Finite Photon Packets and the Photomultiplier Misinterpretation: Avalanche, Not Particles

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(Dated: September 2025)

Physicists often cite single-photon detectors as proof that photons are indivisible particles: one photon in, one discrete click out. We show this is a misinterpretation. Photons are finite electromagnetic packets that always deposit their full energy at a localized site. The apparent discreteness of detection is an artifact of avalanche multiplication and quenching in devices such as photomultiplier tubes (PMTs) and single-photon avalanche diodes (SPADs). In short: the detectors are digital, not the field.

I. INTRODUCTION

PMTs and SPADs are universally used as "single-photon detectors." Their outputs are binary: either a click is registered or not. This has been interpreted since the early days of quantum optics as direct evidence for photons as particles. Yet these detectors are threshold devices, built on avalanche cascades, not direct photon counters. We clarify the distinction between field absorption and avalanche multiplication, and show how the misinterpretation arose.

II. FINITE PHOTON PACKETS AT THE DETECTOR

We adopt the finite photon packet ontology established in Ref. [1]. Each photon is an extended EM packet of length

$$\ell \equiv c\,\tau_{\text{emit}}\kappa, \tag{1}$$

with envelope, polarization, and phase. Upon reaching a detector surface, the packet interacts with a localized absorber (cathode atom, junction site). The entire packet's energy is transferred at that site; no splitting into multiple absorbers occurs.

III. AVALANCHE AND SELF-QUENCHING

In a PMT, a single excited electron is accelerated to the first dynode, liberating multiple electrons. This multiplication proceeds stage by stage, producing 10^6–10^7 carriers from a single absorbed photon [2]. In a SPAD, a single carrier initiates a Geiger avalanche in the high-field junction, which is then quenched actively or passively [3]. In both cases, one photon absorption *must* yield a full digital pulse or nothing at all. There is no half-click. The discreteness is a property of the avalanche mechanism, not of the incoming photon.

IV. WHY IT LOOKS LIKE A PARTICLE

To an observer unaware of the avalanche process, each discrete click seems like the arrival of a localized particle. But the binary nature is imposed by detector dynamics. The myth of the "photon as particle" arises from conflating detector behavior with field ontology.

V. CONSEQUENCES AND PREDICTIONS

This view predicts:

1. Energy deposition is always local, but the spatial distribution of initial absorption events follows the incident field intensity, not particle trajectories.

2. Modifying detector gain and quenching parameters changes detection statistics, but not the underlying field ontology.

3. Multi-photon absorption within a single avalanche window still yields one click (saturation), contradicting naive particle-counting interpretations.

VI. CONCLUSION

PMTs and SPADs demonstrate that finite photon packets always deposit their energy at a point. The apparent discreteness is a consequence of avalanche multiplication and thresholding, not a proof of particle ontology. The detector is digital; the field is not. Recognizing this resolves the long-standing misinterpretation and aligns photon detection with Maxwellian field physics.

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[1] Todd Joel Mondragon. Finite photon packets, overlap criterion, and the bell threshold. 2025. Preprint.
[2] Glenn F. Knoll. *Radiation Detection and Measurement*. Wiley, Hoboken, NJ, 4 edition, 2010.
[3] S. Cova, M. Ghioni, A. Lotito, I. Rech, and F. Zappa. Avalanche photodiodes and quenching circuits for single-photon detection. *Applied Optics*, 35:1956–1976, 1996.