Can one photon hold a complex image?

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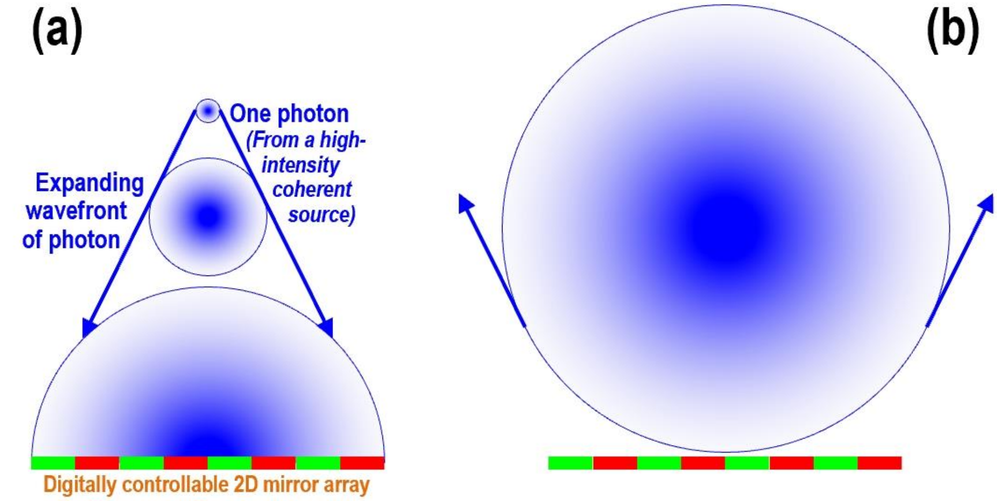
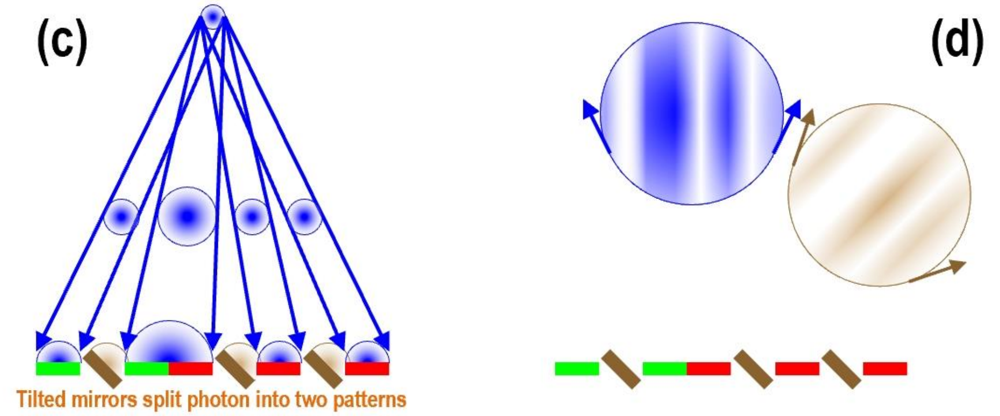


Digital multi-mirror device in all-flat, full-coherence specular reflection mode

No signal (no qubits) are encoded onto the reflected photon.



Selected mirrors split the wave into two complementary entangled qubits patterns

Complementary patterns separate but remain internally entangled. Either can be detected.

Photons can hold and carry complicated images in ways that don't follow classical time.

Question: How hard would it be to encode an entangled image equivalent to thousands of qubits onto a single photon? The surprising answer is "not hard at all." The trick is to stop thinking about individual computer-like gates and devices and instead embrace the bizarre nature of how photons behave in everyday circumstances, including the fact that you can read these letters on your screen.

Step (a) shows a photon (or another particle) emerging from a small source and spreading as a quantum wave. While folks tend to think of quantum waves are nothing more than probabilities of where to find a point-like photon, it's not that simple. The right kind of smooth energy barrier can also reflect the wave without the particle properties of the photon showing up.

Step (b) shows the photon reflecting from a smooth mirror surface created by thousands of identically aligned micromirrors. The important point to notice is that this reflection *does not* involve the detection of the photon by any single atom or particle. The photon responds to the mirror in the same way that a vastly brighter pulse of light would, that is, by following Maxwell's equations. Despite the astonishing weakness of the electromagnetic wave associated with a single photon, that wave still propagates in the same fashion as a far more energetic electromagnetic wave. The particle interpretation doesn't apply here.

Step (c) shows what happens when a sizeable number of the micromirrors point in a new direction. In the quantum world, these new directions do more than "reflect" some photons in the new direction. Since the point interpretation of the photon still does not exist, these subtractive mirrors *change* the wave in a way that doesn't match up well with our classical view of how time works. It is as though the photon decides *from the time of its emission* that it never "really" wanted to go to those angled mirrors and instead heads only the horizontal mirrors.

How is it possible to say that? A careful check of the micromirrors shows that the photon, which has a tiny bit of momentum, bounced only from the horizontal micromirrors and imparted no momentum on the slanted micromirrors. That makes no sense from a classical perspective. How could the photon know which micromirrors to hit to ensure *only* those micromirrors received a share of its momentum? It is as if the entire process is aware of the outcome and shapes the incoming wave to ensure this happens.

Step (d) shows another curious feature: The slanted mirrors form another wave with its version of the wave history. If the photon shows up in that direction, the same wave-shaping effect comes into play, and only those micromirrors that point to the side receive momentum from the photon when it reflects. In that case, the horizontal mirrors remain in the dark and receive no momentum.

The final point is this: Both of these possible single-photon wave functions now contain an astonishingly detailed image created by the micromirrors. If you look at enough of them, the image portrayed on the device shows up clearly, even though each photon can only display one point of that overall image. The reflection pattern on the device entangled the pixel locations in the sense that a photon arriving at one image location prevents the other pixel locations from lighting up simultaneously.

Interestingly, this entangled suppression of other locations is the same issue that first got Einstein in trouble with the quantum mechanics community he helped found. Einstein noticed that Born's exciting new probabilistic interpretation of the wave function required all parts to "know" a particle arrived at some *other* location, and, being Einstein, dared to bring it up. His concern was that taking this "collapse" of the wave function options as a literal wave requires this wave to exceed the speed of light.

Am I wrong to call such fiercely and non-classically entangled pixels in a single-photon image "qubits"? That is for you to decide.

My point is that it's easy to underestimate the complexity of the entanglement patterns one can impose on ordinary photons using off-the-shelf components. Perhaps we are making the task harder than it is.