Heisenberg-Scaling Measurement Protocol for Analytic Functions with Quantum Sensor Networks

Qian, Kevin (School: Montgomery Blair High School)

Highly precise measurements are critical in many fields of science. Quantum metrology studies how accurate measurements can be and how mean squared errors can be minimized to the ultimate accuracy limit (Heisenberg limit) under quantum mechanical principles. In this project, I demonstrate that quantum entanglement can reduce the mean squared error in estimating an analytic function of multiple parameters by a factor proportional to the number of parameters, compared to classical estimation techniques. The parameters each describe the energy difference between the two states in a two-level system. Furthermore, I provide an entangled protocol and show that the proposed protocol is optimal for spin two-level systems in measuring an analytic function. I also conjecture an optimal protocol for a different physical setting, in which photons pass through interferometers and accumulate a fixed phase. Finally, I outline a few potential applications of my protocol such as calibrating lasers in trapped ion quantum computing and enhanced imaging in nanoscale nuclear magnetic resonance.

Awards Won:

Second Award of $1,500