical CW powers by epitaxial design The novel extreme triple asymmetric ETAS design was developed and patented within this work to equip diode lasers that use an extremely thin p waveguide with a high modal gain An iterative variation of diode lasers employing ETAS designs was used to experimentally clarify the impact of modal gain on the temperature dependence of internal differential quantum efficiency IDQE and optical loss High modal gain leads to increased free carrier absorption from the active region However less power saturation is observed which must then be attributed to an improved temperature sensitivity of the IDQE The effect of longitudinal spatial hole burning LSHB leads to above average non linear carrier loss at the back facet of the device At high CW currents the junction temperature rises Therefore not only the asymmetry of the carrier profile increases but also the average carrier density in order to compensate for the decreased

material gain and increased threshold gain This carrier non pinning effect above threshold is found in this work to enhance the impact of LSHB already at low currents leading to rapid degradation of IDQE with temperature This finding puts LSHB into a new context for CW driven devices as it emphasizes the importance of low carrier densities at threshold The carrier density was effectively reduced by applying the novel ETAS design This enabled diode lasers to be realized that show minimized degradation of IDQE with temperature and therefore improved performance in CW operation

*Integration von optischen Wellenleitern und optischen Bauelementen in konventionelle und planare Leitungssätze in Kraftfahrzeugen*

Thomas Eduard Kibler,2005-04-15

**Molekularstrahlepitaxie GaAs-basierender Mischungshalbleiter für 1300**

**nm-nahe Laserdiodenemission** Irene Ecker,2004

**Charakterisierung und Simulation optischer Eigenschaften**

**von mikromechanisch abstimmbaren Filterbauelementen** Friedhard Römer,2006

**Organische**

**oberflächenemittierende Laser mit vertikaler Kavität: Entwicklung neuer Design und Herstellungsansätze** Hans

Wilke,2019 Diese Arbeit behandelt die Herstellung organischer oberflächenemittierender Laser mit vertikaler Kavität für den

blauen bis ultravioletten Spektralbereich Das Ziel ist die Herstellung zweier verschiedener OVCSEL mit neuartigen Ansätzen

im Laserdesign und der Prozessierung Die aktive Region wird entweder durch Lithographie oder die nachträgliche Infiltration

des organischen aktiven Materials in eine bestehende dielektrische Struktur lateral eingeschränkt Bei letzterem Ansatz ist

das organische Material als hochbrechende Schicht Bestandteil der Bragg Spiegel Die eingesetzten Materialien werden

hinsichtlich ihrer mechanischen Spannungen optischen Eigenschaften und ihrem Verhalten unter reaktiven Ionen

untersucht Die realisierten OVCSEL werden optisch angeregt und charakterisiert

**Mikromechanisch weit**

**abstimmbare Oberflächen-emittierende Laserdioden für Sensoranwendungen** Benjamin Kögel,2009-07-27 Laser mit

abstimmbarer Wellenlänge sind die Schlüsselkomponenten zukünftiger optischer Kommunikationssysteme Darüber hinaus ist

ein breitbandig und kontinuierlich abstimmbarer Laser mit hoch reinem Emissionsspektrum ein vielseitiges Werkzeug für

verschiedene Sensoranwendungen So kann z.B. die Emission von Treibhausgasen durch Absorptionsspektroskopie oder die

Deformation von Bauwerken durch die Abfrage von Faser Bragg Gittern FBG Messwandlern überwacht werden Aufgrund

ihres monomodalen Verhaltens der geringen Leistungsaufnahme und Kompaktheit sind Oberflächen emittierende Laser mit

Vertikalresonator engl vertical cavity surface emitting laser VCSEL hierfür besonders geeignet Im Rahmen dieser Arbeit

werden der Entwurf die Technologie und Charakterisierung sowie Sensoranwendungen von mikromechanisch weit

abstimmbaren VCSELn mit Wellenlängen um 1,55 µm vorgestellt Der entwickelte Laser besteht aus einer aktiven optischen

Komponente Halb VCSEL und einer beweglichen mikromechanischen Komponente engl micro electro mechanical system

MEMS die in einem hybriden Aufbau zusammengefasst werden Mittels elektrothermischer Aktorik kann die Spiegelmembran

ausgelenkt der zwischen beiden Komponenten eingeschlossene Luftspalt vergrößert und so die Resonanzwellenlänge

kontinuierlich abgestimmt werden In einem neuartigen Resonatorentwurf werden die Elemente des MEMS VCSELs

entkoppelt und der Abstimmbereich auf 60 nm gesteigert. Dabei wird eine gekrümmte Spiegelmembran eingesetzt, um ausschließlich den gewünschten Grundmode-Gaustahl anzuregen. Hierdurch werden monomodal Ausgangsleistungen bis 2,8 mW erzielt, die sogar im Vergleich mit nicht abstimmbaren VCSELn bei dieser Wellenlänge einen internationalen Bestwert darstellen. Wegen der zylindrischen Resonatorgeometrie ist die Stabilität der Polarisation ein grundsätzliches Problem von VCSELn. Durch Verwendung einer elliptischen Spiegelmembran wird diese Symmetrie aufgehoben und gezielt eine lineare Polarisation eingestellt. Eine schmale Emissionslinie und eine hohe Abstimmungsgeschwindigkeit sind zwei gegensätzliche Eigenschaften, da flinke mechanische Komponenten thermischem Rauschen unterliegen. Durch Erhöhung der Federkonstante, Steifigkeit des MEMS können Linienbreiten 40 MHz und die Abstimmung mit Wiederholraten von 100 Hz nachgewiesen werden. Abschließend werden die Absorptionsspektroskopie und die von Kohlenmonoxid und Dioxid sowie die FBG-Messtechnik als zwei Anwendungen demonstriert, bei denen der einzigartige Vorzug der breitbandigen und kontinuierlichen Abstimmbarkeit des MEMS-VCSELs besonders zum Tragen kommt.

Lasers and Current Optical Techniques in Biology Giuseppe Palumbo, Riccardo Pratesi, 2007-10-31. The introduction of innovative light sources, fibre laser sources and light emitting diodes is opening unexpected perspectives into optical techniques and is promising new exciting applications in the field of biomedicine. *Lasers and Current Optical Techniques in Biology* aims to provide an overview of light sources together with an extensive and authoritative description of the optical techniques in biomedicine. This book is designed to give biomedical researchers a strong feel for the capability of physical approaches, promote new interdisciplinary interests and persuade more practitioners to take advantage of optical techniques. Current developments in a variety of optical techniques including Near Infra-Red Spectroscopy and traditional and advanced fluorescence techniques are covered, ranging from those that are becoming common practice to those that need much more experimentation before they can be accepted as real breakthroughs. Further topics include optical coherence tomography and its variations, polarised light imaging and principle laser and lamp sources, a usually fragmentary topic often dispersed among specialist publications. The wide range of topics covered make *Lasers and Current Optical Techniques in Biology* of interest to a diverse range of scientific communities.

**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.

*Optische Kommunikationstechnik* Edgar Voges, Klaus Petermann, 2019-06-12. Dieses Nachschlagewerk wendet sich vor allem an Ingenieure und Physiker in der Telekommunikationsindustrie bei Netzbetreibern.

und in der Datenkommunikation Weiterhin kann es diesen Nutzern sowie Wissenschaftlern und Studenten einen Einblick in das Fachgebiet verschaffen und die Einarbeitung in speziellere Felder ermöglichen Die grundlegenden Beziehungen und Technologien werden zusammengestellt und in ihren wesentlichen Zielen erläutert Grafische Darstellungen und Abbildungen vermitteln die Zusammenhänge anschaulich und ingenieurgerecht Zu dem Werk haben maßgebliche Forscher und Industrieingenieure aus dem deutschen Sprachraum beigetragen Als Vorbild für die Konzeption diente das Standardwerk über Hochfrequenztechnik von MEINKE und GUNDLACH

*Lasers For Scientists And Engineers* L Wilmer Anderson, John B Boffard, 2017-06-19 Since the invention of the laser the variety of lasers and their uses have grown at a phenomenal rate Scientists and engineers have at their disposal an enormous array of sophisticated laser equipments with the possibility of carrying out experiments that were inconceivable only a few decades ago Lasers for Scientists and Engineers is a grand and glorious book that discusses the principles of laser operation and the details of how selected lasers operate This book is short and easy to read enabling the reader to thoroughly grasp the subject with discussions that begin at an elementary level and lead to a complete understanding of lasers This book is suitable for a one semester college course for upper level undergraduate or first year graduate level students in physics chemistry biology astronomy and the various fields of engineering The background needed for this book would be junior level courses in optics and modern physics including elementary quantum mechanics

**Theorie und Simulation des Doppelstreifen-Lasers** Miguel Ángel Palacios Lázaro, 2011-01-13 In der heutigen Welt ist der Informationsaustausch einer der stärksten Motoren der Wirtschaft und der Entwicklung der Gesellschaft Dementsprechend spielt die Kommunikationstechnik eine immer wichtigere und bedeutendere Rolle im Bereich der Forschung der Technik und der Ausbildung Neue Systeme werden entwickelt die existierenden werden ständig verbessert und ihre Datenübertragungsgeschwindigkeit überschreitet weitere Grenzen Diese Prozesse sind die Antwort auf den wachsenden Bedarf an technischen Lösungen die das Wachstum der oben genannten wirtschaftlichen und technologischen Welt unterstützen Unter diesen Lösungen sind optische Übertragungssysteme diejenigen die höchsten Geschwindigkeiten zur Datenübertragung ermöglichen Auf sehr langen Strecken können optische Fasern analoge sowie digitale Informationen übertragen Der Einsatz von optischen Verstärkern EDFA hat den Umfang dieses Informationsaustausches auf bisher unbekannte Größen gebracht Als Quelle dieser Systeme werden Laserdioden verwendet die mit den unterschiedlichsten Technologien entworfen und aufgebaut werden können Diese Dioden Fabry Perot und DFB Laserdiode Heteroübergang Heteroübergang und Quantenbrunnenlaserdiode werden meist mit modulierten Strömen angeregt sodass die Information im Basisband übertragen wird Der Einsatz dieser Quellen zur Erzeugung von Mikrowellen- und Millimeterwellenoszillationen ist jedoch ein weniger bekanntes Anwendungsgebiet Doppelstreifen Laser sind Halbleiterstrukturen in denen nicht nur eine aktive Schicht sondern zwei parallele aktive Streifen vergraben sind Die Existenz dieser zwei aktiven Bereiche ermöglicht das Entstehen einer Schwingung des vom Halbleiter abgestrahlten Lichts

Dieses Licht könnte unter bestimmten Bedingungen moduliert oder als Mikrowellen bzw. Millimeterwellenoszillator benutzt werden. Diese Arbeit befasst sich mit dieser Art von Strukturen. Die Einleitung der Arbeit stellt die Prinzipien der Erzeugung kohärenten Lichts vor sowie die meist verbreiteten Arten von Laserdioden. Darauf folgend werden die theoretischen Grundlagen der Arbeit präsentiert. Das Ziel unserer Forschung ist die Entwicklung einer Modellierung, die zum theoretischen Begreifen des Doppelstreifen Lasers beiträgt. Dieses Verständnis soll zur Optimierung dieser Struktur führen. Die Erzeugung einer rauscharmen Oszillation im Bereich von Gigahertz ist der endgültige Zweck der Optimierung. Diese Arbeit geht von der Anwendung eines Wanderwellenmodells aus. Herkömmliche Modellierungen wurden jedoch auf die Simulation von gewöhnlichen Lasern mit einem einzigen aktiven Streifen angewendet. Auf der Theorie dieser Modelle basierend wurde ein Wanderwellenmodell für Doppelstreifen Laser entwickelt. Das Entstehen von zwei gleichzeitig existierenden lateralen Moden als symmetrische bzw. antisymmetrische Mode bezeichnet die leicht unterschiedlichen Brechungsindizes aufweisen ermöglicht die Erzeugung der angestrebten Oszillation. Unseren Überlegungen zu Folge sind zwei nachrichtentechnische Anwendungen dieses Phänomens von Bedeutung. Ein Laser kann nur im Basisband moduliert werden. Wird eine vom Bauteil abhängende Frequenz erreicht, fällt die Leistung des Lichts stark ab. Die Bandbreite der modulierenden Signale kann aus diesem Grund nur einige Gigahertz betragen. Die Erzeugung einer Oszillation im Bereich von Gigahertz ermöglicht jedoch die Modulation des Lasers um diese Schwingung, was eine zusätzliche Bandbreite zur Signalübertragung bietet, wie diese Arbeit bewiesen hat. Eine besonders wichtige Anwendung eines Doppelstreifen Lasers kann durch die Optimierung der erzeugten Oszillation erreicht werden. Dies führt zu einer rauscharmen Schwingung, die eine sehr niedrige Linienbreite aufweist. Solche Oszillationen können als Mikro- und Millimeterwellenquellen zum Einsatz kommen, die über lange Strecken mittels Glasfaser übertragen und verteilt werden, was aus nachrichtentechnischer Sicht sehr attraktiv ist. Solche engen Linienbreiten können bisher nur mittels komplizierter Systeme, z. B. über optische Injektion, erreicht werden. Die vorliegende Arbeit hat gezeigt, dass die dem Doppelstreifen Laser inhärente optische Kopplung eine technisch machbare Reduktion der Linienbreite ermöglicht. Die Erweiterung des Wanderwellenmodells und die theoretische Erklärung der zweiten der oben genannten Anwendungen bilden die wichtigsten Ergebnisse der vorliegenden Arbeit, die zu einer zukünftigen praktischen Entwicklung solcher Quellen als Grundlage dienen könnten.

**Unlocking Dynamical Diversity** Deborah M. Kane, K. Alan Shore, 2005-11-01 Applications of semiconductor lasers with optical feedback systems are driving rapid developments in theoretical and experimental research. The very broad wavelength gain bandwidth of semiconductor lasers combined with frequency filtered strong optical feedback create the tunable single frequency laser systems utilised in telecommunications, environmental sensing, measurement and control. Those with weak to moderate optical feedback lead to the chaotic semiconductor lasers of private communication. This resource illustrates the diversity of dynamic laser states and the technological applications thereof, presenting a timely synthesis of current findings and providing the roadmap for exploiting their future potential. Provides



theory based explanations underpinned by a vast range of experimental studies on optical feedback including conventional phase conjugate and frequency filtered feedback in standard commercial and single stripe semiconductor lasers Includes the classic Lang Kobayashi equation model through to more recent theory with new developments in techniques for solving delay differential equations and bifurcation analysis Explores developments in self mixing interferometry to produce sub nanometre sensitivity in path length measurements Reviews tunable single frequency semiconductor lasers and systems and their diverse range of applications in sensing and optical communications Emphasises the importance of synchronised chaotic semiconductor lasers using optical feedback and private communications systems Unlocking Dynamical Diversity illustrates all theory using real world examples gleaned from international cutting edge research Such an approach appeals to industry professionals working in semiconductor lasers laser physics and laser applications and is essential reading for researchers and postgraduates in these fields

*Integrated Photonics for Data Communication Applications* Madeleine Glick, Ling Liao, Katharine Schmidtke, 2023-07-26 *Integrated Photonics for Data Communications Applications* reviews the key concepts design principles performance metrics and manufacturing processes from advanced photonic devices to integrated photonic circuits The book presents an overview of the trends and commercial needs of data communication in data centers and high performance computing with contributions from end users presenting key performance indicators In addition the fundamental building blocks are reviewed along with the devices lasers modulators photodetectors and passive devices that are the individual elements that make up the photonic circuits These chapters include an overview of device structure and design principles and their impact on performance Following sections focus on putting these devices together to design and fabricate application specific photonic integrated circuits to meet performance requirements along with key areas and challenges critical to the commercial manufacturing of photonic integrated circuits and the supply chains being developed to support innovation and market integration are discussed This series is led by Dr Lionel Kimerling Executive at AIM Photonics Academy and Thomas Lord Professor of Materials Science and Engineering at MIT and Dr Sajan Saini Education Director at AIM Photonics Academy at MIT Each edited volume features thought leaders from academia and industry in the four application area fronts data communications high speed wireless smart sensing and imaging and addresses the latest advances Includes contributions from leading experts and end users across academia and industry working on the most exciting research directions of integrated photonics for data communications applications Provides an overview of data communication specific integrated photonics starting from fundamental building block devices to photonic integrated circuits to manufacturing tools and processes Presents key performance metrics design principles performance impact of manufacturing variations and operating conditions as well as pivotal performance benchmarks

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