**Project Title:** Automation and Machine Learning for Robust and Self-Tuning Magneto-Optical Traps

**Project Description:**

Problem statement:

Following the discovery of neutral atom trapping via laser cooling in 1987, the Magneto-Optical Trap (MOT) has become a standard technology used in almost every AMO laboratory (Atomic, Molecular and Optical physics). The experimental setup of the MOT is rather complex, as it combines an ultra-high vacuum system (UHV), complex laser system, and various sources of magnetic fields. While the technology of individual components evolved over time to provide better and more stable solutions, the alignment of the trap still requires constant and tedious maintenance performed hands-on by skilled experimentalists. The objective of the project is to develop a self-tuning Magneto-Optical Trap using automation approaches and machine learning techniques to remove the need for a trained operator.

Student activities:

1. *Develop a custom control system for piezo mirror mounts responsible for the mechanical adjustment of the position of laser beams*. The student will perform the following tasks:

* Develop software compatible with the existing experimental apparatus (using Python, .NET, LabVIEW)
* Test the system on the optical bench using a single standalone mirror mount. Test the system using the MOT

2. *Implement an algorithm to tune the trap*. The objective is to obtain a cloud of trapped atoms that is as dense and as cold as possible. In order to accomplish this, the student will:

* Operate the experiment to obtain the density and the temperature of the trapped atoms, as well as the shape of the cloud
* Adjust the piezo mirror mounts and other MOT parameters to understand their impact on the MOT density and temperature
* Develop a procedure for MOT self-adjustment. This will use Python Optimisation/Machine Learning packages such as scipy.optimize or Mystic

NOTE: Students will be protected from laser hazards through a suitable combination of using Class 1 lasers whenever possible, operating the experiment from a remote computer when possible, and working under the close supervision of a mentor when neither control is possible.

Learning objectives:

* Develop skills in LabVIEW, python, and learn how to design an architecture for experiment automation
* Become familiar with certain ML optimization methods, such as simplex algorithms, stochastic approximation for noisy systems, and deep learning.
* Understand physics of neutral atoms trapping, in particular radiation pressure and Doppler cooling

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**Academic Discipline for the Project (1 or more):** Robotics, Engineering

**If COVID-19 impacts prevent an onsite internship, can this project be conducted virtually?**

Yes – partially, but it’s not recommended

The project can be partially executed remotely. The development of a program to control piezo mounts can be done completely off-site, as it does not require the hardware to be connected to the developer’s machine. Tests the control program as well as implementation of the machine learning algorithms can be done remotely after coordinating this exercise with an experimentalist on-site, who will set the experiment. The experiment can be controlled remotely over the network.