Our Research Approach

A Cyclical Research Process that Accelerates Materials Creation

By repeatedly moving through the four stages of Create, Resolve, Measure, and Understand, we create new quantum materials and uncover the mechanisms underlying their functionalities.

1 Create | Materials Creation

Drawing on crystal chemistry, electronic structures, trends in known materials, and theoretical models, we design promising chemical compositions and crystal structures. We then create new materials using solid-state reactions, high-temperature and high-pressure synthesis, elemental substitution, mixed-anion chemistry, flux methods, single-crystal growth, and other techniques.

2 Resolve | Structural Analysis

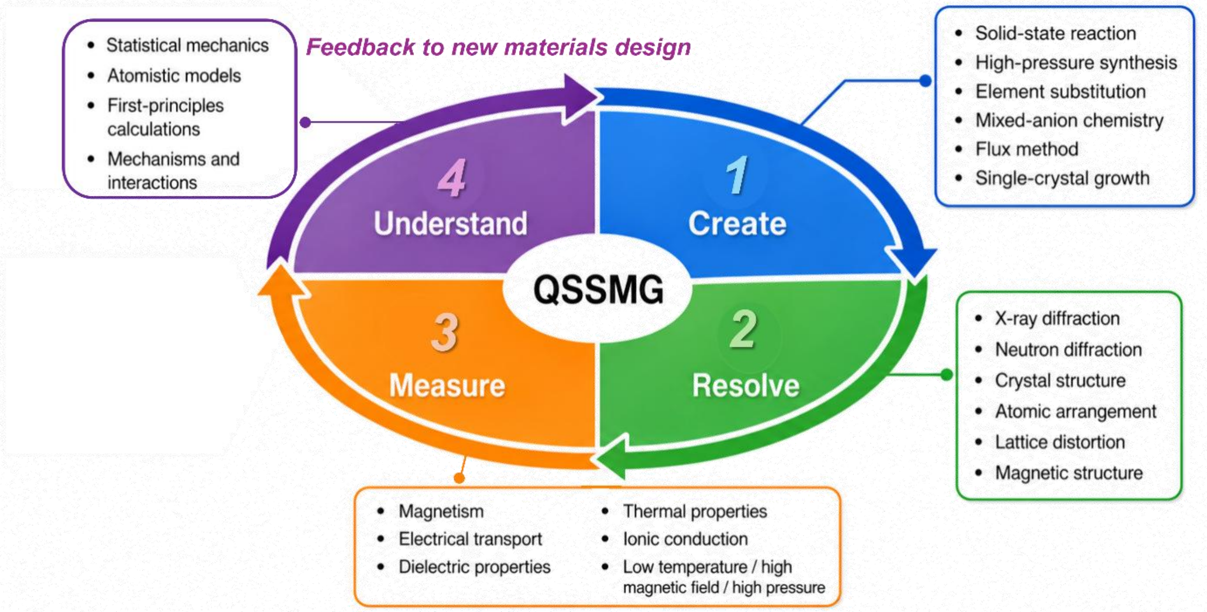
Using X-ray and neutron diffraction and related techniques, we determine crystal structures, elemental arrangements, lattice distortions, crystal symmetries, and magnetic structures. In this way, we precisely identify how atoms and spins are arranged within a material.

3 Measure | Physical-Property Characterization

We measure magnetic, electrical, dielectric, thermal, and ion-transport properties. We also use extreme conditions, including low temperatures, high magnetic fields, and high pressures, to explore phase transitions and quantum states that are difficult to access under ordinary conditions.

4 Understand | Mechanistic Understanding

Using statistical mechanics, atomistic models, first-principles calculations, and related approaches, we identify the interactions and mechanisms governing the observed functionalities. The resulting understanding is fed back into the chemical compositions, elemental substitutions, crystal structures, and synthesis conditions to be explored next.



By repeating this cycle of materials creation, structural analysis, physical-property characterization, and mechanistic understanding, we accelerate the discovery and development of new materials.

Research Themes

New Magnetic and Quantum Phenomena

We search for new materials exhibiting low-dimensional magnetism, quantum magnetism, spin gaps, spin-orbit coupling, exchange bias, stepwise magnetization changes under magnetic fields, unconventional magnetic transitions, and related phenomena.
We seek to clarify how lattice geometry, elemental arrangements, and competing magnetic interactions generate particular magnetic and quantum states.

Ferroelectric and Multiferroic Materials

We create materials in which electric polarization and magnetic order coexist and are mutually coupled, and clarify the relationships among crystal structure, magnetism, and dielectric properties.
We explore materials-design principles for controlling electrical properties with magnetic fields and magnetic properties with electric fields.

High-Pressure-Stabilized and Metastable Phases

We stabilize crystal structures and chemical compositions that cannot be obtained at ambient pressure by using high-temperature and high-pressure conditions.
By realizing unusual oxidation states, unconventional coordination environments, and complex cation ordering, we open pathways to new electronic states and functionalities.

Mixed-Anion Compounds

We use the chemical bonding and crystal structures formed by multiple anion species, including oxygen, nitrogen, sulfur, and halogens, to control magnetic, electronic, ion-transport, and optical properties.
By designing the types and arrangements of anions, we create new materials with layered structures, open frameworks, electronic states, and ion-conduction pathways that are not available in conventional oxides.

Structural and Phase Transitions and Magnetization Dynamics

By combining experiments with theoretical models, we clarify the mechanisms of structural and magnetic phase transitions, magnetization reversal, spin reorientation, and nonequilibrium responses induced by temperature, magnetic field, pressure, and other external parameters.
Structural analysis, physical-property measurements, and atomistic simulations reveal how atomic and spin arrangements change and how those changes manifest themselves in material properties.

Our Goals

From Discovery to Principles, and from Principles to the Next Material

Our goal is not simply to discover a single new material and stop there.

We create new materials, understand the quantum phenomena that emerge in them, and use the principles obtained to guide the design of the next material. By deliberately controlling chemical composition, atomic arrangements, anion arrangements, crystal symmetry, and magnetic interactions, we seek to create magnetic, electronic, dielectric, thermal, and ion-transport functionalities that cannot be realized in existing materials.

Through fundamental research, we aim to generate promising materials for quantum sensors, nonvolatile memory, energy conversion, magnetic refrigeration, solid electrolytes, low-power devices, and related technologies. At the same time, beyond the development of individual materials, we seek to establish broadly applicable scientific principles for designing quantum materials.

Unknown materials are gateways to unknown phenomena.

We create those gateways through chemistry,
and use structural analysis, physical-property measurements, and theory
to uncover the principles that lie beyond them.