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Cooperative Energy Acceptor of Three Yb^{3+} Ions

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Abstract

Our previous work first reported the cooperative sensitized luminescence from Cu^{2+} or Pb^{2+} by three clustered Yb^{3+} ions, in which three NIR photons can be converted into a high energy photon. Could a reverse process happen that a high energy photon is cut into three NIR photons? This work demonstrated an example of three-photon quantum cutting (QC) phosphor, CaF_2:Ce^{3+},Yb^{3+}, in which three clustered Yb^{3+} ions (Yb^{3+}-trimer) cooperatively and indirectly received a 306 nm ultraviolet (UV) photon energy transferred from a Ce^{3+} ion in 5d excited state and emitted three 975 nm near-infrared (NIR) photons. The cluster destruction experiments were designed to verify the necessity of the presence of Yb^{3+}-trimers for QC. The dynamical analysis on luminescence of Ce^{3+} ions confirmed the energy transfer from Ce^{3+} ions to Yb^{3+}-trimers. The doping concentration effect on luminescence was investigated. Furthermore, the maximum energy transfer (ET) efficiency and the corresponding QC efficiency were estimated to be 61% and 222%, respectively. Therefore, the reported three-photon QC phosphor has an attractive prospect in efficiently harvesting solar energy for silicon solar cells.

Keywords

Cooperative acceptor, Yb^{3+}-trimer, Ce^{3+}-Yb^{3+}, Quantum cutting, Solar cells; rare earths

1. Introduction

Quantum cutting (QC), known as downconversion, has been an exciting technique in improving the quantum efficiency of luminescent materials, by which high quantum yield can be acquired through converting a high energy photon into two or more lower energy photons. Visible QC materials can be used in lighting and display industry. Applying NIR QC materials to silicon solar cells can not only improve the photoelectric conversion efficiencies, but also minimize the energy losses by reducing the thermalization of electron-hole pairs.[1-3] Since the QC in single Pr^{3+} doped fluorides was first demonstrated,[4] RE^{3+} doped QC materials have attracted great research interest.[5] For examples, $LiGdF_4$:Eu^{3+} emitted two red photons per vacuum

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