AKPIK 4: Focus: Applications of Deep Neural Networks

Time: Tuesday 14:00–15:30 Location: H5

Invited Talk AKPIK 4.1 Tue 14:00 H5
The Scaling of Intelligence: From Transformers to Agentic AI — •Oliver Mey — Vodafone Tech Innovation Center, Dresden, Germany

The 2024 Nobel Prize in Physics recognized fundamental contributions to artificial intelligence and highlighted its profound impact on all disciplines, including physics. Generative AI has become a central tool in science and beyond, and understanding its underlying principles, the forces driving its rapid progress, and its emerging applications opens the door to new scientific breakthroughs and transformative innovations. We trace the evolution from Moore's Law to the scaling principles that enable today's large-scale AI models. At the heart of this transformation lies the Transformer architecture, the foundation of large-scale language models (LLMs) that generate coherent, context-aware text. These models are evolving into multimodal systems that seamlessly integrate text, images and other data types, greatly expanding their capabilities. Retrieval-augmented generation (RAG) extends LLMs with dynamic memory, enabling access to external information. In parallel, new concepts for task-dependent scaling of computations allow LLMs to distribute computational effort based on task complexity, increasing their efficiency in reasoning and adaptive problem solving. These advances pave the way for AI systems that act as collaborative agents and are capable of context-aware, goal-oriented interactions. In this talk, I will provide an overview of these developments and discuss them in the context of their broader implications, setting the stage for further specialized discussions.

Invited Talk AKPIK 4.2 Tue 14:30 H5
Inverse Design in Electromagnetics with Artificial Intelligence — •Willie Padilla — Duke University, Durham, North Carolina, USA

Artificial electromagnetic materials (AEMs) have enabled exotic electromagnetic responses that are difficult or impossible to achieve with naturally occurring materials. However, as AEMs have become more complex, the relationship between their structure and resulting properties is increasingly less understood, or sometimes completely unknown. Deep neural networks (DNNs) have been shown to effectively infer the relationship between AEM geometry and their electromagnetic properties, using simulated training data. More recently, a type of DNN * termed a large language model (LLM) * has shown a remarkable ability to respond to complex prompts. This presentation explores the potential of DNNs and LLMs for the inverse design of AEMs. I present a LLM fine-tuned on simulated data that can predict electromagnetic spectra over a range of frequencies given a text prompt that only specifies the AEM geometry. In view of the great potential of deep learning for the future of AEM research, we review the status of the field, focusing on recent advances, open challenges, and future directions.

Invited Talk AKPIK 4.3 Tue 15:00 H5
Inverse design of lateral hybrid metasurfaces with machine learning — •Rui Fang[1], Amir Ghasemi[1], Dagou Zeze[1], Koen Valk[2], Yuqing Jiao[2], Peter Zijlstra[2], and Mehdi Keshavarz Hedayati[1] — [1]Durham University — [2]Eindhoven Technology University

The development of metasurface structural colour typically depends on laborious and time-consuming simulations such as Finite Element Method (FEM) or Finite-Difference Time-Domain (FDTD) simulation, along with human intuition for parameter adjustments, rendering it impractical for design optimization. In this context, we have introduced an innovative AI-assisted design process that circumvents the intricate simulations, allowing for a swift and precise correlation between metasurface parameters and colour coordinates. In this study, we have applied the model to the lateral hybrid design, a novel concept in metasurfaces proposed by our research group and demonstrated that the model can predict a structure tailored to achieve continuous colour coordinates with an accuracy of up to 97%. A noteworthy aspect of our discovery is that the model is capable of predicting the range of colours that can be generated from a single design of an active metasurface. Our deep learning approach proves to be a valuable tool in designing active metasurfaces for structural colours. This advancement contributes to the development of highly sensitive sensors, bringing tunable metamaterials closer to practical applications.