# Fabricating Microscale Antenna for Single-Photon Sources

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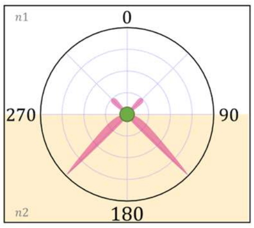
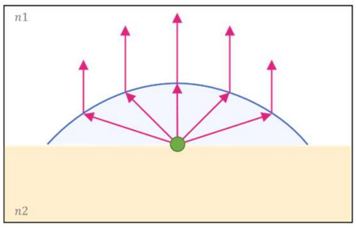
## Motivation: Single-Photon Sources

- Single-photon sources (SPS) are great emitters but are difficult to work with
- They emit **omnidirectionally**: we need an antenna to direct light
- They are **fragile**: existing techniques to make an antenna will destroy the SPS
- They are **randomly placed** making it difficult to place an antenna on top
- Existing methods to make antennas result in **surface artefacts**




*Sketch of single-photon source's emission spectrum*




*Sketch of a parabolic antenna placed on top of an emitter*

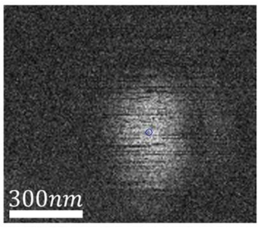
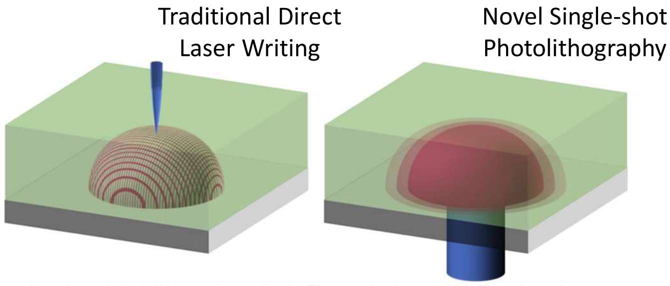



*Figure 1: Image of quantum dot using a homemade confocal microscope*

## Method: Photolithography

- Photolithography uses light to polymerise a photosensitive material (photoresist) into a solid dielectric structure
- The traditional method is **direct laser writing** which fabricates an antenna **separately from the emitter** by raster scanning
- This novel method is **single-shot** which fabricates an antenna in one quick exposure **on top of the emitter**[1]
- Using a confocal microscope setup with a piezoelectric stage, we can print structures on top of emitters, controlling exposure time and defocussing




*Sketches of photolithography methods. Photoresist (green) is exposed to a laser (blue) and polymerises along iso-intensity contours (pink).*

## Results

- We can successfully fabricate arrays of parabolic micro scaled antenna while varying exposure time and defocussing.
- Structure diameter varies linearly when varying the exposure time: we can control the voxel size within the Rayleigh range.

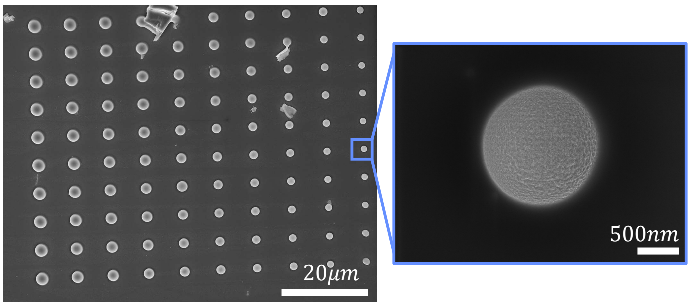



*Figure 2: SEM images of fabricated structures. Left: structures fabricated with a laser power of $10\mu W$ with exposure time varying (horizontally) between $50ms$ and $150ms$ and defocussing varying (vertically) between $-50nm$ and $50nm$. Right: Parabolic mirror fabricated with a laser power of $10\mu W$, exposure time of $50ms$ diameter $= 1.6\mu m$.*

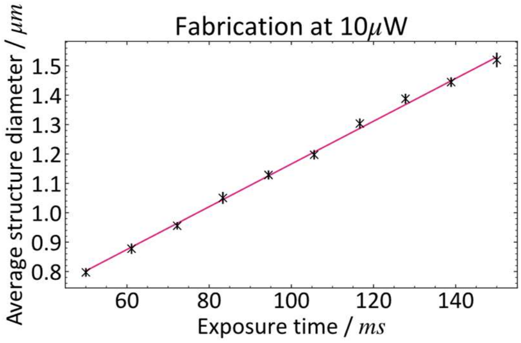



*Figure 3: Average structure diameter of Figure 2. Gaussian image filtering has been applied and structures have been fitted with randomised Hough transforms using OpenCV2 and SkImage packages.*

## Outlook

- The next steps are to print antennas on top of a quantum dot and measure the emission spectrum
- Future work can focus on fabricating complex structures using radially polarised beams or a digital micromirror device
- Single-shot photolithography can also be used to print cylindrical antennae on top of nanowires

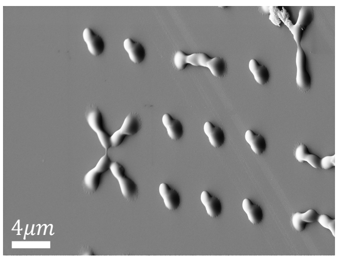



*Figure 4: Tilted SEM image of 'dumbbells' fabricated with a Gaussian Beam.*

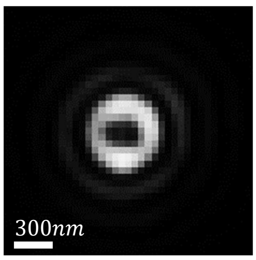
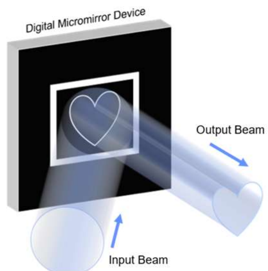



*Figure 5: First order 'donut' Gauss-Laguerre beam (taken with CCD camera).*




*Sketch of a DMD system. Only the white outline of the heart will reflect an incoming beam.*

References

[1] Morozov, S. (2019) *Photonic and electric control of single photon emission from individual quantum dots.* PhD thesis. Imperial College London.

Imperial College London