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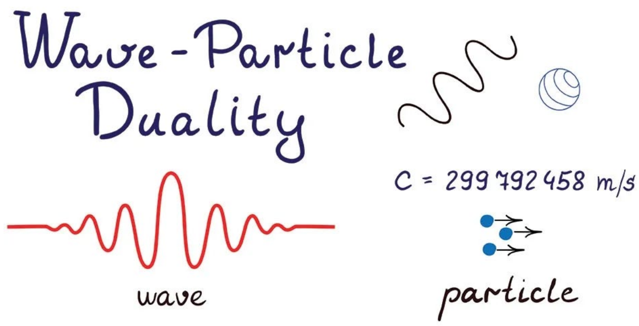
Experimental Quantum Technologies

Properties of Photons



Experiment 1: Wave Nature of Photons

A fundamental concept in classical physics is given by so-called waves and an example is given by the electromagnetic field. A distinguished feature of such waves is their ability to interfere with each other: Field amplitudes of two waves add up and the combined intensity is given by the square of the sum. Since amplitudes can be positive or negative, any two waves can interfere constructively or destructively depending on the experimental setup.

The prime example of this phenomenon is given by the Michelson interferometer with which the different lengths of two optical paths can be used to tune the nature of the interference (see fig. 1).

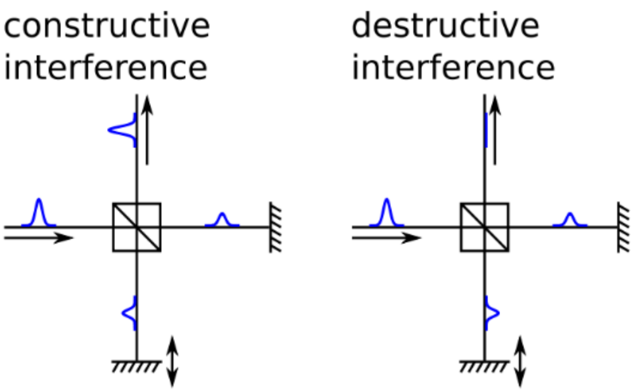


Figure 1: Michelson interferometer

The beam splits an incoming wave among two arms. The two resulting waves are then reflected by mirrors and overlap on the beam splitter. The phase difference $\Delta\phi = k \cdot d$ of the two waves depends length difference d of the two arms as well as the wave number k and the resulting intensity can be calculated to be

$$I_{sum} = \frac{I}{2}(1 + \cos(\Delta\phi)) = I\cos^2\frac{\Delta\phi}{2},$$

where I denotes the intensity of the incoming wave. Consequently, depending on $\Delta\phi$, the resulting intensity will vary between 0 (destructive interference) and I (constructive interference).

Experiment 2: Particle Nature of Photons

Another fundamental concept in classical physics is that of particles. They are localized at any point in time and correspondingly, the trajectory of any such particle is a definite quantity. If a photon was a classical particle, we would correspondingly expect that it a beam splitter will forward the photon to precisely one of the output arms (see fig. 2).

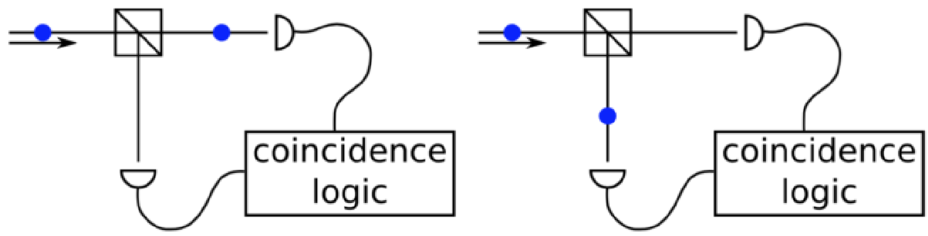


Figure 2: Michelson interferometer

Consequently, the coincidence logic should never see that both detectors in the respective arms fire at the same time. In our experiment the photon source produces two light beams of which one is sent to the beam splitter as in fig. 2 and the other is sent directly to another single photon detector. Using a combined coincidence measurement, we then indeed find that any single photon only causes one detector to fire and not two, suggesting that a photon indeed carries particle-like features.