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Design of GaN-Based Low-Loss Y-Branch Power Splitter

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Abstract

We present a Y-branch power splitter design with a multimode section using GaN on Sapphire at telecommunication wavelength. The GaN sample optical properties were also investigated, resulting in a refractive index for the GaN layers nTE=2.289±0.001 and nTM=2.324±0.00. Optimization of the structure parameters for this structure was conducted accurately using BPM methods. The results demonstrated the possibility of realizing a GaN-based Y-branch power splitter for various applications.

Abstrak

Desain Pembagi Daya Pencabangan Y Rugi-Rugi Rendah Berbasis GaN. Pada penelitian ini dilaporkan desain pembagi daya pencabangan Y dengan memanfaatkan pandu gelombang moda jamak pada panjang gelombang telekomunikasi menggunakan material GaN pada Safir. Hasil pengukuran sifat optik menunjukkan bahwa indek bias sampel GaN pada Safir adalah nTE=2,289±0,001 dan nTM= 2,324±0,00. Dari hasil optimasi parameter struktur dengan metoda BPM ditunjukan bahwa pembagi daya pencabangan Y berbasis bahan GaN.berpotensi untuk direalisasi

Keywords: GaN, Y-branch, power splitter, waveguide, telecommunication

1. Introduction

III-nitride wide-band-gap semiconductor materials have attracted a great deal of attention in recent years due to their ability to operate at high temperatures and high power levels [1-2]. Thus far, research in III-nitrides has focused on applications in the blue/UV wavelength regions [3-6]. However, very little work has been done on the GaN-based optical waveguide for application in optical communication [7-9]. In this paper, we propose a design of a low-loss Y-branch, which is a fundamental element in constructing photonic integrated circuits, such as power splitters, and Mach Zehnder interfero-meters. Since the optical characteristic of the material is essential, we also investigated the optical characterization of the GaN on Sapphire sample.

2. Experiment

The sample used in this work is composed of a GaN active layer with a high carrier density (4 x 10^{17} cm^{-3}) was grown on high temperature/low temperature AlN/GaN buffer layers. This sample differs from those used in previous works [10-11]. The structure of the sample is shown in Figure 1. To investigate the optical properties of the GaN epilayer, we used the guided wave technique based on prism coupling, [12-13] consisting of a rutile TiO2 prism in a Metricon M2010 setup. The principal component of this equipment is depicted in Figure 2. A laser beam strikes the base of a high refractive index prism and is reflected into a photo-

Table 1. The Structure of the GaN on Sapphire Sample

GaN 1µm 4x10^{17} cm^{-3}	Waveguide
GaN 0,5 µm > 10^{18} cm^{-3} Buffer NID ~ 2 µm LT GaN	Buffer layer
Sapphire (Al_2O_3) 0001	

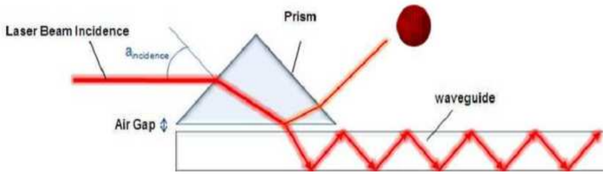

Figure 2. Principal Component of Metricon

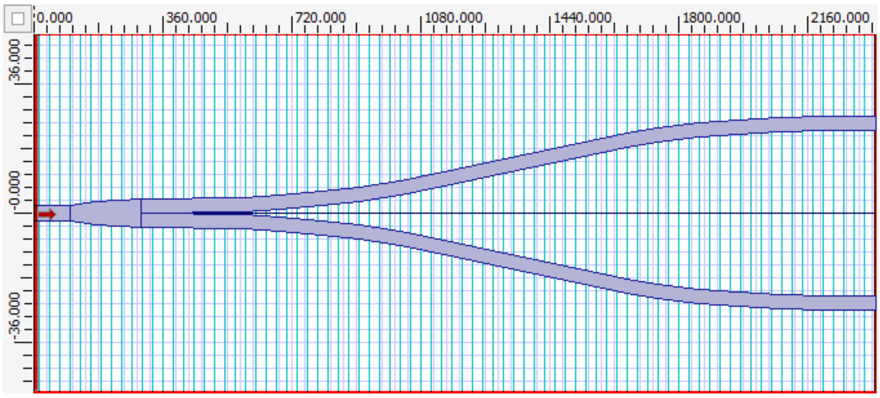

Figure 3. Y-Branch Power Splitter Design

detector. By measuring the reflected intensity versus the angle of incidence to the normal of the prism, we can plot the guided TE and TM mode spectrum of the sample.

Low-Loss Y-Branch Design. Figure 3 shows the schematic structure for a symmetric Y-branch design. The design consists of widely used large cross-section rib waveguides, a multimode section, and two branching waveguides, and thus differs from the design used in previous works [14-17]. The branching waveguide is based on a reflected S-bends mathematic curve, for which excellent splitting ratios have been demonstrated [18-19]. The functional form of S-bend is $\left(\frac{h}{l}\right)z - \left(\frac{h}{2\pi}\right)\sin\left(\left(\frac{2\pi}{l}\right)z\right)$, where h refers to the height of the bend, l is the length of the bend, and z refers to the propagation axis. The design was made using OptiBPM commercial software. The key design feature is the optimization of the waveguide cross-section, a multimode section, and the S-bend waveguide configuration in order to minimize losses and achieve good optical field distribution. In order to obtain a low-loss Y-branch that divides the light, we simulated the $\left(\frac{h}{l}\right)$ ratio of the S-bend. In this design, a rib waveguide as the input waveguide is connected to a multimode waveguide section. At the end of the multimode section, the light is coupled into two branching output waveguides. The numerical simulation resulted in optimal parameters of the design. The width and thickness of the input and output waveguides are 4 µm and support only single mode propagation. The investigated Y-branch is 2350 µm long and no more than 50 µm wide.

3. Results and Discussion

The TE mode spectrum is shown in Figure 4. The reflectivity dips observed at certain angles correspond to the excitation and propagation of guided modes in the film structure. These very sharp modes indicate a good film quality of the GaN epilayer [20-21]. We measured refractive indices for four wavelengths, namely, 532, 633, 975, and 1550 nm, with an accuracy of 10^{-3}. We

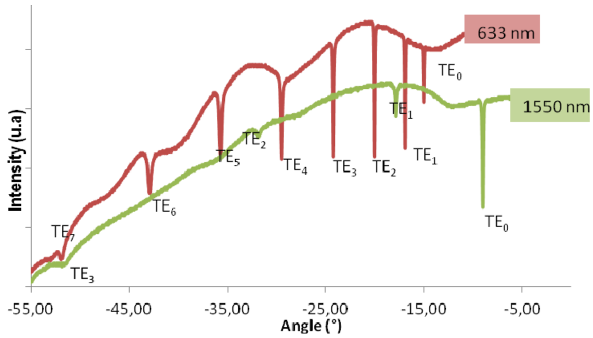

Figure 4. Guided TE Mode Spectrum at λ = 1550 and 633 nm

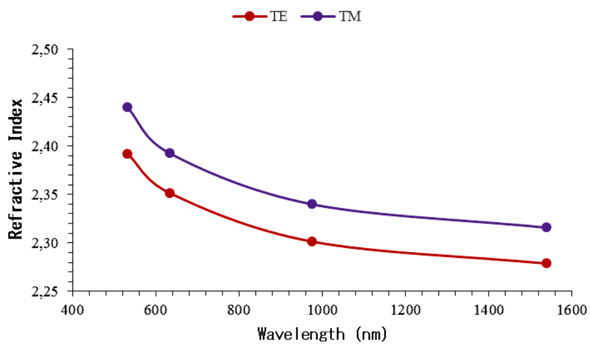

Figure 5. Refractive Index of GaN Optical Waveguide Structure Deposited on a Sapphire Substrate for TE and TM Polarization

found that the refractive index of GaN decreases with wavelength and reaches to approximately nTE= 2.289±0.001 and nTM= 2.324±0.001 in a 1550-nm wavelength window.

The dispersion of the TE and TM refractive index is plotted in Figure 5. Due to its plane wave, TM polarization refractive index values are more sensitive to the layer quality. The measurement results of refractive indices versus wavelength are in good agreement with previously reported values [10,22-23].

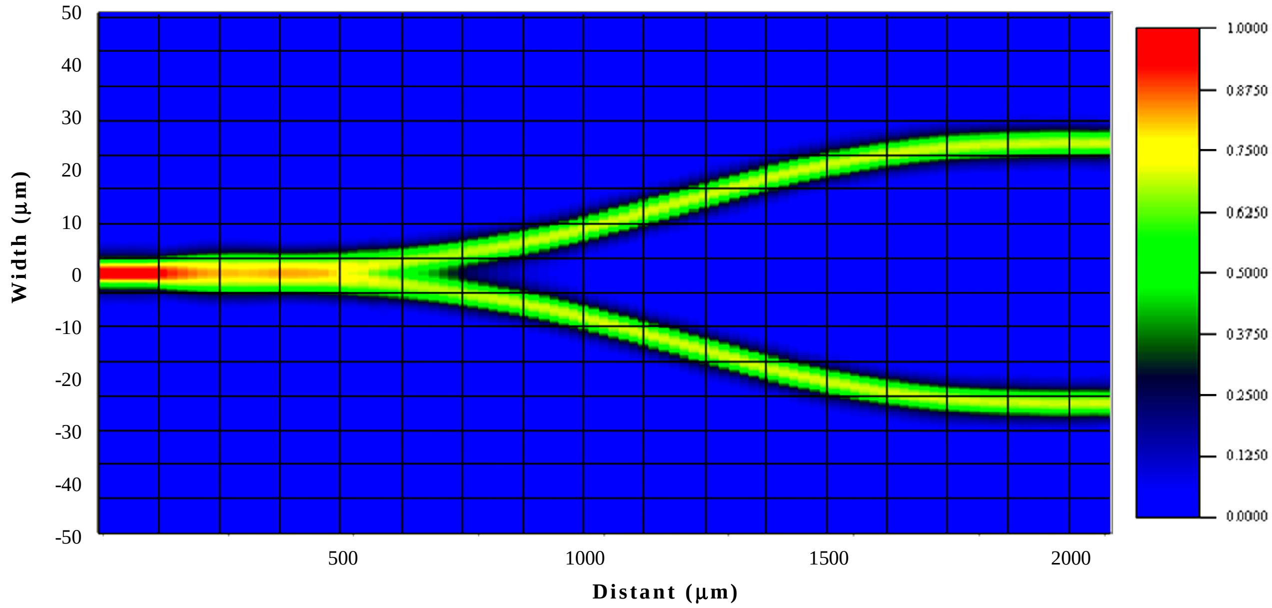

Figure 6. The Y-Branch Optical Field Distribution

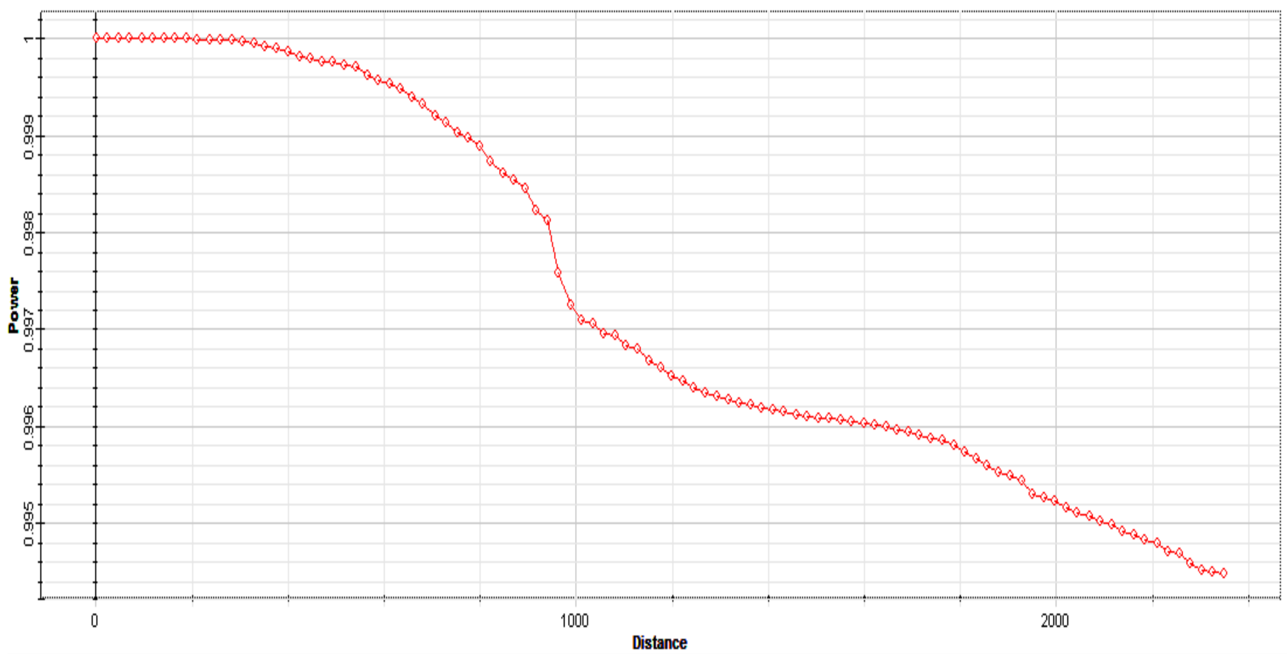

Figure 7. The Relative Optical Intensity Variation

To test the Y-branch design, the 1.55 µm light as an input wave is coupled in through a linear waveguide. Using beam propagation method analysis, the optical field distribution of the proposed Y-branch is presented in Figure 6. The red color in the straight input waveguide of the design indicates that the relative power is maximum. As the branching begins, the power splits into two arms equally, as indicated by the green color in the two arms. The relative optical power distribution as a function of distance is shown in Figure 7. Note that the relative optical power decreases with distance. The resulting relative power output is 0.99.

4. Conclusions

In conclusion, a Y-branch with a multimode waveguide section has been designed using GaN on Sapphire for a telecommunication wavelength of 1,55 µm. The designed Y-branch offers a minimal loss, as verified by the simulation results using OptiBPM. The optical characteristics of the sample required for this simulation were also investigated.

Acknowledgments

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