1 Overview

Power electronics is critical to electrification and sustainable energy technologies, with growing demands for compact, high-power devices requiring innovative thermal management solutions. Modern power electronics face multiple coupled physical **challenges**, from thermal-mechanical stress and electromagnetic interference to high voltage insulation degradation and two-phase cooling, as illustrated in Fig. 1. These interlinked phenomena necessitate a holistic, multiphysics optimization approach that can simultaneously address thermal, electrical, and mechanical constraints while ensuring system reliability.

Traditional design optimization approaches are limited by computational costs and design space constraints, while the increasing complexity of power electronics systems requires consideration of coupled electromagnetic-thermal-mechanical phenomena. This project **aims** to develop a novel framework for accelerated topology optimization of power electronics components using Physics-Informed Neural Networks (PINNs), leveraging our team's complementary expertise in mechanical engineering, power electronics, and Artificial Intelligence (AI), as shown in Fig. 2.

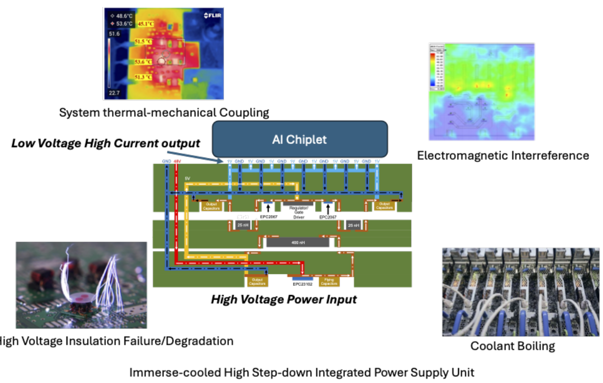

Figure 1: Challenges in modern microelectronics design: thermal-mechanical coupling, electromagnetic interference, high voltage insulation failure, and coolant boiling in an immerse-cooled high step-down integrated power supply unit.

The proposal integrates three **key innovations**: (1) specialized PINN architectures that incorporate electromagnetic-thermal-mechanical physics directly into the learning process, ensuring physically meaningful predictions while accelerating optimization; (2) a scalable computing framework for efficient training and validation; and (3) experimental validation through the Spellman High Voltage Power Electronics Laboratory.

Our research builds on strong preliminary results, including (1) **PI Chen**'s recent success in the topology optimization of thermal cloaks using extended level set methods; (2) **Co-PI Luo**'s experimental capabilities in high-voltage power electronics at the Spellman Laboratory, which provides essential infrastructure for validating our PINN-optimized designs; For instance, existing high-voltage testing setups and thermal imaging capabilities allow for direct experimental verification of predicted thermal and electrical performance in optimized components; (3) **Co-PI Yin** brings expertise in developing and scaling advanced machine learning models, critical for tackling the high-dimensional design spaces and complex loss functions inherent in PINN-based topology optimization. Yin's previous work on self-supervised learning demonstrates the capacity to develop the robust and scalable PINN frameworks required for this project.

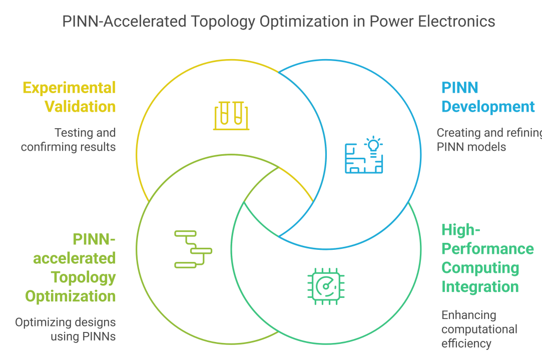

Figure 2: Proposed PINN-based framework for accelerated TO of power electronics.

Success in this seed project will provide essential preliminary results for future **external funding** opportunities, particularly from DOE and NSF. The developed framework will advance both the fundamental understanding of physics-informed machine learning and its practical application in power electronics design, positioning SBU at the forefront of AI-driven engineering design methodology.