Designing Quantum Experiments with Computers: New Windows to the Universe through Artificial Intelligence

Mario Krenn[1]

[1]Maz Planck Institute, Germany

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Physics experiments are our windows to the universe, from the smallest and most fragile systems in biology to the largest and most distant objects in astronomy. Traditionally, most physics experiments have been designed by creative and experienced human researchers. But have humans already discovered the best experimental measurement techniques? Or could there exist measurement devices that are beyond the current state-of-the-art and so unorthodox that humans might never uncover them?

In my tutorial, you will learn about an alternative approach: the discovery of new physics hardware using advanced computational algorithms and artificial intelligence. Based on examples from our recent works in AI-discovered quantum optics experiments [1], gravitational wave detectors [2], and optical microscopy [3], I will explain how to think about this problem, what computational techniques and methods work well, and where potential pitfalls lie.

These examples demonstrate that AI can discover new experimental designs beyond human capabilities. It allows humans to understand these new AI-discovered solutions and thereby learn new concepts and techniques in quantum technology. AI can thereby act as a source of inspiration for new ideas in science [4].

[1] Ruiz-Gonzalez, Arlt, Petermann, Sayyad, Jaouni, Karimi, Tischler, Gu, Krenn, "Digital discovery of 100 diverse quantum experiments with PyTheus," Quantum, 7, 1204 (2023).
[2] Krenn, Drori, Adhikari, "Digital Discovery of interferometric Gravitational Wave Detectors," arXiv:2312.04258 (2023).
[3] Rodriguez, Arlt, Möckl, Krenn, "XLuminA: An Auto-differentiating Discovery Framework for Super-Resolution Microscopy," arXiv:2310.08408 (2023).

[4] Krenn, Pollice, Guo, Aldeghi, Cervera-Lierta, Friederich, Gomes, Häse, Jinich, Nigam, Yao, Aspuru-Guzik, "On scientific understanding with artificial intelligence," Nature Reviews Physics 4, 761–769 (2022)