Machine Learning driven Real-Time Polarisation Control

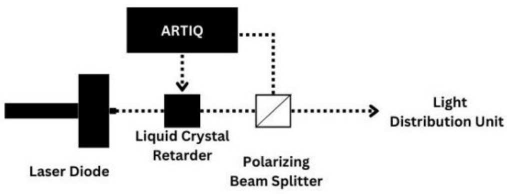
Anurag Borah[1,*], Yogeshwar B Kale[1,#], Yuheng Huyan[1], Yeshpal Singh[1]
[1]*University of Birmingham, Birmingham, United Kingdom*
[*] *axb1688@bham.ac.uk*, [#] *y.kale@bham.ac.uk*

The quantum sensors are demonstrating unprecedented performance for real-world applications in terms of their accuracy and sensitivity. Thus, machine learning (ML) in quantum technologies (especially which are field deployable) is a crucial and necessary step to minimize human interference during their operations. This study develops an ML-based model to dynamically control laser beam polarization using voltage-controlled liquid crystal retarders, utilizing real-time feedback for optimal adjustments. The model is being trained and validated using a comprehensive dataset, demonstrating its effectiveness in maintaining (and if required altering) the desired polarization states despite system variations.

Introduction

The precise control of laser beam polarization is crucial in various optical experiments and applications, including microscopy, quantum computing, communication systems, and material science. Polarization manipulation enables enhanced control over beam properties, such as intensity distribution, phase, and direction, which is essential for optimizing experimental outcomes and ensuring repeatability and accuracy. Traditional methods of polarization control often rely on manual adjustments using wave plates, polarizers, and other optical components. These manual methods can be time-consuming and lack the precision required for modern experimental demands. Additionally, manual adjustments introduce variability that can affect the reproducibility of experimental results, leading to inconsistencies and potential errors in data interpretation. With the transportable optical lattice clock, which we are aiming for, manual adjustments are not the most effective way of tuning the clock parameters. With the clock operating outside the laboratory conditions, various parameters need to be tuned to make it operational. This paper will present a novel approach that leverages machine learning techniques to automate and refine the polarization correction process, ensuring consistent beam quality and reducing the need for manual intervention. By integrating real-time feedback mechanisms and advanced predictive algorithms, the proposed system can dynamically adjust polarization states to maintain optimal performance under varying experimental conditions. This approach not only enhances the precision and stability of polarization control but also significantly increases the efficiency and reliability of optical experiments. Other works on automation have also been successfully implemented in the field of ultracold atoms, demonstrating the potential and versatility of such approaches. This novel work on real-time polarization correction using machine learning will be a valuable addition to the scientific community, complementing and enhancing the existing body of research on automation in optical and quantum systems.

Schematic of the experimental setup:



Conclusion

This work demonstrates the effectiveness of combining machine learning with real-time feedback systems to automate laser polarization control. By integrating a voltage-controlled liquid crystal half wave plate and a polarizing beam splitter with a machine learning model, the system ensures precise, stable, and consistent polarization states, significantly enhancing experimental efficiency and reliability. The automation reduces manual interventions and errors, making it ideal for high-precision applications such as quantum computing and microscopy. This approach represents a significant advancement towards more intelligent and autonomous optical systems, paving the way for future innovations in optical research and technology.