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Beating the diffraction limit in astronomy via quantum cloning *(Corrigendum)*

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In Sect. 3.3 of Kellerer (2014) I suggested detector read-out times below the coherence time of photons. If one assumes, instead, read-out times not less than the coherence time, $\Delta t = \lambda^2/(c\,\Delta\lambda)$, the spontaneous photons exceed, even for a very small field-of-view, the number of stimulated photons per incoming photon.

With the notation employed in Kellerer (2014) the mean number of cloned photons per incoming photon is:

$$N - 1 = \frac{\sigma}{S}\, I \tag{1}$$

where I is the number of excited atoms, σ is the cross-section of excited atoms and S is the aperture- and amplifier-area. A field of angular diameter $\theta = 2.44\,\lambda/D$ – where D is the aperture diameter – corresponds to the Airy disc up to its first minimum. Within the read-out time $\Delta t = \lambda^2/(c\,\Delta\lambda)$, equal to the photon coherence time, this "diffraction area" receives a mean number of spontaneous photons:

$$M = \frac{\pi\,\theta^2}{4} \cdot \frac{1}{4\pi} \cdot A\,\Delta t \tag{2}$$

A is the spontaneous emission rate.

From these relations one obtains the average fluence ratio of spontaneous and stimulated photons on the diffraction area:

$$\frac{M}{N-1} = 0.74\,\pi^2 \sim 7.3 \tag{3}$$

in line with calculations by Prasad (1994) and his conclusions that the spontaneous emissions dominate the stimulated ones. On the other hand, on average $0.64\,N$ cloned photons end up on the central standard deviation range of diameter $1/3$ of the Airy disc. This area is 9 times smaller than the Airy disc considered above. Thus the ratio of spontaneous to stimulated fluence is not 7.3 but merely $7.3/(9 \times 0.64) \sim 1.3$ in this region around the centre of the cloned photons.

The spontaneous photons will prevent a large improvement of resolution as long as our set-up lacks a stage to recognize events where the stimulated emissions dominate. Such a stage is in principle possible, see notably the probabilistic noiseless amplification processes discussed by Duan & Guo (1998), Ralph & Lund (2009). The main message of my article remains: it is fundamentally possible to improve the resolution of a telescope beyond the diffraction limit at the price of sensitivity, i.e. it is possible to trade sensitivity against resolution. The set-up that I have suggested will be incomplete unless it is given a suitable heralding stage.

References

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