Docket #: S24-365

Breakthrough Optical Frequency Processing for Quantum Computing and Beyond

Stanford scientists have developed an advanced optical technology that can separate and recombine thousands of extremely close light frequencies with unprecedented precision. This breakthrough directly addresses a fundamental scaling challenge in quantum computing by enabling simultaneous control of 1000+ quantum elements with MHz-level resolution - a critical advancement for practical quantum systems. The same revolutionary capabilities that unlock quantum computing scaling also transform other fields requiring precise optical frequency control, including high-bandwidth communications, advanced spectroscopy, optical tweezers, and sophisticated sensing systems where ultra-narrow channel spacing enables previously impossible applications.

Atom array quantum computers present a fundamental challenge: identical atoms emit and absorb light at identical frequencies, making it difficult to individually control and read out information from multiple atoms simultaneously. As quantum computing scales toward practical applications, there's an increasing need to handle 1000+ separate channels with extremely narrow frequency spacing in the MHz range. Existing optical multiplexing technologies face an inherent trade-off - they can either process many channels or achieve narrow spacing between frequencies, but not both. This limitation has become a significant bottleneck in scaling quantum computing systems and other applications requiring high-resolution optical frequency control.

The multi-pass refocusing Virtually Imaged Phased Array (VIPA) overcomes fundamental limitations of traditional optical multiplexers through an innovative design that incorporates re-imaging optics within the device. This approach prevents beam divergence that typically constrains channel capacity and resolution, enabling the system to process 1000+ frequency channels with MHz-level precision - a combination previously unattainable with existing technologies. The device functions bidirectionally, allowing it to separate a combined light beam into individual frequency channels (demultiplexing) or combine many separate frequency channels into a single beam (multiplexing). This breakthrough capability enables individual control and readout of atoms in large arrays, parallel quantum networking, and high-bandwidth atom state manipulation - solving a critical bottleneck in scaling quantum computing systems while opening new possibilities across numerous fields requiring precise optical frequency control.

Stage of Development:
Proof of Concept

Applications

- Scaling quantum computing systems through simultaneous control of 1000+ atoms
- Enabling next-generation optical communications with ultra-dense channel spacing
- Advancing optical sensing and metrology with unprecedented precision
- Developing MHz-speed spatial light modulators for advanced display technologies
- Creating high-bandwidth optical interconnects for quantum and classical computing

Advantages

- 10-100x more frequency channels than conventional technology
- Achieves MHz-level channel spacing while maintaining high channel count
- Compact design suitable for integration into existing systems
- Operates bidirectionally (multiplexing and demultiplexing) with identical performance
- Compatible with existing optical communication infrastructure
- Addresses a critical bottleneck in scaling quantum computing systems

Innovators

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