Adaptive design of thulium evaporative cooling experiment using Gaussian Process

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A proper design of experiment is an important part of experimental research. While in many cases integration of complex statistically powered methods is not justified, there are experiments where each point of a design is expensive in terms of money, computational resources or time. We use an adaptive design based on Gaussian process regression [1] for the online optimization of evaporative cooling efficiency in the setup for the production of thulium atom Bose-Einstein condensate(BEC). We show that while traditional methods of greedy optimization are not accessible in our setup, efficient multiparameter optimization allows achieving the desired performance.

Quantum simulations with ultracold atoms provide great opportunities for study complex quantum many-body problems [2]. Forced evaporative cooling is one of the most important technique in production of quantum gases [3]. Though it is robust and easily accessible in most of laser cooling experiments, an evaporation process lack of quantitive models due to the complexity of 3-dimensional dynamics, high uncertainties in shape of trapping potentials. The case of thulium has several additional obstacles: BEC of thulium is not achieved yet, thulium atom as other lanthanides has complex interaction properties, the proximity of trapping laser to atom resonance leads to highly anisotropic polarizability, small lifetime leads to high non-adiabaticity of evaporative process.

Using the Gaussian process we build a statistical model allowing search for optimum point without building model based on underlying complex physical processes.

References

[1] *Paul B Wigley et al,* Fast machine-learning online optimization of ultra-cold-atom experiments. In: Scientiffc reports **6**, P. 25890, (2016).

[2] *Immanuel Bloch, Jean Dalibard, and Sylvain Nascimbene,* Quantum simula- tions with ultracold quantum gases Nature Physics P. 267, (2012).

[3] *K. B. Davis, M. -O. Mewes, M. R. Andrews, N. J. van Druten, D. S. Durfee, D. M. Kurn, and W. Ketterle,* Bose-Einstein Condensation in a Gas of Sodium Atoms Phys. Rev. Lett. 75, 3969, (1995).