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Nanofibers for Room-Temperature Quantum Technologies

Can one generate a guided optical mode that extends to a distance of several wavelengths away from the guide? In work published this year, we realized this situation using an extremely thin optical fiber and showed that it enables coherent interaction of guided light with room-temperature atoms.¹

Such coherent interaction lies at the heart of different quantum technologies. For example, quantum communication between distant processing nodes requires the faithful mapping of information between matter and light. Room-temperature atomic vapors constitute a unique material node, with potential applications in quantum memories, quantum sensing and quantum nonlinear optics. Optical fibers, widely used in modern communication, are a natural choice for optical interconnections

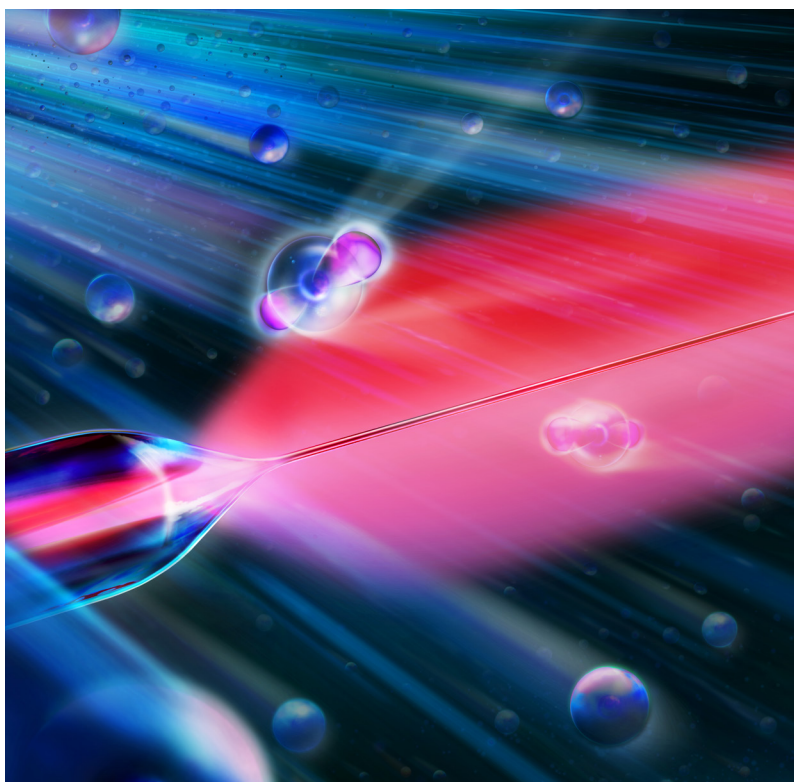
between such nodes. Our work brings these ingredients together by realizing a coherent interface between an extremely thin optical fiber and an atomic vapor at ambient temperatures.

For efficiency, the interface between light and matter requires strong collective interactions, which in turn benefit from tightly confined light fields and from a large number of atoms interacting simultaneously with such fields.² These two requirements, however, are hard to settle in a regular optical setup, which uses laser beams that can be focused only over a short distance and then quickly diverge. Such divergence is absent when using modes guided by optical fibers, which moreover enable a straightforward integration and scaling up of devices in optical networks.³

We achieved an optimal interface between the guided mode and the atomic vapor by gradually thinning an optical fiber down to a diameter of 200 nm—about 600 times narrower than its original width, and around a quarter of the optical wavelength of the fiber-guided light. Reaching these dimensions resulted in a unique optical field with more than 99% of the energy residing outside the fiber itself. The optical mode extends far beyond the surface of the fiber, up to a distance of several times the light's wavelength.

Such a field enables a long interaction time between the light and the atoms, even though the thermal atoms move rapidly across the field. Indeed, we measure a 10-MHz linewidth in two-photon spectroscopy and, correspondingly, temporal dynamics with more than 10 ns coherence time. The large ratio between the extent of the light field and the physical dimensions of the fiber also greatly reduces the detrimental effect of atoms interacting or colliding with the fiber itself.

We believe that this demonstration may pave the way for realizing new, fully integrated devices for quantum technologies. 



Artist's view of room-temperature atoms in ballistic motion interacting coherently with an evanescent light field that extends significantly beyond the surface of a thin optical fiber.