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Entangled photons beat noise through teamwork

'Quantum illumination' proof lights the way to improving quantum encryption and radar.

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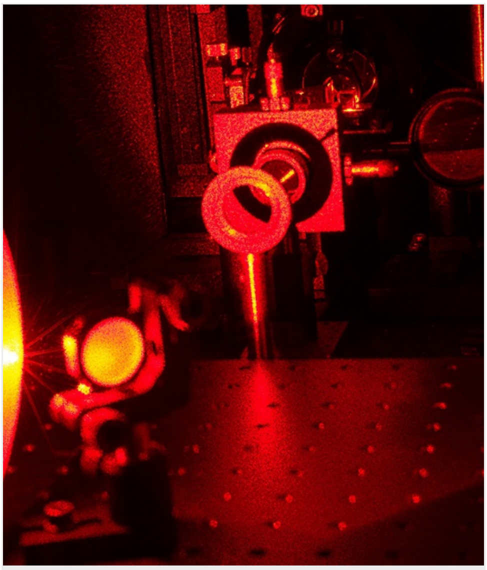
Technologies that rely on 'quantum-weirdness' phenomena, such as electrons being in two places at the same time, are inherently delicate: the smallest disruption can make such uncertain states 'collapse' into well-defined outcomes. Now, however, physicists have shown that quantum effects do not always succumb entirely to disruptions — at least not those from electromagnetic noise.

Their technique, called quantum illumination, could enable schemes based on quantum effects to work in much noisier environments than they can now. It could even make quantum physics useful in applications such as radar, which now relies on classical physics.

Quantum illumination was first proposed in 2008 by Seth Lloyd, a physicist at the Massachusetts Institute of Technology in Cambridge, as a way of improving the sensitivity of radar and other methods of detecting distant objects[1]. The principle of radar is simple: a device sends electromagnetic waves into the environment and then listens for echoes that would signify the presence of an object. The trouble arises when there is a lot of electromagnetic noise — either from heat in the environment, or the radar's own circuits, which can obscure the fainter echoes from small or very distant objects.



Giorgio Brida

Using quantum twins of photons from a laser (pictured here) improves the detection of an object in a noisy environment.

Buddy system

Lloyd's idea was to 'entangle' the beam sent out from a device with a reference beam, so that each photon in one beam would be matched to a photon in the other, like soldiers in two marching lines. Any noise would involve photons coming in at random, which could be told apart and ignored because they lack a correlated twin. By filtering out noise in this way, Lloyd suggested, quantum illumination offered a means to detect objects that would be invisible using non-entangled beams.

Physicists were surprised by Lloyd's theoretical result. Noise is normally thought to destroy entanglement. This is why quantum cryptography — a highly secure scheme for sharing information — is usually done inside fibre-optic cables. But Lloyd calculated that a trace of entanglement can remain despite the presence of noise.

Now, for the first time, researchers have experimentally demonstrated a version of Lloyd's proposal. The result, by Marco Genovese, a physicist at the National Institute for Metrological Research in Turin, Italy, and his colleagues, is published on the preprint server arXiv[2] and is forthcoming in *Physical Review Letters*.

To generate a pair of entangled beams, the researchers sent laser light through a 'nonlinear' crystal, which split the beam of incoming photons into two beams of correlated, lower-energy photons. They sent one of these beams to a reference detector and the other through a space, next to which they placed a primary detector. Nearby they added a light-scattering device, similar to a disco ball, to generate noise.

When no object was in the space, the beam just went through and Genovese and his colleagues recorded only a few random photon correlations typical of background noise. When they placed a small piece of glass in the space, however, photons scattered off it and the number of correlated hits on the detectors rose by 10 times. To check that this signal was indeed caused by quantum illumination, the researchers repeated the experiment with non-entangled light. They recorded few photon correlations, both when the object was present and when it was not.

"It's a good experiment, and it's a good first start in trying to demonstrate the effect," says Lloyd, although he points out that that the method he originally proposed was slightly different, and potentially more powerful.

Genovese suggests that the experiment challenges the common belief that quantum schemes are highly susceptible to noise. Indeed, there have been theoretical proposals to exploit the basic physics of quantum illumination to improve the robustness of some quantum schemes, including quantum cryptography[3].

“Up to now, every [quantum] experiment performed was strictly limited by noise,” says Genovese. “This perspective highlights the possibility of using quantum protocols in more realistic situations.”

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References

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2. Lopaeva, E. D. *et al*. Preprint available at http://arxiv.org/abs/1303.4304 (2013).
3. Shapiro, J. H. Preprint available at http://arxiv.org/abs/0903.3150 (2009).