Increasing the extraction efficiency of quantum light from 2D materials

C. Woodhead[1], J. Roberts[1], Y. Noori[1], A Kozikov[2], Y.Cao[1], R. Bernardo-Gavito[1] K. Novoselov[2] and R. J. Young[1]

[1]Physics Department, Lancaster University, Lancaster, Lancashire, LA1 4YB

[2] School of Physics and Astronomy, University of Manchester, Oxford Road, Manchester, M13 9PL

Direct bandgap 2D semiconductor materials such as monolayers of transition metal dichalcogenides (TMDCs), show great promise in optoelectronic devices enabling exciting new technologies such as ultra-thin quantum light LED's [1]. These structures can have incredible advantages, enabling almost seamless integration into conventional silicon structures. However, extracting light out of these structures can be a challenge, often requiring costly and time consuming processing e.g. engineered waveguides or cavities [2]. Furthermore none of these methods allow you to observe the light directly, therefore are unhelpful in certain applications, such as an optical version of a quantum unique device [3].

We have previously demonstrated that epoxy based solid immersion lenses can be used to increase light out of semiconductor nanostructures. We furthered this idea to see if they could be used to increase the light out of monolayer TMDC materials; and investigate how the epoxy-2D material interface affects the emission. Our studies revealed that a SIL can greatly enhance the photoluminescence of WSe_2 by up to 6x (more than theory predicts for a SIL of this shape), without effecting the wavelength (figure 1). However we also found that the epoxy appears to reduce the emission of the MoS_2, suggesting that there could be doping effects due to the epoxy. Overall this method shows great promise as a cheap, and scalable method for enhancing the efficiency of low intensity WSe_2 based devices.

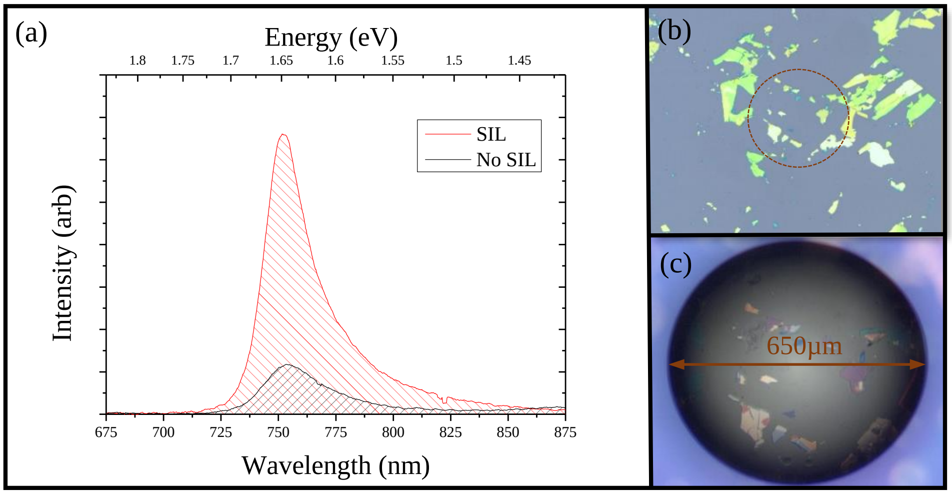

Figure 1- (a) Enhancement in the photoluminescence from mounting a SIL, (b) WSe2 flake before mounting a SIL, (c) Magnified WSe2 flake with a SIL

[1] B. Palacios et al. "Atomically thin quantum light emitting diodes", arXiv, 160308795P, 2016.
[2] F. Xia, "Two-dimensional material nanophotonics," nphoton, **8**, pp. 899, 2010.
[3] J. Roberts, "Using Quantum Confinement to Uniquely Identify Devices," SciRep, **5**, p. 16456, 2015.