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Feasible enhancement of collection efficiency of light from trapped ions

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We present a theoretical analysis of optimisation of detection efficiency of optical signal scattered from dipole emitters using a far-field interference. These calculations are motivated by previous experimental demonstrations of coherent interaction of light with long strings of trapped ions [1,2,3]. For our models, we consider an ion string containing up to 10 ions, stored and laser cooled in a linear Paul trap [4].

Considering realistic trapping parameters and dipole radiation patterns, the distances between ions have been optimised to maximise a signal in the axial trapping direction. We compare these results to the case of equidistant positions and to the case of ions in a harmonic trap where the individual scattering phases can be tailored by an application of addressable phase shift to ions.
Crucially, our simulations predict that the overall gain of detection efficiency in the feasible case of a harmonic trap with non-equidistant positions of ions and tuneable solely by the axial potential strength is better than the idealised case of equidistant emitters. The optimal number of ions for feasible trapping parameters and large feasible numerical apertures is 6. The optimisation can be significantly beneficial for very small numerical apertures. The relative intensity of the optimised case can be approximately two orders of magnitude higher than the relative intensity of the non-optimised case. We further evaluate the effect of the thermal motion of ions on detection efficiency.

We present our progress towards the realisation of Paul traps focused on the experimental implementation of such directional emission and efficient collection of light from trapped ion strings [5,6].

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