CENTRE FOR JOINT WARFARE STUDIES

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CENJOWS

QUANTUM RADAR DEVELOPMENTS IN CHINA AND USA

1. **Quantum Radar Developments in China and USA.** A mini–arms race is unfolding in the quantum field, initiated by press reports in 2016 that China had built quantum radar—potentially threatening the ability of stealthy military aircraft to hide in plain sight from conventional radars[1]. The quantum radar story began in 2008, when Seth Lloyd, a quantum engineer at MIT, unveiled his concept of quantum illumination. Lloyd argued that you could more easily detect an object against a bright background if, instead of merely reflecting light off it, you exploited a quantum connection between particles called entanglement. Every photon has a frequency that determines its energy. Quantum theory says, that a photon can have multiple frequencies at once—until it's measured and collapses randomly to one frequency or another. Even, two such photons can then be entangled so that their frequencies, although uncertain, are correlated. As a visionary scheme, some researchers hope to improve the ability of radar to spot a target against background radiation by exploiting a quantum connection between microwave pulses.

2. Quantum illumination seemed to promise a way to defeat stealth technologies. However, demonstrating the scheme with microwaves has proved daunting. Physicists can generate pairs of entangled microwave pulses from single ones using, instead of a crystal, a gizmo called a Josephson parametric converter. But that device only works at temperatures near absolute zero, which requires working within cryostats cooled with liquid helium[2].

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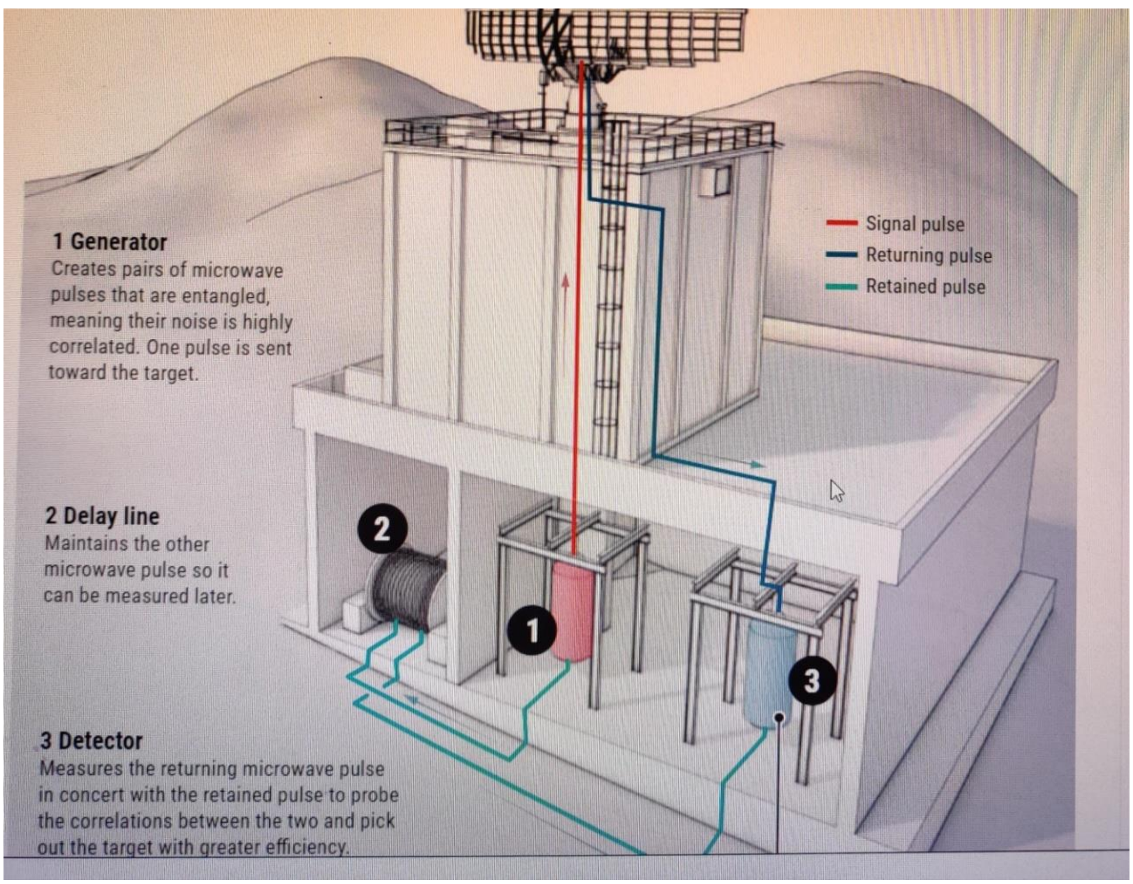
[1] ***Adrian Cho, Science, 23 Sep 20; https://www.sciencemag.org/news/2020/09/short-weird-life-and-potential-afterlife-quantum-radar***

[2] ***Ibid***

3. Lloyd calculated that an observer could more easily pick out an object by generating entangled pairs, shining one photon toward the object, keeping the other, and then measuring the retained and returning photons together in a particular way. Essentially, the entanglement correlations would make it harder to mistake a background photon for one reflected off a target. The signal to noise ratio would scale with the amount of entanglement. The more frequencies spanned by each photon in an entangled pair, the stronger the signal[3].

4. Lloyd's calculation relied on a highly idealized form of entanglement. So that same year, he, Shapiro, and colleagues redid it for the real entangled light pulses that experimenters can generate with a special crystal that converts a single higher frequency pulse to two entangled pulses at lower frequencies. The pulses have no definite number of photons—just an average number—and they are noisy, like radio static. But thanks to the entanglement, the noise in the two pulses is highly correlated.

5. The researchers compared the sensitivity of a detector relying on the entangled pulses with a conventional one sending out single pulses of laser light, also known as coherent states. They found that the quantum effects boosted the signal-to-noise ratio by just a factor of four, less than they hoped for.



(C. BICKEL/SCIENCE)

[3] ***ibid***

6. But to really make the scheme work, physicists must also preserve the retained microwave pulse until the reflected pulse returns. Then, both pulses can be measured together in a way that enables the quantum waves to interfere. So far, however, nobody has done that. Instead, they've measured the retained pulse immediately and the returning pulse later, which in the experiments wipes out any gain from the quantum correlations.

7. Even if experimenters can overcome the technical hurdles, quantum radar would still suffer from a serious weakness, researchers say. The entangled pulses of microwaves provide an advantage only when the broadcast pulses are extremely faint. The extra quantum correlations fade from prominence if pulses contain significantly more than one photon—which is overwhelmingly the case in real radar. If you increase the power, you won't see any difference between the quantum and the classical. And increasing the power is a much easier way to improve the sensitivity.

8. Such considerations suggest quantum radar is unlikely to be deployed for long-range uses such as tracking airplanes. And whatever system China may have developed, it almost certainly isn't quantum radar as commonly conceived[4].

[4] ***ibid***