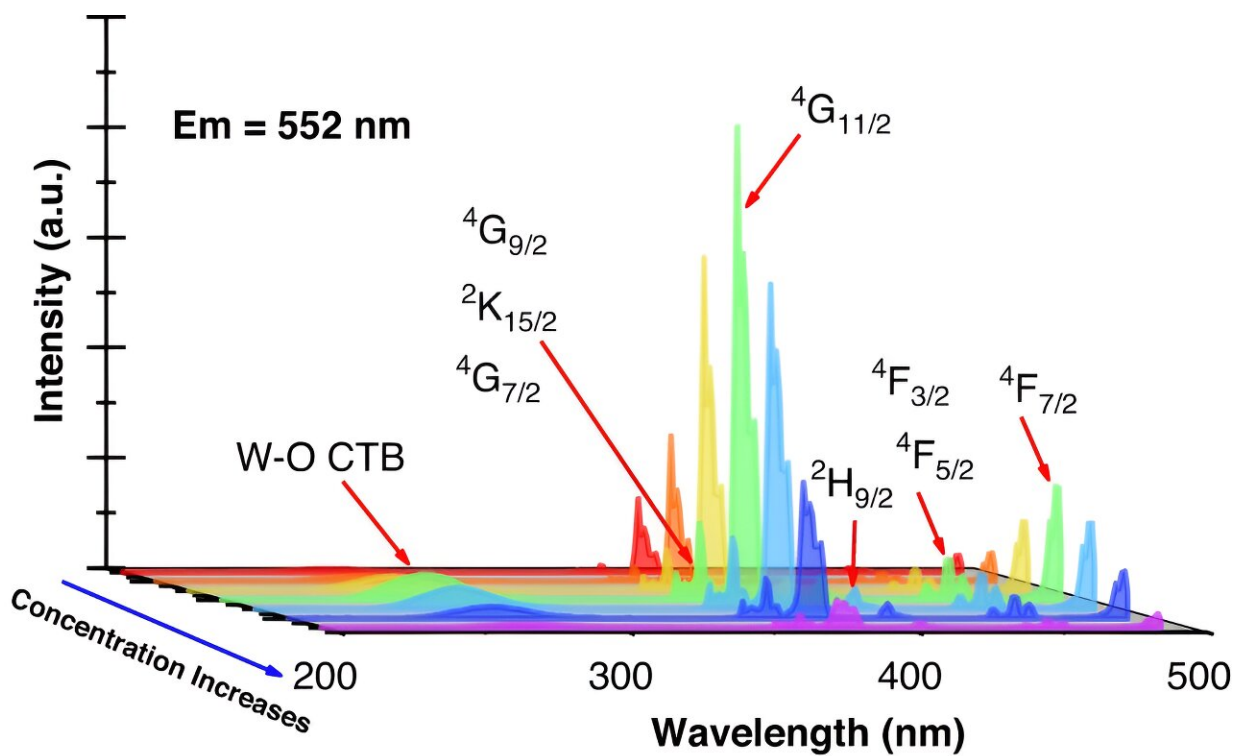


Quantum cutting, upconversion, and temperature sensing help with thermal management in silicon-based solar cells

February 5 2024



Short wavelength absorption of Er^{3+} in $\text{NaY}(\text{WO}_4)_2$. Excitation spectra for $\text{NaY}(\text{WO}_4)_2:\text{Er}^{3+}$ doped with different Er^{3+} concentrations by monitoring 552 nm emission. Credit: *Light: Science & Applications* (2024). DOI: 10.1038/s41377-023-01365-2

Introducing light conversion materials into silicon-based photovoltaic devices is an effective way to improve their photoelectric conversion efficiency. Light conversion materials include quantum cutting materials and upconversion materials.

The purpose of introducing quantum cutting materials is to divide a short-wavelength photon into two or more photons that can join the photoelectric conversion in silicon-based photovoltaic devices.

Introducing upconversion materials is done to combine two or more [infrared photons](#) into one photon that can also be used for photoelectric conversion in silicon-based photovoltaic devices.

The introduction of light conversion materials can improve photoelectric conversion efficiency without changing the performance of silicon-based solar cells themselves. This method can greatly reduce the technical difficulty of improving the efficiency of silicon-based photovoltaic systems. In addition, silicon-based photovoltaic devices are exposed to sunlight, so their temperature must be managed. Managing this temperature necessitates measuring it in advance.

However, it is possible that if three materials that can individually achieve quantum cutting, upconversion, and temperature sensing are simultaneously introduced into silicon-based solar cells, it will lead to difficulties in solar cell structure design and unnecessary increase in the product costs. Therefore, finding and developing high-performance materials that combine the above three functions is a challenge.

In a new paper [published](#) in *Light: Science & Applications*, researchers from the School of Science, Dalian Maritime University reports that they have achieved highly efficient photo split, nearly pure infrared upconversion emission, and suitable temperature sensing for thermal management in silicon-based solar cells by adjusting the doping concentrations of Er^{3+} and Yb^{3+} in $\text{NaY}(\text{WO}_4)_2$ phosphor.

The work reveals that this all-in-one material is an excellent candidate for application in silicon-based [solar cells](#) for improving their photoelectric conversion efficiency and enhancing their heat management.

An in-depth understanding of the quantum cutting mechanism is significant for designing and assessing the quantum cutting materials. However, in many cases, quantum cutting processes are complicated. In this work, the authors carefully decrypted the photo-splitting steps in $\text{Er}^{3+}/\text{Yb}^{3+}$ co-doped $\text{NaY}(\text{WO}_4)_2$ to assist the doping-concentration-dependent spectroscopy and fluorescence dynamics.

The team states, "Based on the optical spectroscopic analyses, the quantum cutting mechanism was discovered, and the photon splitting process includes two-step energy transfer processes, namely, ${}^4\text{S}_{3/2} + {}^2\text{F}_{7/2} \rightarrow {}^4\text{I}_{11/2} + {}^2\text{F}_{5/2}$ and ${}^4\text{I}_{11/2} + {}^2\text{F}_{7/2} \rightarrow {}^4\text{I}_{15/2} + {}^2\text{F}_{5/2}$."

The quantum cutting efficiency can be confirmed experimentally and theoretically. In the ideal case, the measured quantum cutting efficiency is also defined as the internal quantum efficiency, but it is different from the traditional definition of internal quantum efficiency. The measuring technique for the quantum efficiencies is still not satisfactory since the measuring results are complicated by too many uncontrollable factors.

Therefore, the theoretical internal quantum cutting efficiency becomes significant. The authors claim, "The quantum cutting mechanism was discovered by the optical spectroscopic analyses, and the quantum cutting efficiencies were calculated in assistance of Judd-Ofelt theory, Förster-Dexter theory, energy gap law." The authors estimated the internal quantum cutting efficiencies for $\text{NaY}(\text{WO}_4)_2: \text{Er}^{3+}/\text{Yb}^{3+}$ by taking radiative transitions, non-radiative transitions, and energy transfers into account, and achieved an efficiency as high as 173%.

Another important point of this work is that the researchers achieved nearly pure near-infrared emission of Yb^{3+} .

The team observes, "These upconversion mechanisms tell us that both Er^{3+} and $\text{Er}^{3+}/\text{Yb}^{3+}$ doped $\text{NaY}(\text{WO}_4)_2$ phosphors exhibit strong near-infrared emissions from $^4\text{I}_{11/2}$ $^4\text{I}_{15/2}$ of Er^{3+} and $^2\text{F}_{5/2}$ $^2\text{F}_{7/2}$ of Yb^{3+} that indicates the studied phosphors are good light [conversion](#) candidate[s] for silicon-based solar cell applications."

More information: Duan Gao et al, Near infrared emissions from both high efficient quantum cutting (173%) and nearly-pure-color upconversion in $\text{NaY}(\text{WO}_4)_2:\text{Er}^{3+}/\text{Yb}^{3+}$ with thermal management capability for silicon-based solar cells, *Light: Science & Applications* (2024). [DOI: 10.1038/s41377-023-01365-2](https://doi.org/10.1038/s41377-023-01365-2)

Provided by Chinese Academy of Sciences

Citation: Quantum cutting, upconversion, and temperature sensing help with thermal management in silicon-based solar cells (2024, February 5) retrieved 28 April 2024 from <https://phys.org/news/2024-02-quantum-upconversion-temperature-thermal-silicon.html>

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