



Yiwen Rong

# High Speed Germanium-Silicon Modulators For Optical Interconnect



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# High Speed Germanium Silicon Modulators For Optical Interconnect

**Rosina Ehmann**



## **High Speed Germanium Silicon Modulators For Optical Interconnect:**

**High Speed Germanium-Silicon Modulators For Optical Interconnect** Yiwen Rong, 2014-11-28 Information processing requires interconnects to carry information from one place to another Optical interconnects between electronics systems have attracted significant attention and development for a number of years because optical links have demonstrated potential advantages for high speed low power and interference immunity With increasing system speed and greater bandwidth requirements the distance over which optical communication is useful has continually decreased to chip to chip and on chip levels Monolithic integration of photonics and electronics will significantly reduce the cost of optical components and further combine the functionalities of chips on the same or different boards or systems Modulators are one of the fundamental building blocks for optical interconnects

**High Speed, Low Driving Voltage Vertical Cavity Germanium-silicon Modulators for Optical Interconnect** Yiwen Rong, 2010 Information processing requires interconnects to carry information from one place to another Optical interconnects between electronics systems have attracted significant attention and development for a number of years because optical links have demonstrated potential advantages for high speed low power and interference immunity With increasing system speed and greater bandwidth requirements the distance over which optical communication is useful has continually decreased to chip to chip and on chip levels Monolithic integration of photonics and electronics will significantly reduce the cost of optical components and further combine the functionalities of chips on the same or different boards or systems Modulators are one of the fundamental building blocks for optical interconnects Previous work demonstrated modulators based upon the quantum confined Stark effect QCSE in SiGe p i n devices with strained Ge SiGe multi quantum well MQW structures in the i region While the previous work demonstrated the effect it did not examine the high speed aspects of the device which is the focus of this dissertation High speed modulation and low driving voltage are the keys for the device s practical use At lower optical intensity operation the ultimate limitation in speed will be the RC time constant of the device itself At high optical intensity the large number of photo generated carriers in the MQW region will limit the performance of the device through photo carrier related voltage drop and exciton saturation In previous work the devices consist of MQWs configured as p i n diodes The electric field induced absorption change by QCSE modulates the optical transmission of the device The focus of this thesis is the optimization of MQW material deposition minimization of the parasitic capacitance of the probe pads for high speed low voltage and high contrast ratio operation The design fabrication and high speed characterization of devices of different sizes with different bias voltages are presented The device fabrication is based on processes for standard silicon electronics and is suitable for mass production This research will enable efficient transceivers to be monolithically integrated with silicon chips for high speed optical interconnects We demonstrated a modulator with an eye diagram of 3 125GHz a small driving voltage of 2 5V and an f3dB bandwidth greater than 30GHz Carrier dynamics under ultra fast laser excitation

and high speed photocurrent response are also investigated

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**Ge/SiGe Quantum Well Waveguide Modulator for Optical Interconnect Systems** Ren Shen, 2011 Thanks to the development of silicon VLSI technology over the past several decades we can now integrate far more transistors onto a single chip than ever before However this also imposes more stringent requirements in terms of bandwidth density and power consumption on the interconnect systems that link transistors The interconnect system is currently one of the major hurdles for the further advancement of the electronic technology Optical interconnect is considered a promising solution to overcome the interconnect bottleneck The quantum confined Stark effect in Ge SiGe quantum well system paves the way to realize efficient optical modulation on Si in a fully CMOS compatible fashion In this dissertation we investigate the integration of Ge SiGe quantum well waveguide modulators with silicon on

insulator waveguides For the first time we demonstrate the selective epitaxial growth of Ge SiGe quantum well structures on patterned Si substrates The selective epitaxy exhibits perfect selectivity and minimal pattern sensitivity Compared to their counterparts made using bulk epitaxy the p i n diodes from selective epitaxy demonstrate very low reverse leakage current and high reverse breakdown voltage Strong quantum confined Stark effect QCSE is for the first time demonstrated in this material system in the telecommunication C band at room temperature A 3 dB optical modulation bandwidth of 2.8 THz is measured covering more than half of the C band We propose analyze and experimentally demonstrate a novel approach to realize butt coupling between a SOI waveguide and a selectively grown Ge SiGe quantum well waveguide modulator using a thin dielectric spacer Through numerical simulation we show that the insertion loss penalty for a thin 20 nm thick spacer can be as low as 0.13 dB Such a quantum well waveguide modulator with a footprint of 8  $\mu\text{m}^2$  has also been fabricated demonstrating 3.2 dB modulation contrast with merely 1V swing at a speed of 16 Gpbs **CMOS-Compatible Key**

**Engineering Devices for High-Speed Silicon-Based Optical Interconnections** Jing Wang, 2018-11-23 This book discusses some research results for CMOS compatible silicon based optical devices and interconnections With accurate simulation and experimental demonstration it provides insights on silicon based modulation advanced multiplexing polarization and efficient coupling controlling technologies which are widely used in silicon photonics Researchers scientists engineers and especially students in the field of silicon photonics can benefit from the book This book provides valuable knowledge useful methods and practical design that can be considered in emerging silicon based optical interconnections and communications And it also give some guidance to student how to organize and complete an good dissertation Silicon Photonics for High-Performance Computing and Beyond Mahdi Nikdast, Sudeep Pasricha, Gabriela Nicolescu, Ashkan Seyedi, Di Liang, 2021-11-16 Silicon photonics is beginning to play an important role in driving innovations in communication and computation for an increasing number of applications from health care and biomedical sensors to autonomous driving datacenter networking and security In recent years there has been a significant amount of effort in industry and academia to innovate design develop analyze optimize and fabricate systems employing silicon photonics shaping the future of not only Datacom and telecom technology but also high performance computing and emerging computing paradigms such as optical computing and artificial intelligence Different from existing books in this area Silicon Photonics for High Performance Computing and Beyond presents a comprehensive overview of the current state of the art technology and research achievements in applying silicon photonics for communication and computation It focuses on various design development and integration challenges reviews the latest advances spanning materials devices circuits systems and applications Technical topics discussed in the book include Requirements and the latest advances in high performance computing systems Device and system level challenges and latest improvements to deploy silicon photonics in computing systems Novel design solutions and design automation techniques for silicon photonic integrated circuits Novel materials devices and photonic integrated

circuits on silicon Emerging computing technologies and applications based on silicon photonics Silicon Photonics for High Performance Computing and Beyond presents a compilation of 19 outstanding contributions from academic and industry pioneers in the field The selected contributions present insightful discussions and innovative approaches to understand current and future bottlenecks in high performance computing systems and traditional computing platforms and the promise of silicon photonics to address those challenges It is ideal for researchers and engineers working in the photonics electrical and computer engineering industries as well as academic researchers and graduate students M S and Ph D in computer science and engineering electronic and electrical engineering applied physics photonics and optics **High-Speed**

**Photonics Interconnects** Lukas Chrostowski, Krzysztof Iniewski, 2017-12-19 Dramatic increases in processing power have rapidly scaled on chip aggregate bandwidths into the Tb/s range This necessitates a corresponding increase in the amount of data communicated between chips so as not to limit overall system performance To meet the increasing demand for interchip communication bandwidth researchers are investigating the use of high speed optical interconnect architectures Unlike their electrical counterparts optical interconnects offer high bandwidth and negligible frequency dependent loss making possible per channel data rates of more than 10 Gb/s High Speed Photonics Interconnects explores some of the groundbreaking technologies and applications that are based on photonics interconnects From the Evolution of High Speed I/O Circuits to the Latest in Photonics Interconnects Packaging and Lasers Featuring contributions by experts from academia and industry the book brings together in one volume cutting edge research on various aspects of high speed photonics interconnects Contributors delve into a wide range of technologies from the evolution of high speed input/output I/O circuits to recent trends in photonics interconnects packaging The book discusses the challenges associated with scaling I/O data rates and current design techniques It also describes the major high speed components channel properties and performance metrics The book exposes readers to a myriad of applications enabled by photonics interconnects technology Learn about Optical Interconnect Technologies Suitable for High Density Integration with CMOS Chips This richly illustrated work details how optical interchip communication links have the potential to fully leverage increased data rates provided through complementary metal oxide semiconductor CMOS technology scaling at suitable power efficiency levels Keeping the mathematics to a minimum it gives engineers researchers graduate students and entrepreneurs a comprehensive overview of the dynamic landscape of high speed photonics interconnects *Integrated Optical Interconnect Architectures for Embedded Systems* Ian O'Connor, Gabriela Nicolescu, 2012-11-07 This book provides a broad overview of current research in optical interconnect technologies and architectures Introductory chapters on high performance computing and the associated issues in conventional interconnect architectures and on the fundamental building blocks for integrated optical interconnect provide the foundations for the bulk of the book which brings together leading experts in the field of optical interconnect architectures for data communication Particular emphasis is given to the ways in which the photonic

components are assembled into architectures to address the needs of data intensive on chip communication and to the performance evaluation of such architectures for specific applications      Optical Interconnects Lorenzo Pavesi, Gérard Guillot, 2007-05-17 Optical Interconnects provides a fascinating picture of the state of the art in optical interconnects and a perspective on what can be expected in the near future It is composed of selected reviews authored by world leaders in the field and these reviews are written from either an academic or industrial viewpoint An in depth discussion of the path towards fully integrated optical interconnects in microelectronics is presented This book will be useful not only to physicists chemists materials scientists and engineers but also to graduate students who are interested in the fields of microelectronics and optoelectronics      **Optical Interconnects for Future Data Center Networks** Christoforos Kachris, Keren Bergman, Ioannis Tomkos, 2012-11-07 Optical Interconnects in Future Data Center Networks covers optical networks and how they can be used to provide high bandwidth energy efficient interconnects for future data centers with increased communication bandwidth requirements This contributed volume presents an integrated view of the future requirements of the data centers and serves as a reference work for some of the most advanced solutions that have been proposed by major universities and companies Collecting the most recent and innovative optical interconnects for data center networks that have been presented in the research community by universities and industries this book is a valuable reference to researchers students professors and engineers interested in the domain of high performance interconnects and data center networks Additionally Optical Interconnects in Future Data Center Networks provides invaluable insights into the benefits and advantages of optical interconnects and how they can be a promising alternative for future data center networks

High Speed Germanium Silicon Modulators For Optical Interconnect: Bestsellers in 2023 The year 2023 has witnessed a remarkable surge in literary brilliance, with numerous captivating novels enthralling the hearts of readers worldwide. Lets delve into the realm of top-selling books, exploring the engaging narratives that have captivated audiences this year. High Speed Germanium Silicon Modulators For Optical Interconnect : Colleen Hoover's "It Ends with Us" This poignant tale of love, loss, and resilience has gripped readers with its raw and emotional exploration of domestic abuse. Hoover expertly weaves a story of hope and healing, reminding us that even in the darkest of times, the human spirit can prevail. Uncover the Best : Taylor Jenkins Reids "The Seven Husbands of Evelyn Hugo" This intriguing historical fiction novel unravels the life of Evelyn Hugo, a Hollywood icon who defies expectations and societal norms to pursue her dreams. Reids compelling storytelling and compelling characters transport readers to a bygone era, immersing them in a world of glamour, ambition, and self-discovery. High Speed Germanium Silicon Modulators For Optical Interconnect : Delia Owens "Where the Crawdads Sing" This captivating coming-of-age story follows Kya Clark, a young woman who grows up alone in the marshes of North Carolina. Owens spins a tale of resilience, survival, and the transformative power of nature, captivating readers with its evocative prose and mesmerizing setting. These top-selling novels represent just a fraction of the literary treasures that have emerged in 2023. Whether you seek tales of romance, adventure, or personal growth, the world of literature offers an abundance of captivating stories waiting to be discovered. The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts. The Secret History is a exceptional and thrilling novel that will keep you guessing until the very end. The novel is a cautionary tale about the dangers of obsession and the power of evil.

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