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NTU Q

HIGHLIGHTING NEWS

QUANTUM AMPLIFICATION PUSHES OPTICAL CLOCKS BEYOND THE QUANTUM LIMIT

A team of physicists at the Massachusetts Institute of Technology has demonstrated a breakthrough technique that enhances the precision of the world's most accurate timekeepers — optical atomic clocks. By combining quantum amplification with a new type of spectroscopy known as *global-phase spectroscopy*, the researchers achieved measurement precision surpassing the standard quantum limit, a milestone in quantum metrology.

The experiment, reported in *Nature* by **Leon Zaporski** and **Vladan Vuletić**, used ytterbium atoms whose electronic transitions define the "ticks" of an optical clock. The team applied a quantum process called *squeezing* and its time reversal, *unsqueezing*, to amplify weak signals by about 10 decibels without requiring improved detection hardware. The newly developed *global-phase spectroscopy* method enabled them to isolate and measure a subtle geometric phase of the atomic system, allowing for more robust frequency measurements even in the presence of laser noise.

This dual technique not only boosts clock precision but also simplifies laser stabilization requirements, paving the way for portable optical clocks and more resilient quantum sensors. By reducing systematic errors and improving noise tolerance, the method could accelerate the search for new physics within atomic structure and spacetime itself.

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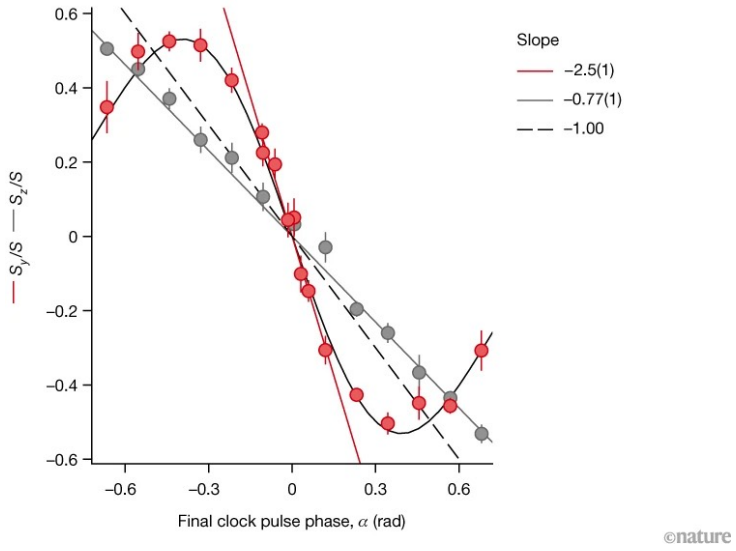

Figure 1
A quantum method to improve the precision of optical clocks

New Truncation Strategy Accelerates Quantum Simulations of Molecules

VQE algorithms are central to quantum chemistry, enabling the computation of molecular ground-state energies by optimizing quantum circuits. However, they often require a large number of circuit evaluations, making them costly to run on current hardware. Xu and Setia address this bottleneck with a **physically intuitive truncation technique** that begins with a simplified, "truncated" Hamiltonian and gradually adds back smaller terms during optimization.

The researchers developed two complementary versions of this approach:

A two-step hard cutoff method, which starts with dominant Hamiltonian terms and later transitions to the full model; and

An operator classification method, which groups Hamiltonian terms by their physical significance — such as number, Coulomb, and excitation operators — to systematically reintroduce complexity.

Numerical simulations on molecules including H_2, LiH, and H_2O show that these strategies can reduce the number of quantum measurements by **50–70%** without sacrificing accuracy. The results suggest a clear path toward more practical quantum chemistry applications in the NISQ era, providing a general framework that integrates easily with existing optimizers and ansatz circuits.

By trimming redundant quantum resources while maintaining precision, this truncation framework could help bring realistic molecular simulations — a long-standing goal of quantum computing — closer to experimental reality.

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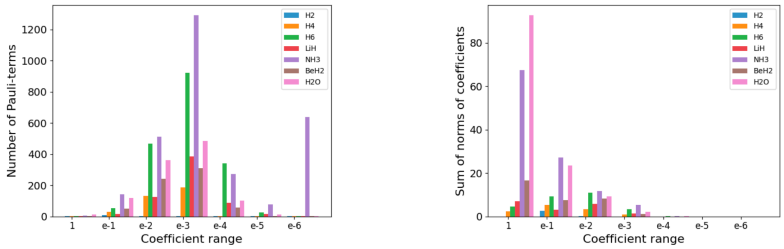

Figure 2
Even Pauli terms with the largest coefficient were very few, they still are dominant.

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