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Materials discovery of next-generation quantum materials

Today, one of the most important research areas that attracts enormous interest for humanity is the design, discovery, characterization and control of novel quantum materials. Various societal challenges such as energy, water quality, air quality, medicine and environment all need to be solved by the discovery of new compounds with dramatically improved, or even new, properties. The search and exploration for such materials requires a blending of skills and mindsets that, traditionally, have been segregated into different academic disciplines: physics, chemistry, metallurgy, materials science and engineering. Quantum materials contain several candidates, which exhibit large tunability of nontrivial electronic states by chemical doping or hydrostatic pressure. Despite extensive worldwide efforts, the synthesis of high-quality materials with well-controlled stoichiometries has shown to be a significant bottleneck in the exploration of quantum materials. I will present and discuss the basic motivations for making single crystals with the highest quality, which are important due to their continuous, uniform, and highly-ordered structure. Materials discussed will span superconductors, 2D magnets, transition metal dichalcogenides, topological electronic systems, and magnetic materials. I will also describe recent extreme condition experiments, including low temperature in millikelvin regime and high pressure up to 60 GPa, performed in our laboratory that address how extreme conditions can provide new insights into various fundamental problems.

I will present my short- and long-term visions for the Louisiana Accelerator Center with my core missions in Quantum Materials Research at UL Lafayette:

- Designing and synthesizing energy-efficient, revolutionary new forms of matter that have specific, tailored properties.
- Controlling complex and atomic level interactions of optical, magnetic thermal, and electrical properties in materials.
- Understanding and exploring how complex phenomena emerge from simple ingredients.

Quantum materials research program would strengthen UL Lafayette's position at the forefront of fundamental research toward applied research. The program would provide potential routes for discovering novel physical phenomena useful for information and energy related technologies.

Short bio: Dr. Mahmoud Abdel-Hafiez is an Associate Professor with a habilitation degree of Physics. He has a highly interdisciplinary background combined with extensive international experiences throughout his academic career. Prior to the current affiliations, he has held appointments at different Universities in Belgium, China, Sweden and Germany. He pursued his doctoral studies at Dresden University of Technology, Germany. He received a three-year German Science Foundation Young Investigator Award in 2015. During his work at Center for High Pressure Science and Technology Advanced Research in Shanghai, he was a recipient of the Outstanding Young Scientist award from the Overseas Chinese Physicists Association in 2018. He has been a Visiting Professor at Moscow State University. Professor Abdel-Hafiez's research interests seek to reveal fundamental problems in quantum (magnetic) materials and tackles long-standing questions, such how quantum fluctuations, topology and disorder can be demonstrated to create states of matter with novel and functional properties. He is an expert in various thermodynamics, synthesis and spectroscopic techniques under various conditions including high pressure, low temperature and high applied magnetic fields. He uses large scale facilities, synchrotron (one of the first accelerator concepts), as in Neutron scantron, X-ray scattering and muSR spectroscopy to study the magnetic ground state He has published 96 papers in these areas in high impact scientific journals. He has already supervised 11 Masters and four PhD-students and currently have 2-employed postdocs, one PhD and 4-Master-students. He has extensive academic leadership skills (e.g. as German president, 2022, of the Arab-German young academy of Sciences and Humanities (AGYA): www.agya.info) with a great interest in science communication and public outreach.