Illuminating Future Infrared Technologies: Colloidal Quantum Dot Lasers

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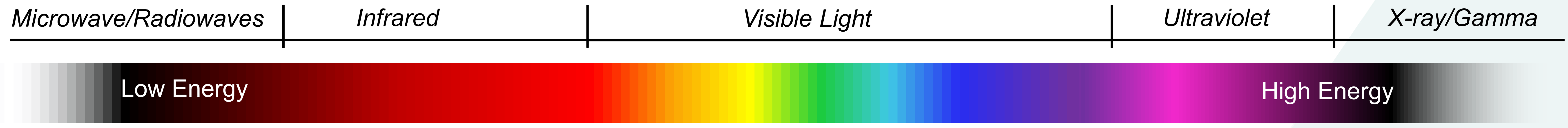
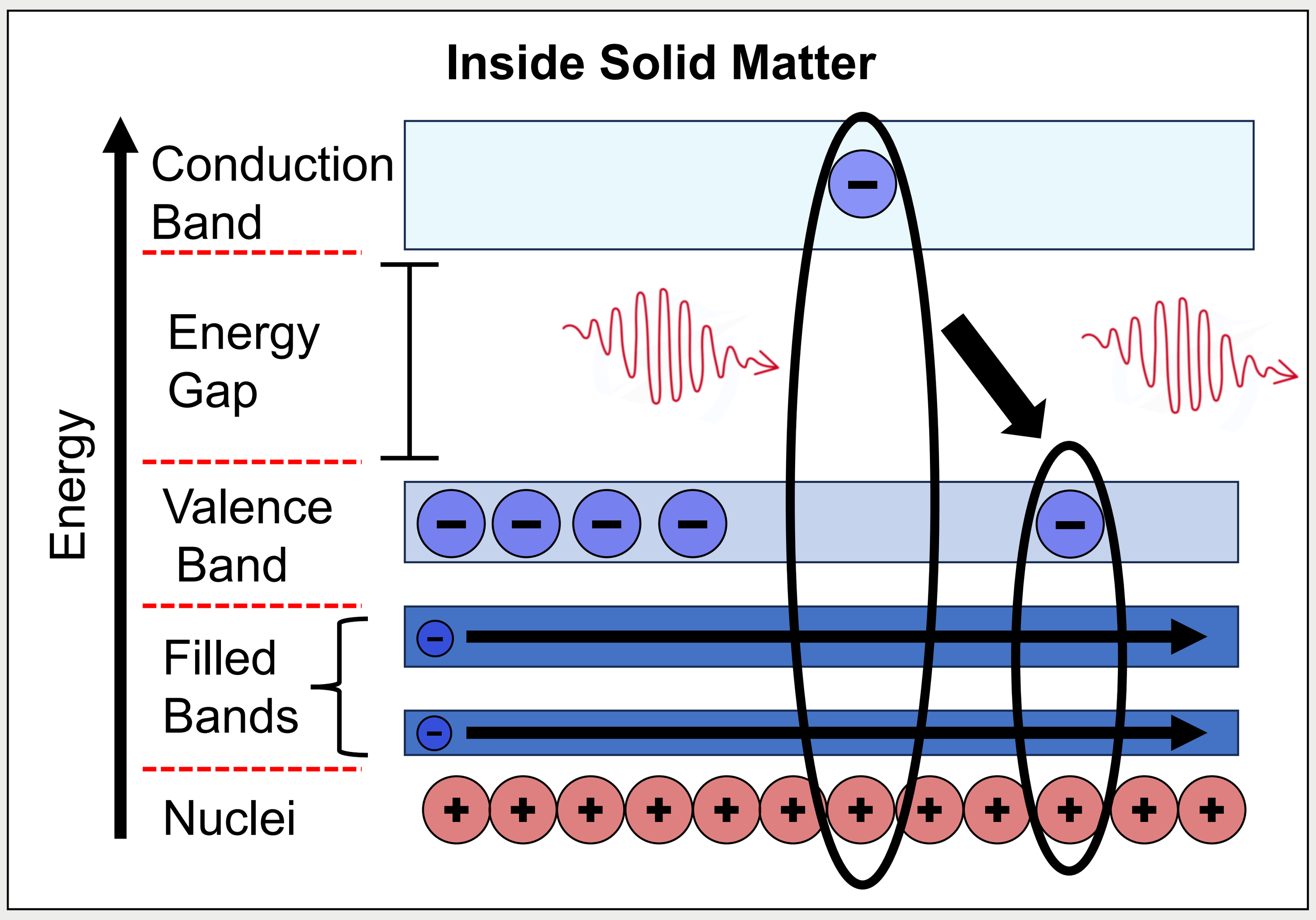
The Electromagnetic Spectrum



What is a Quantum Dot?

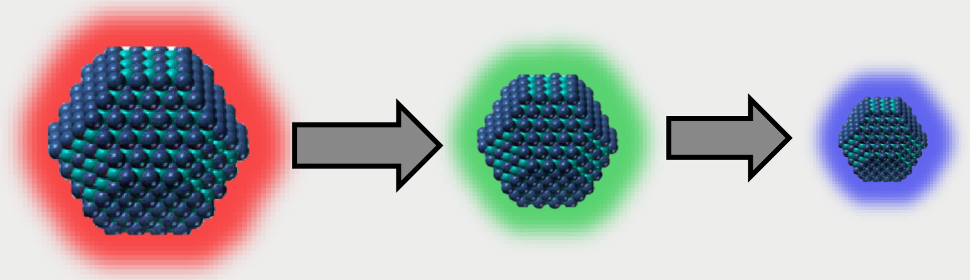
Semiconductors

The electrons in solids can only exist in certain energy "bands". Naturally, they occupy the lowest possible energy bands as they are attracted to the positive nuclei. You can input energy into electrons to excite them into higher energy bands; this is like stretching an elastic band. The more the elastic band stretches, the more energy it can store. When the electron snaps back to the lower band, it releases its energy as a photon equal to the energy gap



Quantum Confinement

The energy gap is normally fixed for any given semiconductor. However, if we make the semiconductor into extremely small crystals (10,000 times smaller than the width of a human hair), we can squeeze the electrons, effectively stretching the "elastic band" further and can tune the colour of the emitted light through the size of the crystals.

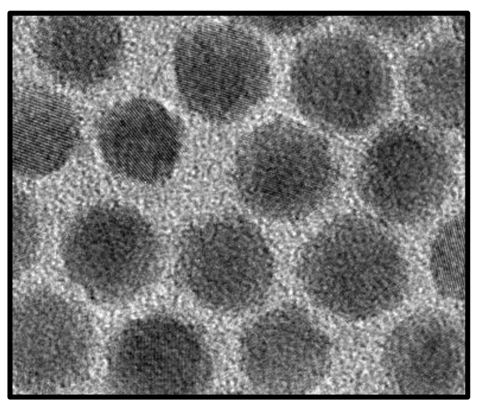


Quantum Dot Technology

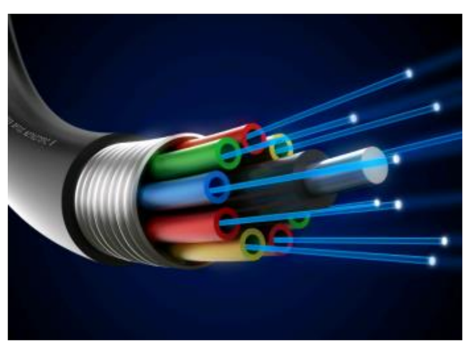
In 2023, the Nobel Prize in Chemistry was awarded to the synthesis of quantum dots, recognising their impact in QLED technology, medical imaging and solar cells. The QLED industry alone is worth globally > 30 billion dollars, and the total quantum dot industry is expected to grow at a CAGR of 16.4 % in the next 7 years.

Infrared Quantum Dots

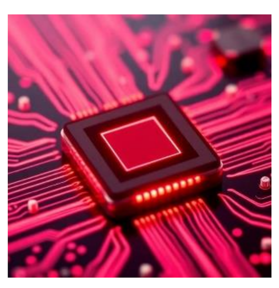
Much of the research into quantum dots has focused on those that emit in the visible portion of the electromagnetic spectrum. However, there are many interesting applications in the infrared for which quantum dots can be used, which are incredibly important for society.



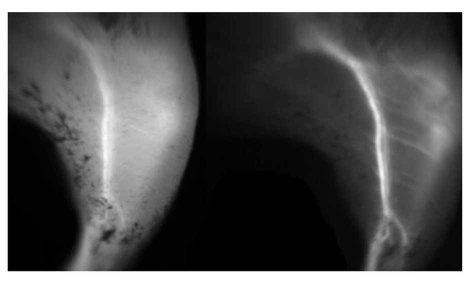
Applications



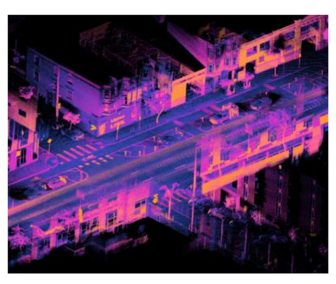
Telecommunications: The entire internet is based on an optical fibre network around the world that transmits data using laser signals in the short-wave infrared (SWIR).



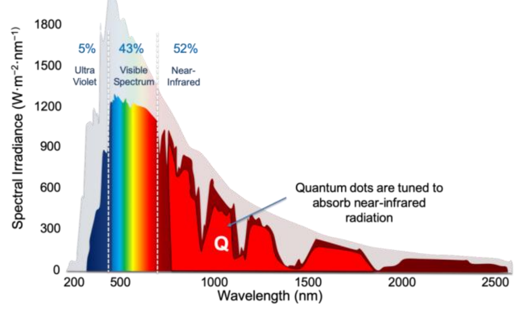
Silicon Photonics: There is a large drive to perform ultrafast computing using light signals as opposed to electronics, which can be done using infrared wavelengths and silicon waveguides



Bio-imaging: Biological tissue is more transparent in the infrared, making it very useful for improved bioimaging tools at deeper wavelengths.



LiDAR: Light Detection And Ranging, uses infrared light to detect distance, which is the basis of driverless vehicle sensors

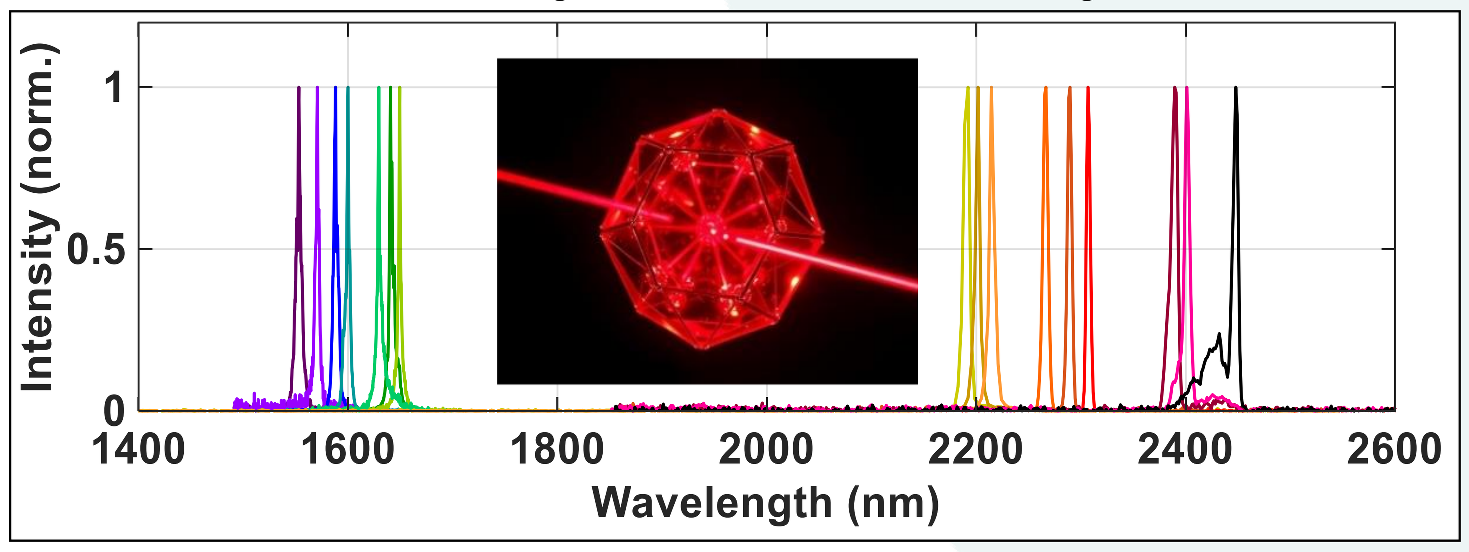


Infrared Solar Cells: Current Solar cells do not absorb a lot of the infrared photons from the sun, and so including infrared quantum dots could improve energy generation.

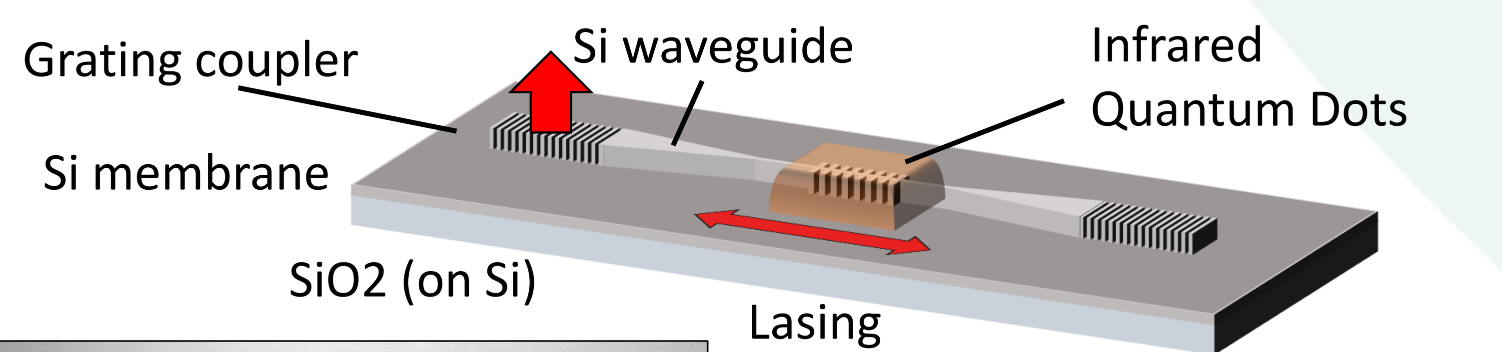
SWIR Cameras: Due to the transparency of water, SWIR cameras can see in difficult weather conditions such as fog.

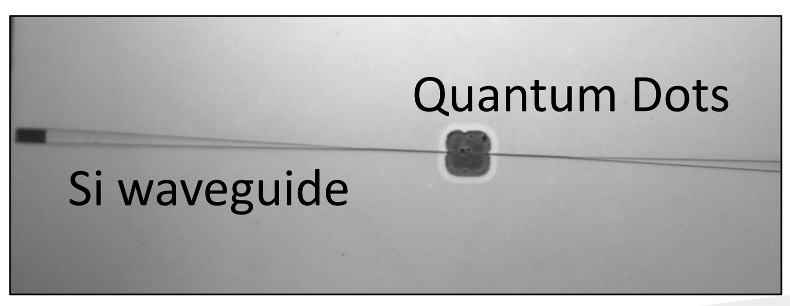
Nano Lasers for Silicon Photonics

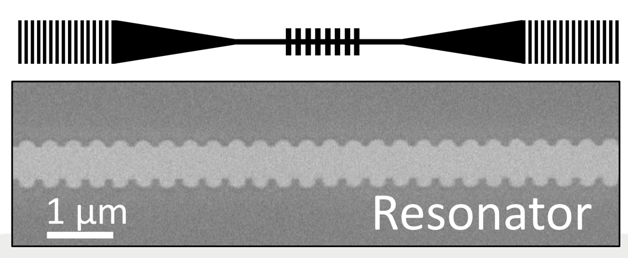
My expertise lies in using nanofabrication techniques and combining them with infrared colloidal quantum dots to make lasers. Below, you can see the first-ever lasers fabricated from SWIR quantum dots, which were tuned over a wide range of infrared wavelengths.



My current research involves integrating the infrared quantum dot lasers directly into silicon waveguides, taking advantage of the solution-processed nature of quantum dots. This will create new light sources to be used for future silicon photonics and quantum technologies. Below are diagrams and real images of my lasing structures, which were made using advanced nanofabrication techniques.







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