Docket #: S20-402

Perfect color routers for solid state image sensors

Image sensors are used across the board in high-resolution image sensing technologies, and critically rely on their ability to separate colors of light. Current commercial standards utilize color filters, which absorb unwanted wavelengths to filter and transmit only the desired color to the photodetector of the corresponding color channel, , e.g., red (R), green (G), blue (B). Although effective, this design is very inefficient and captures only a small fraction of light at the detector (less than 20-25% for a color filter array with a typical 2 by 2 pixel RGGB Bayer kernel), which makes low light imaging challenging and limits the practical size of image sensor pixels. The Fan group has designed a color router based on lossless materials that cleanly routes all incident light based on its spectral content (colors) with perfect (~ 100%) photon efficiency to the proper photodetector for all color channels. This results in a 4-5 times increase in the number of photons at the pixel photodetector level compared to a color filter-based approach. This color router design allows further scaling of image sensor pixels to sub-wavelength sizes (400 nm) since no light is reflected or absorbed. The underlying design principles can be applied to any desired wavelength of light and dielectric materials, allowing this technology to push the performance and size in color-separating devices to the absolute limit.

Photo description: a) Diagram of a typical color filter (CF) setup (ML = microlens) and b) diagram of a color router setup. Credit: Zhao et al. Adv. Photonics. Res. (2021).

Stage of Research

- Proof of concept

Applications

- Image sensor types: solid state, CMOS, and CCD
- Camera types: digital photography, camcorders, mobile, webcams, security, automotive

Advantages

- Very high efficiency: no incident light is absorbed, perfect spectral color photon efficiency, near-perfect broadband photon efficiency, near-perfect spectral shape-matching, and angular robustness
- Size: color router can be scaled to wavelength scale in height, sub-wavelength in width
- Wavelength range: shown for red, green, blue, and near-infrared channels, can be expanded as needed
- Manufacturing compatibility: integration on image sensor pixels and compatible with dielectric materials
- Low light performance: significantly improved (4-5 times) photon efficiency versus color filters

Publications

- Catrysse, Peter B., Nathan Zhao, Weiliang Jin, and Shanhui Fan, "Subwavelength Bayer RGB color routers with perfect optical efficiency," *Nanophotonics* 11, 2381–2387 (2022)
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- Catrysse, Peter B., Nathan Zhao, Weiliang Jin, and Shanhui Fan, "Subwavelength Color Router" *Technical Digest CLEO:QELS: Fundamental Science,* FM5F.2. (2022)
- Zhao, Nathan, Peter B. Catrysse, and Shanhui Fan. "Perfect RGB?IR Color Routers for Sub?Wavelength Size CMOS Image Sensor Pixels." Advanced Photonics Research 2.3 (2021): 2000048.

Patents

- Published Application: WO2022094453
- Published Application: 20230417960

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