Docket #: S24-290

Novel Device for Upconversion of Sub-Silicon Bandgap Photons

Stanford University and University of Wisconsin–Madison researchers have developed a new device to achieve upconversion (UC) of incoherent near-infrared (NIR) photons beyond 1100nm to visible photons, through sensitized triplet–triplet annihilation (TTA). This advancement has significant potential in enhancing solar energy harvesting, night vision, cameras, and bioimaging technology.

Triplet-triplet annihilation upconversion (TTA-UC) is particularly promising for these applications due to its low up-conversion thresholds and broadband, tunable absorption. However, current NIR-to-visible TTA-UC systems are significantly less efficient than their visible-to-visible counterparts. For example, the current best NIR-to-visible TTA-UC solid-state devices, made of PbS quantum dots and rubrene, are limited by (1) low absorption of NIR photons, (2) low energy transfer rates, and (3) low conversion efficiency, which restricts their broader application.

The Stanford team proposed a novel device architecture enabling strongly absorbing PbS films with improved efficiencies. Key innovations include (1) a 5-tetracene carboxylic acid interlayer to improve film homogeneity and upconversion efficiencies, and (2) a gold-based nanostructure to enhance absorption and emissive properties, yielding a fivefold improvement over control devices.

Figure:

Figure Description Left: Illustration of the upconversion mechanism, converting photons from a longer wavelength (lower energy) to a shorter wavelength (higher energy).
Right: Upon excitation with an 850 nm LED, the Stanford team captured clear pictures of the upconverted images, including the Stanford logo and an outline of

the Stanford Memorial Church, under room lighting.

Applications

- Photovoltaics
- Cameras/photodetectors
- Night vision
- Anti-counterfeiting
- Bio-imaging

Advantages

- Access to sub-silicon bandgap photons (NIR photons beyond 1100nm)
- Higher upconversion efficiencies
- Enhanced absorption and emissivity
- Compatible to solid-state device fabrication processes

Publications

- Hamid, Rabeeya, et al. All-passive upconversion imaging of incoherent near-infrared light at intensities down to 50 nW/cm2. *arXiv* 2024.
- Narayanan P, Hu M, Gallegos AO, Pucurimay L, Zhou Q, Belliveau E, et al. (2024). "Overcoming the Absorption Bottleneck for Solid-State Infrared-to-Visible Upconversion," ChemRxiv, doi: 10.26434/chemrxiv-2024-h0k05. (This content is a preprint and has not been peer-reviewed.)
- T. H. Schloemer and D. N. Congreve (2023). "Smashing Photons: Changing the Color of Light Supercharges Solar Energy, 3D Printing, and Night Vision," IEEE Spectrum, 60(10), 44-49.

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