Research and development of photodetectors based on van der Waals heterostructures integrated on a waveguide

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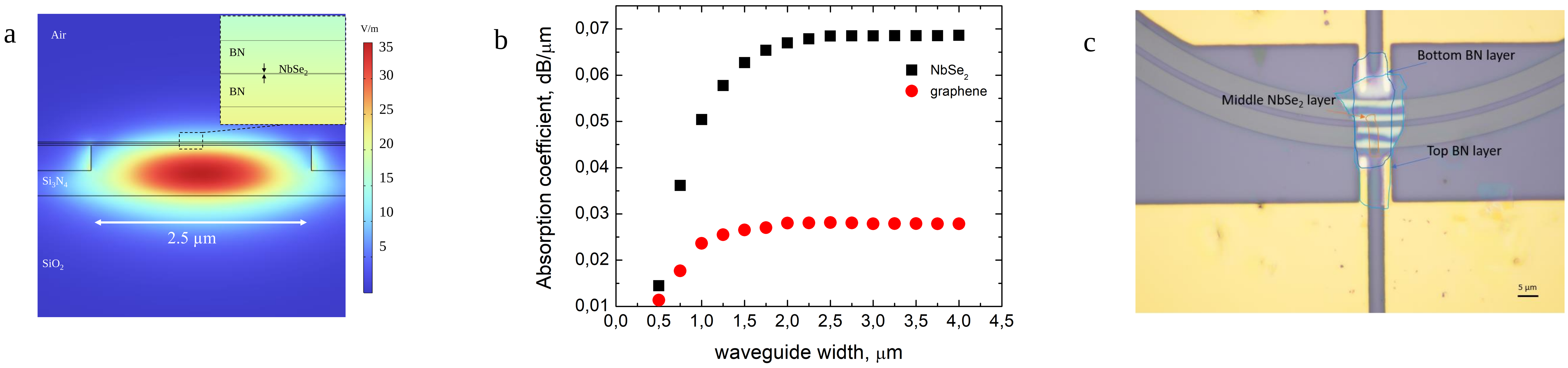
Introduction

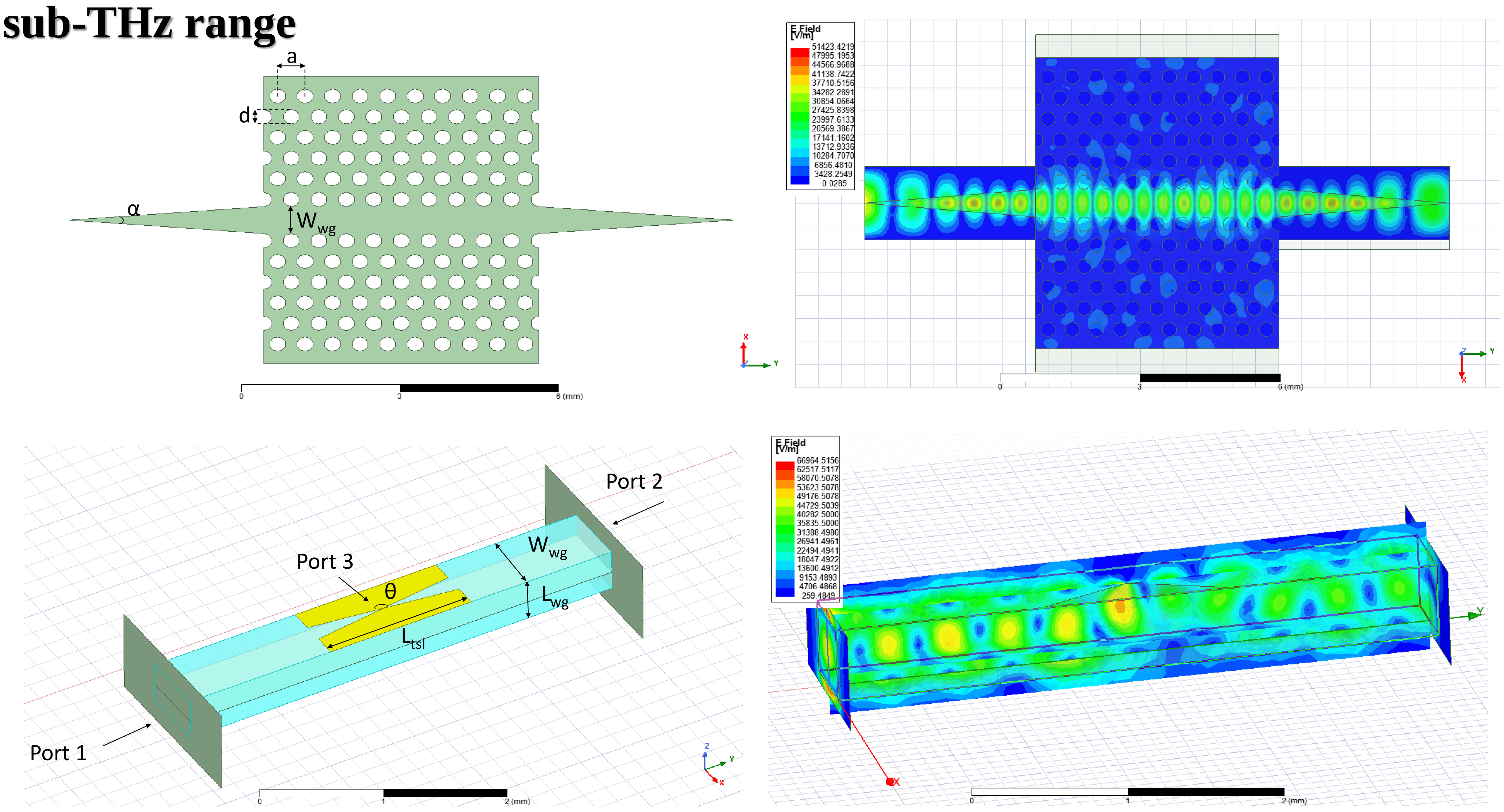
2D structures can be successfully integrated into photonic integrated circuits by simple mechanical transfer [1]. Graphene, which exhibits ultrafast charge carrier dynamics, and niobium diselenide NbSe2, in which a photoresponse at a wavelength of 1500 nm has been observed, have been chosen as photodetector materials [2]. As frequencies of electromagnetic radiation two practically important ranges were chosen: telecommunication (wavelengths of 1.55 μm), as well as the sub-THz range with a frequency of 130 GHz, which is now considered as the carrier frequency for future 6G communication systems. A silicon nitride film substrate was chosen to fabricate waveguides for the telecoms wavelengths as it has low infrared light propagation loss [4], good mechanical properties and is compatible with the CMOS fabrication process [3]. For the terahertz range, a high resistivity silicon substrate was chosen to create waveguides based on an efficient dielectric medium [5].

Telecommunication range



a-the mode profile for the TE-like mode in a Si_3N_4 waveguide with a layer hBN/$NbSe_2$/hBN atop , b - modelled absorption coefficient as a function of waveguide width, c - photograph of the hBN/$NbSe_2$/hBN structure transferred to the waveguide

sub-THz range



a- b – electromagnetic model of 130 GHz silicon waveguide with tapers: expansion angle α = 10˚, waveguide width W_{wg} = 585 μm, height L_{wg} =400 μm, hole period a = 528 μm, hole diameter d = 316 μm. The loss in the modelled structure was 0.18 dB; c-d - Electromagnetic model of a silicon ribbon waveguide integrated with a tapered slotted line of length L_{tsl} = 1287 μm, angle of spreading θ = 165˚. We observe reflection and transmission coefficients with magnitudes $S33=-10$ dB and $S31=S32=-4$ dB

Results

Modelling of the waveguide at telecommunication wavelengths has been carried out, allowing the development of a blueprint of the waveguide structure. The modelling data also helps to calculate the necessary dimensions of two-dimensional crystals to create structures with the required characteristics. To date, a process route for manufacturing optical circuits for telecommunication as well as terahertz wavelengths has been developed and fine-tuned. Initial measurements of the characteristics of graphene and niobium diselenide have been obtained.

Acknowledgments

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