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Engineered core/shell quantum dots as phosphors for solid-state lighting

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Light-emitting diodes (LEDs) for solid state lighting (SSL) typically combine a blue or near-ultraviolet drive LED with one or more downconverting phosphors to produce "white" light. Further advances in both efficiency and white-light quality will require new phosphors with narrow-band, highly efficient emission, particularly in the red. A team led by principal investigator Dr. Victor Klimov of Los Alamos National Laboratory proposes to develop engineered semiconductor nanocrystal quantum dots (QDs) that combine optimal luminescent properties with long-term stability under typical downconverting conditions to enable new performance levels in SSL. The white LED phosphor industry is estimated to have sales of roughly $400 million in 2018 and would significantly benefit from the development of bright and narrow red-emitting QD phosphors because they would enable warmer whites without wasting energy by emission of light beyond the response of the human eye. In order to capitalize on the market opportunity, the LANL team is partnering with a local company called UbiQD that will facilitate US manufacturing.

Although QDs have not yet found use in commercial solid-state lighting, recent developments suggest that specifically engineered QDs can offer important advantages over current technologies, especially in white light quality and efficiency, at low cost. The team proposes to leverage these recent advances in QDs to engineer red-emitting phosphors with high emission quantum yields, narrow peak widths, and excellent stability under conditions relevant to downconverting applications. The team also propose to develop high efficiency cost-effective green/yellow-emitting emitters based on novel cadmium-free QDs in order to demonstrate an all-QD warm white-light phosphor directly on a blue light-emitting diode chip with effective color rendering capability and high luminous efficiency. Central to the project will be advanced spectroscopy feedback during phosphor development including time-resolved photoluminescence measurements on individual QDs as well as ensembles across a range of commercially relevant conditions such as high temperature and high light flux. The matrix-embedded QD phosphors developed during the project will be superior, drop-in replacements for current phosphors, and will be amenable to solution processing for additional cost benefits.

These efforts will particularly leverage the expertise of a local company called UbiQD that was founded by project partner Dr. Hunter McDaniel, who recently completed a postdoctoral appointment with the LANL team. UbiQD is commercializing low-hazard QDs with high emission QYs tunable throughout the visible spectrum. The company seeks to enable QDs to become ubiquitous by leveraging novel low-cost manufacturing methods of high performance materials for a range of applications including SSL. Successful completion of the project will benefit consumers with more efficient and visually satisfying lighting, and benefit the US economy with value creation and job growth.