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Efficient nonlinear interactions in GaN waveguides

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Abstract: We have been able to fabricate low loss GaN planar waveguides designed for efficient second harmonic generation. By using modal phase matching we reached 2% power conversion between the TM0 pump and the TM2 harmonic modes.

1. State of the art

Nonlinear interactions in AlGaN semiconductors recently generated considerable research interest [1-3]. Indeed, the combination in these materials of a relatively high nonlinear coefficient 10pm/V, a large transparency window 200nm-5μm and a direct band gap can lead to novel applications in the future.

Although a lot of progress has been done for the sputtered AlN films [3], mono-crystalline AlGaN layers mainly grown by epitaxy on Si or Sapphire substrates still show poor photonic quality [1,4]. In this paper we present an approach, which allows us to fabricate low loss GaN waveguides epitaxially grown on Sapphire substrate. Low propagation losses allow NIR to visible power conversion with 2% efficiency, which to our best knowledge is the highest value reported so far for the GaN waveguides.

2. Fabrication of low loss waveguides for efficient nonlinear interactions

Modal phase matching which is crucial for the efficient nonlinear interactions can be realized in AlGaN waveguides due to the high refractive index difference between GaN and AlN. We exploit this difference to compensate the material dispersion by the modal dispersion in a multi-modal waveguide.

Low propagation losses is a major requirement to obtain efficient SHG. Here we perform a careful study to identify the main sources of propagation losses. We demonstrate that about 1μm thick AlGaN buffer layer is sufficient to isolate all the modes confined in the GaN layer from the substrate and the perturbed nucleation layers. This buffer layer allows us to improve drastically the waveguide performance although the propagation losses still remain to high for SHG (10dB/cm at 630nm).

An important discovery was made during this study when we realised that the so-called kinetic surface roughness associated with the epitaxial growth has a major impact on the waveguide losses. The amplitude of the kinetic roughness depends on the layer thickness and the growth temperature determines its spatial frequency. As MBE and MOVPE growths, take place at different temperatures, respectively 800°C and 1050°C the surface aspect of the layer depends very much on the chosen process. Combining them, we were able to reduce the amplitude and the spatial frequency of the surface roughness in such a way that the propagation losses drop down from 10 to 1dB/cm.

3. Second harmonic generation

Those low propagation losses allowed us to study second harmonic generation using modal phase matching with the setup shown on Fig. 1. Using the prism-coupling technique we inject the pump at 1260nm in the TM0 mode. The pump propagates about 3mm in the waveguide and generates the harmonic in the TM2 mode at 630nm. Both are collected and separated by a second prism and send on appropriate detectors.

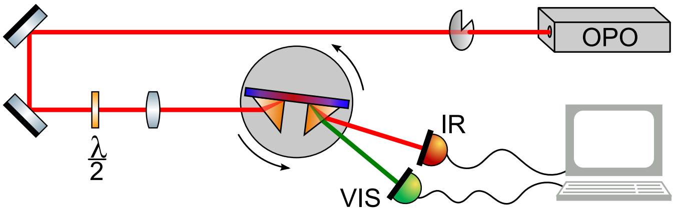

Fig. 1. Experimental setup. Prism coupling is used for the planar waveguide.

In Fig. 2 a) we plot the harmonic signal as a function on the pump wavelength and observe a sharp phase matching curve as predicted by the theory. In Fig. 2 b) we plots the SH intensity as a function of pump energy. The conversion efficiency reaches 2% for 400nJ pump pulses.

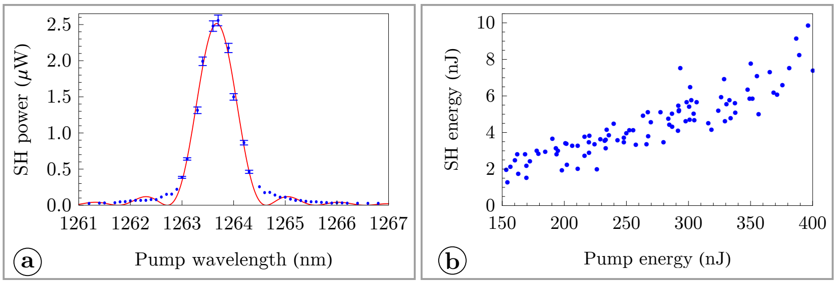

Fig. 2. a) Acceptance curve. b) Harmonic energy as a function of pump energy.

To further improve these state of art results, we plan to fabricate ridge waveguides to reach higher power densities and to use polarity inversion to increase the TM0/TM2 modal overlap.

References

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