Inverse-designed meta-optics for light sorting

Dr. Calum Williams
Centre for Metamaterials Research and Innovation, University of Exeter, EX4 4QL, United Kingdom

Colour cameras utilize absorptive filter arrays atop the image sensor to spectrally discriminate light into red, green and blue (*RGB*) bands. These colour filter arrays (CFAs) are typically arranged in 2x2 unit cells (*RGGB* Bayer kernel) and tessellated across the image sensor (**Fig.1A**). Albeit providing spectral sensitivity, this spatial arrangement means only 50% of the total incident light reaches the green pixels, 25% the blue pixels and 25% the green pixels. Further, as the absorptive dyes themselves only transmit ~40% light, it means in combination ~70% of incident light upon the sensor is lost.

In recent years, nanophotonic colour routers (*light sorters*) have been proposed as an alternative filtering approach to absorptive CFAs.[1,3] Colour routers split the incident light into separate colours (wavelengths) and *route* the energy to specific pixels (**Fig.1B**). This *meta-optic* is composed of many sub-wavelength scatterers, with a designed distribution such that light is routed to different output positions depending on its wavelength. [4] Theoretical efficiencies as high as ~95% have been reported[3] yet experimental realization is challenging.

In this project, we will develop generalized light sorters based on inverse-designed meta-optics to efficiently route different wavelengths to different spatial positions. Our approach will employ 2D and ~2.5D meta-optic approaches (**Fig.1C**) in order to increase manufacturability while maintaining high optical performance (transmission efficiency, spectral sensitivity, angular sensitivity). We will extend our light sorter design scheme to: (1) longer waveband imaging (i.e. short-wave and mid-wave infrared); (2) polarimetric imaging, and (3) plenoptic (depth) imaging.

The research spans fundamental optical physics through to applications, and the student will develop a diverse skillset during the PhD project, including: computational optics, electromagnetic simulation (incl. *Lumerical FDTD* and *COMSOL*), nanofabrication within a state-of-the-art cleanroom (incl. e-beam lithography, physical vapour deposition etc.), electro-optic systems characterisation, validation of performance, and advanced data analysis.

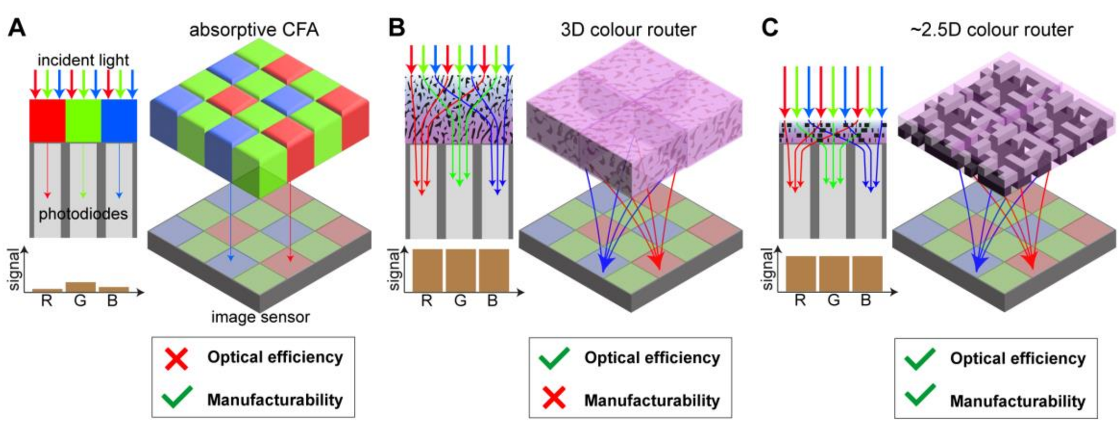

Fig 1. A. *Conventional RGB Bayer absorptive colour filter array (CFA), where separate absorptive filters spectrally discriminate the incident light.* ***B.*** *An alternate approach whereby sub-wavelength scatterers (3D distribution) route the light to specific pixels, thereby increasing the output signal.* ***C.*** ~2.5D meta-optic colour router.

References

[1] Chen, Q.,et al., Adv. Mater. 2021, 33, 2103815 (2021)
[2] Williams, C. et al., ACS Photonics 6(12), 3132-3141 (2019)
[3] Zhao, N., Catrysse, P.B. and Fan, S., Adv. Phot. Res., 2: 2000048 (2021)
[4] Li, Z., et al., ACS Photonics 9 (7), 2178-2192 (2022)