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# Recent Developments in Graphene and Black Phosphorus at MackGraphe

MackGraphe initiated its activities in 2013 with a start-up fund of ~US$ 20,000,000.00, which includes the construction of a new building. The aim is to carry out 2D materials synthesis (via both CVD growth and exfoliation), characterization, and device development. The mission of MackGraphe is to investigate properties 2D materials with an applied engineering thinking. We expect strong collaboration with industries to develop technologies that meet the society needs. We are focused on recruiting the best and brightest students and researchers and creating an environment to encourage long-term thinking.

We present some results about graphene and black phosphorus (BP). With graphene Bahamon et al (Fig. 1) investigate the impact of strained nanobubbles on the conductance characteristics of graphene nanoribbons using a combined molecular dynamics – tight-binding simulation scheme [1]. Romagnoli et al (Fig. 2) demonstrate a new technique of making graphene visible on transparent dielectric substrates via Brewster angle imaging [2]. Zapata et al (Fig. 3) demonstrated a method to construct high efficiency saturable absorbers based on the evanescent light field interaction of CVD monolayer graphene deposited on side-polished D-shaped optical fiber that generated the shortest pulse reported so far [3]. In BP Ribeiro et al (Fig. 4) measured an unusual angular dependence of the Raman response that can be explained only by considering complex values for the Raman tensor elements [4].

## References

[1] D. A. Bahamon, Zenan Qi, Harold S. Park, Vitor M. Pereira, David K Campbell, Nanoscale, 2015, 7, 15300-15309.

[2] Priscila Romagnoli; Henrique G. Rosa; Daniel Lopez-Cortes; Eunézio A. T. Souza; José C. Viana-Gomes; Walter Margulis; Christiano J. S. de Matos, 2D Mater. 2 035017 (2015).

[3] J. D. Zapata, D. Steinberg, L. A. M. Saito, R. E. P. de Oliveira, A. M. Cárdenas and E. A. Thoroh de Souza. Submitted for publication in Scientific Report.

[4] Henrique B. Ribeiro, Marcos A. Pimenta, Christiano J. S. de Matos, Roberto Luiz Moreira, Aleksandr S. Rodin, Juan D. Zapata, Eunézio A. T. de Souza, and Antonio H. Castro Neto, ACS Nano, 2015, 9 (4), pp 4270–4276.

## Figures

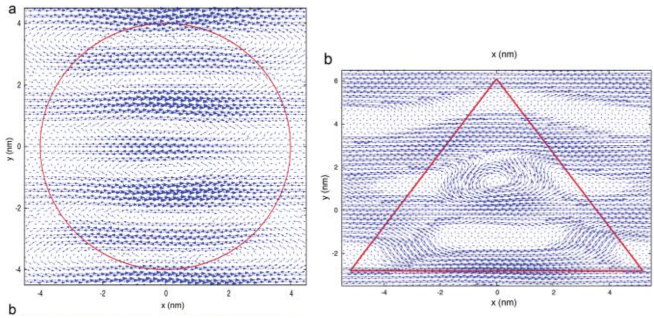


Figure 1: (Color online) Current density at E = 0.215t0 around the clamped circular bubble (a) and triangular bubble (b). The red outline marks the portion of the system corresponding to the bubble region. Each blue arrow indicates the local current flow, and has a magnitude proportional to the current at each lattice site.

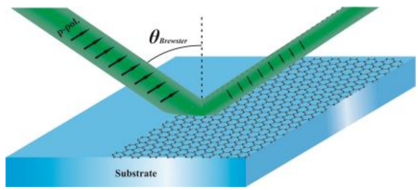


Figure 2: Schematic representation of p-polarized light being reflected solely on graphene when incidence takes place at the substrate's Brewster angle

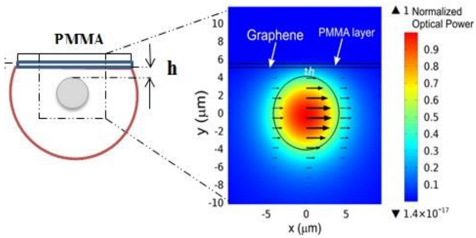


Figure 3: Simulated fiber design with the optical power distribution in the TE polarization.

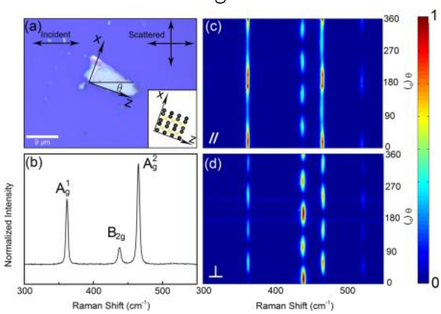


Figure 4: BP: a) Optical microscope image of the measured flake, showing the crystallographic axes, the directions of the incident and analyzed scattered light, and indicating the angle θ between the incident light and the z axis. (b) Raman spectrum for an arbitrary configuration showing the $A_g^1$, $B_{2g}$, and $A_g^2$ modes. Angular dependence of the Raman intensity spectra measured in the (c) parallel and (d) cross-polarization configurations.