Communicating via ignorance & imaging via counting

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Communicating via ignorance. Intuitively, no information can be sent through a completely noisy channel. However quantum physics defies this intuition, enabling information to be sent either via superposition of path, or superposition of causal order. Previous work has shown that: *path superposition*—placing two completely noisy channels in different arms of an interferometer—allows up to 0.16 bits to be communicated; *order superposition*—placing two completely noisy channels in a superposition so we are ignorant of channel order—allows up to 0.049 bits can be communicated. Here we improve on this, showing that perfect information transmission is possible, but *only* in the case of order superposition [1]. Experimentally we use a quantum switch [2] to achieve indefinite causal order, achieving for path and order superposition respectively 0.0341 ± 0.0015 bits and 0.636 ± 0.017 bits, the latter a capacity not possible with simple path superposition. Our results offer intriguing possibilities in applications ranging from communication through to imaging in turbulent media.

Imaging via counting. Physical limits to imaging precision are well known, less well know are ways to circumvent them, e.g. using super-resolution techniques that exploit the physical structure of the object, or object illumination with entangled states of light. However, in many applications—e.g. when the object is very far away—we cannot directly interact with the object, or illuminate it with entangled light: the quantum state of the light field is <i>all</i> that is accessible to the observer. We show the best way to extract the spatial characteristics of the light source, given a finite size imaging system in the far field, is to measure the complex degree of coherence. We do this with linear optics and photon number resolving detectors, measuring the size and position of a small distant source of pseudo-thermal light. Our method outperforms traditional imaging by an order-of-magnitude in precision. Additionally, a lack of photon-number resolution in the detectors has only a modest detrimental effect on measurement precision, highlighting the practicality of this method for a wide range of imaging applications.

[1] K. Goswami, *et al.*, *arXiv* 1807.07383 (2018).

[2] K. Goswami, *et al.*, *Physical Review Letters* **121**, 090503 (2018).

[3] L. A. Howard, *et al.*, *arXiv* 1811.02192 (2018).