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Parametric design study for waveguide-based graphene MIR photodetectors

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SUMMARY

MIR sensing technology has the potential capacity to dramatically improve aspects of real-world problems - from planet formation to molecular species identification – once integrated “system on a chip” sensing devices are available at a palatable cost. A key limiter in achieving a full integrated on a chip design is the lack of broadband waveguide-based detectors, with no designs or experimental broadband devices having been demonstrated to date. Simulation and analysis conducted in this work has produced for the first time, practical graphene-based waveguide detector designs that can be made with existing and improved MIR waveguide technology.

Using Rsoft FemSIM with high resolution graded gridding to accurately capture the effects in single layer graphene; extensive, and time consuming, parametrised simulations have been carried out for different waveguide designs to understand the design space available and optimise the absorption of light in graphene coated chalcogenide waveguides. The accuracy of the optical modelling and the values for the graphene material model were verified by modelling experimentally reported devices[1-3] in the NIR region to ensure there is a close match to the measured points. Geometry (height, width), wavelength, waveguide type (Channel, Rib), Monolayer, bilayer and multilayer graphene layouts were the core variables investigated as functions of the waveguide core refractive index and top and bottom cladding indices. Fig. 1 give the examples of fully-etched waveguide design. Additionally, different materials as buffer/spacer layers to compress the field or to try and locate the graphene in a higher field region were also trialled. The results were contour graphs of absorption versus width and height for the fundamental mode at 10 different wavelengths with different Top/Bottom cladding index contrasts, from which it is possible to design wideband detectors.

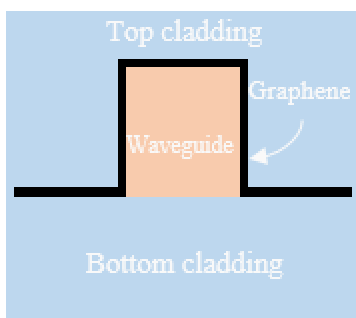

Figure 1. Fully-etched waveguide with graphene covered on surface.

The results show that high refractive index (RI) contrast between core and cladding material maximises the overlap of the optical field with the graphene thereby maximising absorption. This however also comes at a price in terms of the fabrication tolerances required to stay in the high absorption region. As shown in Fig 2e, it is also clear that very large absorption values are possible at shorter wavelengths, but that falls away at longer ones by around an order of magnitude at 10um due to the increase in mode size reducing the overlap to the graphene. Clear design preferences can be seen for devices operating in a single polarisation versus unpolarised, and single polarisation devices (useful for example where polarised laser sources are to be detected) could be made somewhat shorter as a result.

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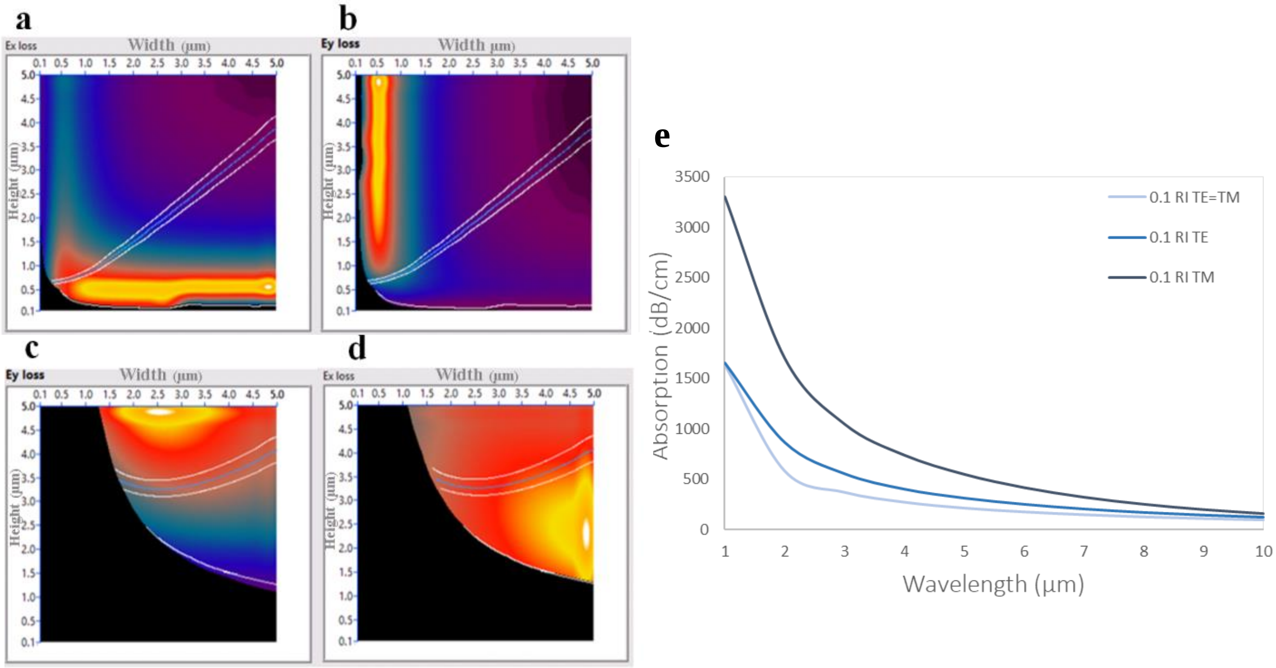

Figure 2. Contour graphs of absorption vs width and height for fully-etched waveguide and the maximum absorption vs wavelength plot with core RI 2.6 and top/bottom cladding RI 2.5. a-b, TE and TM polarization at 2 μm wavelength. c-d, TE and TM polarization at 10 μm wavelength. The Blue line is locus of equal TE and TM absorption, white lines indicate the area within 10% absorption difference between TE and TM. Black areas mean the fundamental mode is cut off. e, Maximum Absorption over wavelength for same waveguide.

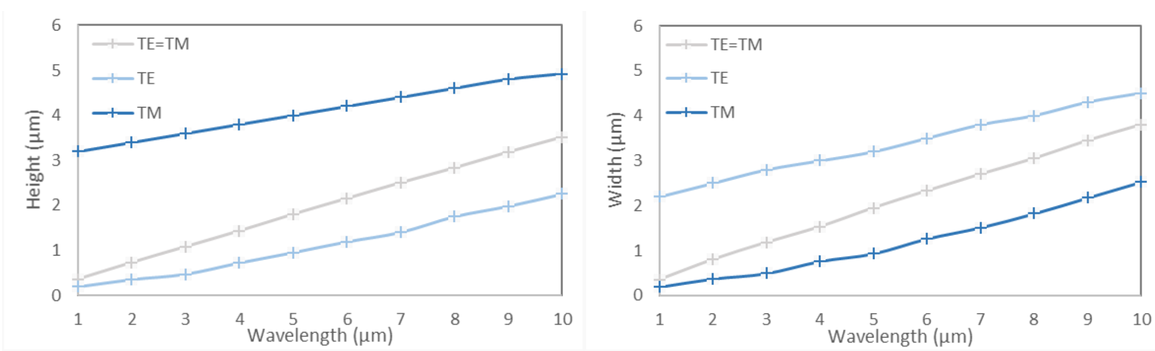

Figure 3. Height and width profile of waveguide design with core RI 2.6. and cladding RI 2.5.

Based on the simulation result, a feasible design of 3.3 mm long fully-etched waveguide is presented in Fig. 3 that cover 1 to 10 μm with absorption 10 dB/cm for each wavelength.

REFERENCE

[1] J. Wang, Z. Cheng, Z. Chen, X. Wan, B. Zhu, H. K. Tsang, C. Shu, and J. Xu, "High-responsivity graphene-on silicon slot waveguide photodetectors," Nanoscale 8, 13206-13211 (2016).

[2] Y. Gao, L. Tao, H. K. Tsang, and C. Shu, "Graphene-on-silicon nitride waveguide photodetector with interdigital contacts," Applied Physics Letters 112, 211107 (2018).

[3] H. Lin, Y. Song, Y. Huang, D. Kita, S. Deckoff-Jones, K. Wang, L. Li, J. Li, H. Zheng, Z. Luo, H. Wang, S. Novak, A. Yadav, C.-C. Huang, R.-J. Shiue, D. Englund, T. Gu, D. Hewak, K. Richardson, J. Kong, and J. Hu, "Chalcogenide glass-on-graphene photonics," Nature Photonics 11, 798-805 (2017).