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TECHNICAL COMMENT

Envisioning a Quantum Supercomputer

Since the publication of my report (*1*), several readers have written to discuss issues that I originally treated peripherally. In addition, I have become aware of additional references that supply useful information about aspects of quantum computation. A full treatment of physical effects that would arise in the complicated quantum-optical device proposed will be given elsewhere. The following questions have been asked.

1) Wouldn't the localized excitations by means of which information is registered rapidly delocalize as excitations "hopped" or tunneled along the polymer chain?

The excitations would eventually hop and delocalize, but the rate at which they would do so would be suppressed because they would have to tunnel through several units with significantly different excitation energies. For relatively weak interactions between units, the characteristic hopping time would generally be longer than the spontaneous emission time.

2) Wouldn't imperfections in the polymer or lattice of spins cause errors?

Indeed they would. The problems of "reflection" of the computation (in which repeated scattering off of multiple defects causes the computation to reverse itself) and of error generation in quantum computers in general have been investigated extensively by Landauer (*2–4*), who has noted that eventually error correction would be required in quantum computers and that it would cause a loss of coherence. This loss of coherence would be evident in the proposed device because error correction is accomplished by spontaneous emission, with accompanied phase randomization; but because the computation would be moved forward from state to state by a sequence of externally applied pulses, reflection would not be a problem. If an imperfection were large enough to throw a unit completely off resonance, however, then the whole computation would grind to a halt.

3) Wouldn't the scattered light depend on the logical state of the computer, thereby causing dissipation and inducing decoherence [for example (*3*)]?

How the light of π pulses is scattered would depend on the logical state, but in general the computer could be constructed and programmed so that this dependence would be too weak to induce decoherence. Because the lifetimes of the excited states are long, inelastic scattering would be minimal, and the entropy of the light would increase by considerably less than $k_B T$ per bit flipped, where k_B is Boltzmann's constant and T is the ambient temperature. Dissipation may be greater than this in whatever mechanisms produce and absorb the light, but the logical updating process itself would be essentially free of dissipation except for error correction.

The main evidence that pulses do not destroy coherence is experimental: If decoherence were at all substantial, then the spin-echo effect and its various incarnations (in nuclear magnetic resonance and optical technologies), in which hundreds of pulses can be delivered without destroying coherence, would never have been experimentally verified.

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