

Over the past decade, scientists have been studying a remarkable new class of materials—**lead halide perovskite nanocrystals**—that can emit light with exceptional brightness and color purity. These crystals are just billionths of a meter in size, yet they hold enormous promise for technologies like LED displays, ultra-precise microscopes, and quantum computing.

An important feature of these and other nanoscale light emitters is that they do not shine steadily. Instead, they “blink”—randomly turning their light on and off. This blinking can be a problem for making stable light sources. However, it is a key feature in powerful imaging methods that enable to study objects unaccessible with conventional optical microscopes. Another fascinating property is that these nanocrystals emit only one photon (a particle of light) at a time. This effect, called photon antibunching is crucial for the development of ultra-secure communication schemes, quantum information, and can also be used to improve the resolution of microscopes.

Our project aims to understand and control the blinking and light-emitting behavior of lead halide perovskite nanocrystals at the level of single particles. Most studies so far have looked at only a handful of nanocrystals, which lead to limited understanding of the processes underlying single photon emission and blinking. In this project, we will use a new generation of fast and sensitive cameras—called SPAD arrays—that let us examine hundreds of nanocrystals at once. With this “multiplexed” approach, we will be able to study multiple properties in parallel: blinking, antibunching, and emission lifetimes. This will allow us to build a much clearer picture of how a nanocrystal size, chemical composition, and surface chemistry influence its light-emitting behavior.

We also plan to explore new ways to control the photon emission behavior of these crystals. One idea is to attach molecules to their surfaces that can “trap” or remove photoexcited electrons. In this way we will control the time periods of blinking, which is a crucial ability for the applications in ultra-precise imaging. Another exciting direction is to control the light emission of single nanocrystals using different colors and patterns of laser pulses to “switch” the nanocrystals’ brightness, activate the emission, or even stop them from emitting altogether.

Ultimately, this research could lead to smarter and more reliable nanocrystal-based devices. It may also open up entirely new ways to use light for sensing, imaging, and information processing. By unlocking the secrets of how these nanoscale light sources work—and how to control them—we are taking an important step toward the next generation of optical and quantum technologies.