Over the past decade, new technologies using near-infrared (NIR) light have developed significantly. These include fields such as telecommunications, agriculture, bioimaging, military technologies, and many “smart” technologies, such as personal health monitoring and consumer-side food safety analysis. To sustain the adoption of these technologies, new, efficient infrared emitter technologies are required that cover the Near Infrared Range (800–2500 nm) and will replace older, inefficient technologies such as incandescent lamps. One of the best ways to achieve this is by utilizing visible-to-infrared converting phosphors – materials that absorb visible light (for example, from a blue LED) and reemit it as infrared light.

A phosphor is made from inorganic compounds through the process of activation – doping with trace amounts of certain elements, such as transition metals (TMs, located in the d-block of the periodic table). These dopants absorb incoming radiation and reemit it at different, longer wavelengths. TM ions are particularly versatile activators because adjusting their atomic surroundings can fine-tune the wavelength of the light they emit.

One of the most successful phosphors are those based on chromium ion activators (Cr^{3+}), which emit light in the 700–1000 nm range. However, finding TM-based materials that can emit at even longer wavelengths—beyond 1000 nm—while maintaining strong performance remains a significant challenge.

This project aims to uncover new luminescent materials using a variety of transition metals to create NIR-emitting phosphors that push beyond the 1000 nm boundary. Here’s how it works: When transition metals are added to host crystals, they establish specific energy levels influenced by their atomic surroundings. These surroundings, known as the "first coordination zone," consist of nearby atoms that affect the behavior of the TM ion. By adjusting the chemical composition of the phosphor, one can control this process and shift the emission wavelength into the desired NIR range—a technique called "crystal field engineering."

To tackle the vast range of possible TM ions and host materials, the project will use machine learning. By analyzing large datasets on optical material properties, machine learning algorithms will identify promising material combinations faster and more effectively than traditional trial-and-error methods. This approach could even reveal unexpected relationships between the host material's composition and its ability to support strong NIR emission.

Once potential materials are identified, they will be synthesized in the lab using techniques like hydrothermal or solid-state synthesis. Their light-emitting properties will be tested under various conditions, including high pressure to simulate stronger crystal field interactions, and low temperatures to better understand their thermal stability. The findings will be compared with theoretical models to refine our understanding of how these materials work.

By blending advanced synthesis techniques, machine learning, and theoretical modeling, this project aims to expand the boundaries of NIR phosphor technology, paving the way for innovations in areas such as sensors, imaging technologies, and beyond.