

# Linear and nonlinear characterization of a broadband integrated Si-rich silicon nitride racetrack ring resonator for on-chip applications

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We demonstrate the linear and nonlinear characterization of a plasma-enhanced chemical vapor deposited silicon-rich silicon nitride (SRSN) racetrack ring resonator for on-chip applications within the telecommunication wavelength range. The SRSN waveguide parameters are optimized by employing the refractive index profile measured by ellipsometry to achieve flat dispersion in the telecom band. Furthermore, we measure the thermo-optic coefficient of the micro-resonator by analyzing the temperature-dependent transmission spectra and assess it to be  $3.2825 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$ . Additionally, we study power-dependent transmission spectra to investigate the effect of local heating and nonlinear absorption. The power-dependent transmission spectra exhibit a blueshifting of the resonance peak in the visible and near-IR regions, which indicates the presence of nonlinear losses in that range. The power-dependent transmission spectra almost remain unchanged in the telecom band, revealing the absence of nonlinear losses and excellent thermal stability in that wavelength range. Our experimental results reveal that the SRSN-based structure can be employed potentially to realize linear and nonlinear applications in the telecom band. © 2023 Optica Publishing Group

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## 1. INTRODUCTION

Over the years, silicon (Si)-photonics has emerged as a promising CMOS-compatible material platform for fabricating low-cost, scalable integrated components for on-chip applications [1,2]. Owing to the high-index contrast, high Kerr coefficient, transparency over a broad wavelength range (telecom to mid-IR), and enhanced device performance, Si-on-insulator (SOI) technologies in Si-photonics has been widely accepted for the future generation of CMOS integrated circuits (ICs). Researchers have harnessed Si-photonics and employed in a plethora of applications, including high-speed data processing, sensing [3,4], nonlinear and quantum photonics [5,6], wavelength-division multiplexing (WDM) systems [7,8], and all-optical signal processing [9]. However, despite the tremendous achievement of Si photonics, the small electronic bandgap of Si (1.12 eV) [6] imposes a fundamental limitation owing to the large two-photon (TPA) and free-carrier absorption (FCA) losses below 2.2  $\mu\text{m}$  wavelength [10]. These nonlinear losses are detrimental to the optical performance even at low power and prevent widespread adoption of the Si platform in the telecommunication band [11–13]. On the other hand, Si exhibits a high

thermo-optic coefficient (TOC) ( $dn/dT = 1.86 \times 10^{-4} \text{ K}^{-1}$ ), which makes SOI devices strongly sensitive to the device temperature [14]. The optical properties of Si-based devices are highly influenced by the local heating that arises due to the launch of high-power sources and changes in the environmental temperature. Therefore, Si-based photonic devices face limitations in applications corresponding to high-temperature variation. Different approaches have been reported to reduce the thermal effect of Si-based devices, such as the incorporation of an external metal heater for thermal stabilization [15], cladding layer deposition with a material of negative TOC to compensate for the positive TOC of Si [16,17], and athermal design [18]. The limitation of the Si platform leads to exploring a new flexible CMOS-compatible platform carrying a refractive index lying between Si and  $\text{SiO}_2$ , which can be realized for a multitude of photonics applications. In the quest for a proper substitution of the Si platform, researchers are harnessing different material platforms to overcome the limitations associated with Si.

Over the years, stoichiometric Si nitride ( $\text{Si}_3\text{N}_4$ ) material has gained significant attention as a promising CMOS platform for building photonic ICs (PICs) [19]. Apart from its

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## **Table of Contents Linear And Nonlinear Loudspeaker Characterization**

1. Understanding the eBook Linear And Nonlinear Loudspeaker Characterization
  - The Rise of Digital Reading Linear And Nonlinear Loudspeaker Characterization
  - Advantages of eBooks Over Traditional Books
2. Identifying Linear And Nonlinear Loudspeaker Characterization
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Linear And Nonlinear Loudspeaker Characterization
  - User-Friendly Interface
4. Exploring eBook Recommendations from Linear And Nonlinear Loudspeaker Characterization
  - Personalized Recommendations
  - Linear And Nonlinear Loudspeaker Characterization User Reviews and Ratings
  - Linear And Nonlinear Loudspeaker Characterization and Bestseller Lists
5. Accessing Linear And Nonlinear Loudspeaker Characterization Free and Paid eBooks
  - Linear And Nonlinear Loudspeaker Characterization Public Domain eBooks
  - Linear And Nonlinear Loudspeaker Characterization eBook Subscription Services
  - Linear And Nonlinear Loudspeaker Characterization Budget-Friendly Options
6. Navigating Linear And Nonlinear Loudspeaker Characterization eBook Formats
  - ePub, PDF, MOBI, and More
  - Linear And Nonlinear Loudspeaker Characterization Compatibility with Devices
  - Linear And Nonlinear Loudspeaker Characterization Enhanced eBook Features
7. Enhancing Your Reading Experience

- Adjustable Fonts and Text Sizes of Linear And Nonlinear Loudspeaker Characterization
  - Highlighting and Note-Taking Linear And Nonlinear Loudspeaker Characterization
  - Interactive Elements Linear And Nonlinear Loudspeaker Characterization
8. Staying Engaged with Linear And Nonlinear Loudspeaker Characterization
    - Joining Online Reading Communities
    - Participating in Virtual Book Clubs
    - Following Authors and Publishers Linear And Nonlinear Loudspeaker Characterization
  9. Balancing eBooks and Physical Books Linear And Nonlinear Loudspeaker Characterization
    - Benefits of a Digital Library
    - Creating a Diverse Reading Collection Linear And Nonlinear Loudspeaker Characterization
  10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
  11. Cultivating a Reading Routine Linear And Nonlinear Loudspeaker Characterization
    - Setting Reading Goals Linear And Nonlinear Loudspeaker Characterization
    - Carving Out Dedicated Reading Time
  12. Sourcing Reliable Information of Linear And Nonlinear Loudspeaker Characterization
    - Fact-Checking eBook Content of Linear And Nonlinear Loudspeaker Characterization
    - Distinguishing Credible Sources
  13. Promoting Lifelong Learning
    - Utilizing eBooks for Skill Development
    - Exploring Educational eBooks
  14. Embracing eBook Trends
    - Integration of Multimedia Elements
    - Interactive and Gamified eBooks

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