Exploiting optical materials to capture hidden data through new imaging approach

GA, UNITED STATES, December 9, 2024 /EINPresswire.com/ -- The paper explores the unique properties of optically active crystals with screw symmetries. These crystals exhibit nonlocal super-dispersion, meaning their polarization rotation properties strongly depend on the wavelength. This nonlocal response allows for the development of a novel camera, the "Nonlocal-Cam." Unlike traditional cameras, the Nonlocal-Cam captures the spectral and polarimetric components of light, providing additional information about the scene. This technology has potential applications in various fields, including biology, machine vision, and remote sensing.

Nonlocal-Cam: Unveiling Hidden Spectral and Polarization Data.

In an era where autonomous navigation, medical diagnostics and remote sensing are rapidly evolving, traditional cameras— limited to capturing only the red, green, and blue (RGB) light intensities—are falling short of data demands. These cameras often miss essential spectral and polarization details crucial for identifying materials, distinguishing healthy from diseased tissue, providing unique 3D situational awareness and tracking environmental changes. The fast development of artificial intelligence and the emerging field of “spatial intelligence” also drive the need for imaging technologies that can capture more information-rich data, empowering us to view and understand the world in unprecedented ways.

Researchers from Purdue University have made a breakthrough stride in advancing spectro-polarimetric imaging by merging the fields of novel optical materials and computational imaging. Their advance is embodied in the development of a novel imaging device called the "Nonlocal-

Cam." Unlike traditional cameras that capture RGB images, the Nonlocal-Cam can extract additional spectral and polarization information that has remained inaccessible to conventional imaging systems. The team's work opens new pathways for applications ranging from machine vision and next-generation microscopes to heat-assisted detection and ranging (HADAR).

Central to the Nonlocal-Cam's innovation is a new mechanism for dispersing light in a compact and effective way. Dispersion is a familiar phenomenon — such as in rainbows or Isaac Newton's famous prism experiment. In conventional dispersion, white light is split into spectral colors by passing through a dispersive material such as water droplet or glass prism. However, this type of dispersion is generally weak in transparent media, and it merely "bends" light, causing color (or wavelength) separation in the spatial domain. This spatial separation is not ideally suited for imaging applications.

The Nonlocal-Cam addresses this limitation by leveraging a property known as 'nonlocal dispersion' in optical activity. Optical activity refers to the phenomenon where light's polarization rotates as it passes through specific materials. This effect arises fundamentally from the 'nonlocality' of optically active materials, where the refractive index varies with the light's momentum. Notably, the researchers have shown that this polarization rotation is always highly dependent on the light's wavelength, allowing for color separation in the polarization domain rather than the spatial domain.

"Our Nonlocal-Cam merges the fields of nonlocal electrodynamics and computational imaging, enabling us to capture hidden information about light's spectrum and polarization," explains lead researcher Xueji Wang.

The camera is based on a simple, robust design using α-quartz crystals—one of the most abundant and affordable materials—making it cost-effective and scalable for various practical uses. By leveraging advanced computational techniques, the Nonlocal-Cam achieves high spectral resolution with minimal hardware requirements while maintaining robustness against noise and measurement errors. The team demonstrated the camera's ability to capture images in laboratory and outdoor environments, showing its potential for applications such as physics-driven machine vision and high-precision imaging in extreme conditions.

Most significantly, the researchers have demonstrated that the nonlocal dispersion of optical activity—the foundation of the Nonlocal-Cam's design—is universal. This phenomenon spans the entire spectrum, from ultraviolet to infrared, and can be harnessed by choosing suitable materials, making the Nonlocal-Cam a versatile tool for advanced imaging applications.

Prof. Zubin Jacob, the team leader of the study, highlights the technology's future potential: "This work paves the way for new imaging devices that could revolutionize fields requiring detailed spectral and polarization data. From environmental monitoring to advanced microscopy, the Nonlocal-Cam offers a new dimension of information capture."

Funded by the Office of Naval Research, the Defense Advanced Research Projects Agency, and the U.S. Department of Energy, this research represents a cutting-edge fusion of optical physics and advanced computational imaging techniques with wide-ranging implications for the future of imaging technologies.

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