Intrinsic Polarity Inversion in III-Nitride Semiconductors for Efficient Nonlinear Interactions

M. Gromovyi[1,2], N. Bhat[2], H. Tronche[3], P. Baldi[3], M. El Kurdi[1], X. Checoury[1], B. Damilano[2], and P. Boucaud[2]

[1]*Université Paris-Saclay, CNRS, C2N, Rue Thomas Gobert, 91120 Palaiseau, France*

[2]*Université Côte d'Azur, CNRS, CRHEA, Rue Bernard Grégory, 06905 Sophia-Antipolis, France*

[3]*Université Côte d'Azur, CNRS, INPHYNI, 06200 Nice, France*

philippe.boucaud@crhea.cnrs.fr

The III-nitrides semiconductors offer a very peculiar property for their second-order nonlinear susceptibility. The sign of the largest component of the nonlinear susceptibility tensor $\chi^{(2)}{}_{zzz}$ is opposite between GaN and AlN. This is a direct consequence of the tetrahedral bonding in these wurtzite-type structures and highlights the sensitivity of the second-order response function to the band structure and momentum matrix elements of the materials [1].

The opposite sign of the nonlinear susceptibility is usually not present within a family of compound semiconductors. However, playing with the sign of the nonlinear susceptibility is a usual requisite in order to achieve high nonlinear conversion efficiencies through phase matching. As an example, in integrated photonics, the efficiency of the nonlinear conversion in the case of modal phase matching is directly proportional to the integral of the product of the nonlinear susceptibility and the mode profiles. Reversing the sign of the nonlinear susceptibility can completely change the value of this integral. Consequently, many different approaches have been developed over the years to achieve phase matching for nonlinear conversion by engineering the nonlinear susceptibility. One of the most standard approach for quasi-phase matching is the use of periodically-poled structures where the orientation of the nonlinear material is periodically reversed along the propagation direction. An alternative approach relies on wafer bonding to reverse the material orientation. These methods remain complex and usually technologically challenging.

The specificity related to the sign of the nonlinear susceptibility in III-nitride materials has usually been overlooked in the literature when dealing with nonlinear conversion efficiency. This is all the more surprising as the epitaxial growth of GaN on AlN is very common and standard. In this presentation, we will show that we can design and grow GaN and AlN bilayers leading to a very simple and smart way to achieve high conversion efficiency for nonlinear interactions. We will show that an enhancement of the conversion efficiency by more than two orders of magnitude can be achieved for second harmonic generation in the near-infrared [2]. This enhancement is experimentally confirmed in III-nitride waveguides epitaxially-grown on sapphire substrate. We will show that these bilayer heterostructures are compatible with high quality photonic resonators, with quality factor values up to 400 000 being experimentally measured [3]. The proposed approach can be applied as well for spontaneous down conversion and the generation of entangled photon pairs using the III-nitride photonic platforms. The specificities of the III-nitride photonic platforms for quantum technologies will be discussed by reference to the other photonic platforms available for the visible spectral range [4].

References

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