Researchers at Aalto University find a fundamental limit for using quantum light stimulation in visual neuroscience

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Jussi Tiihonen, in his Master’s thesis “Utilization of a single-photon gun to measure single-photon responses in retinal rods”, presents a new result that shakes the visual single-photon stimulation field. The combination of direct photon loss measurement and a precise statistical simulation show that the intrinsic photon losses in the human retina set a fundamental limit for using single-photon sources in visual studies.

Conventional light sources used in visual experiments are intrinsically stochastic in the photon creation process. The key prerequisite in previous single-photon source studies in visual neuroscience has been that using a single-photon source results in decreased variance in the photon statistics, which leads to decreased variance in the biological response statistics.

In his thesis, Tiihonen finds a strict bound on the usability of the mammalian retina with single-photon source in visual neuroscience. It was shown that although it is possible to produce non-classical biological signal statistics at individual photoreceptors, it has not been shown in any preceding or current single-photon source study. Surprisingly, in human psychophysics, due to retinal signal losses, the required experimental duration for differentiation of classical and non-classical light stimulation is far beyond the feasible limits even in a purely optimal case. This means that the single-photon sources provide no advantage over conventional light sources in mammalian retinal studies.

The research team stimulated photoreceptor cells (rods) with a single-photon source and measured the amount of visual signal loss in the rods. This result was combined with the known retinal signal losses, and the combined loss was used to simulate large amounts of biological responses with both classical and non-classical light stimulation. This paradigm allowed the authors to perform a power analysis, i.e. predict the required number of experimental trials to reach evidence of decreased variance in biological signal statistics compared to conventional light stimulation. The required number of trials in different experimental paradigms are significantly higher than the previously presented estimates in the field.

The results require fundamental re-evaluation of future and previous visual studies relying on single-photon sources, and set fundamental limits to the perception of non-classical signal statistics at the sensitivity limit of vision.

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Two-sentence summary for social media.

Researcher at Aalto University used a novel combination of direct photon loss measurement and a precise statistical simulation paradigm. The results require fundamental re-evaluation of previous visual studies relying on single-photon sources, and set fundamental limits to the perception of non-classical signal statistics at the sensitivity limit of vision.