Increasing quantum light extraction from TMDC's

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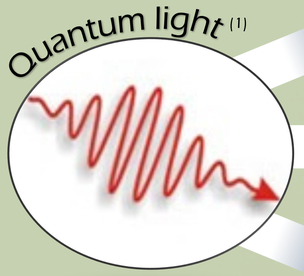
The diversity of single photon light

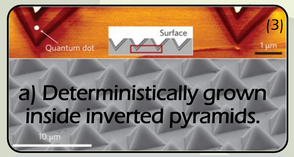
Single photons act differently to classical light in the quantum regime, this can be exploited to create a range of revolutionary technologies.



- Make communications 100% secure (quantum cryptography)
- Eliminate forgery through unclonable devices(2)
- Create Quantum computers that can quickly solve highly factorised problems

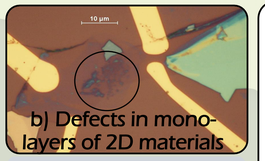
Quantum dots (QD's)

Quantum dots are highly promising single photon sources that can be made in multiple ways.



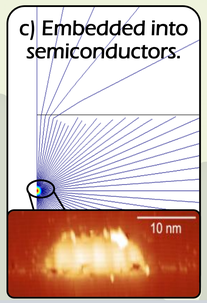
Pros: Site controlled growth.

Cons: Shape causes poor light extraction.



Pros: Thin, cheap and easy to produce.

Cons: Very fragile, lifetime limited.



Pros: High density, easily integrated into semiconductors

Cons: Total internal reflection limits extraction.

To enable single photon technologies, these losses need to be overcome with a cheap and scalable solution.

The solution

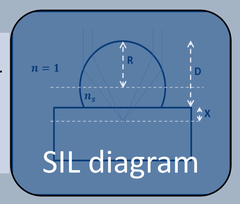
Small (millimeter sized) lenses called **"Solid immersion Lenses" (SIL's)**, *formed from liquid UV cured epoxy.*

Advantages for QD's

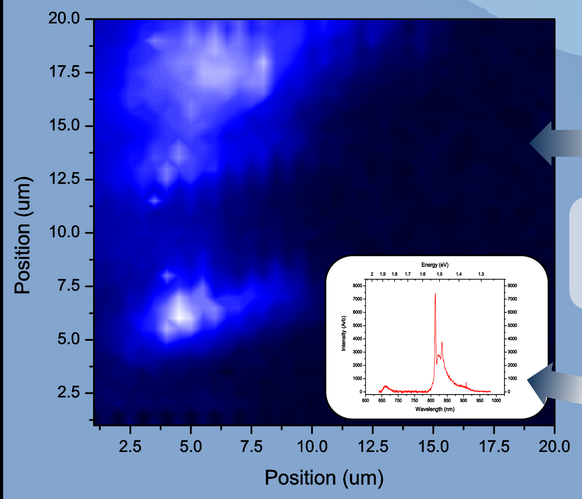
- Position Control.
- Can be placed over any structure.
- Encapsulated and protects structures
- Directly bonds to structure
- Cheap to mass produce

Advantages for optics

- Magnifies due to shape and refractive index.
- Can be tuned to tailor the focus to suit individual samples: $D = R\left(1 + \frac{1}{n_s}\right) - X$ (4)



Improved resolution



Dark field image of bilayer WSe_2, showing the edges in the flake

Photoluminescence maps on flakes through epoxy SIL's, show emission spikes (example inset), that were previously unresolved (white areas).

References

1) Molecules Communicate Via Single Photons, Phontonics.com, [online]:http://www.photonics.com/Article.aspx?AID=50189
2) J. Roberts, Sci Rep **5**, 16456, (2015).
3) J. Juska, et al, Nature Photonics, **7**, 527 (2013).
4) Micro lens formula: S. Yang, et. al, Advanced materials **15**, 940 (2003)