Quantum correlated recording through scattering from turbulent media

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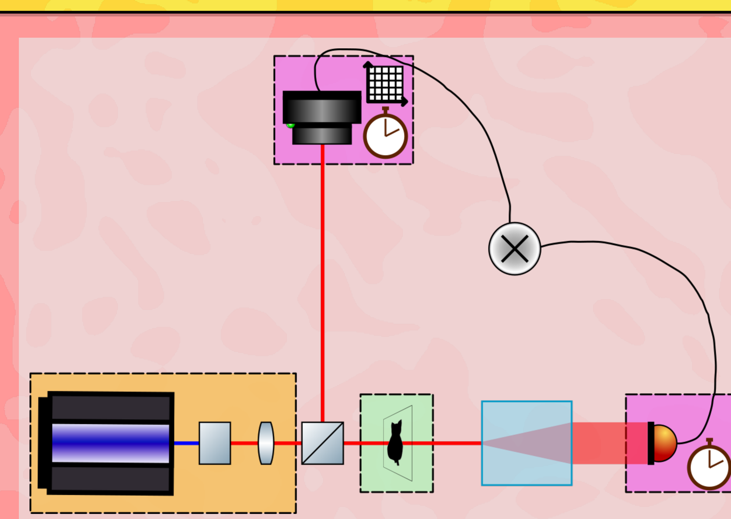
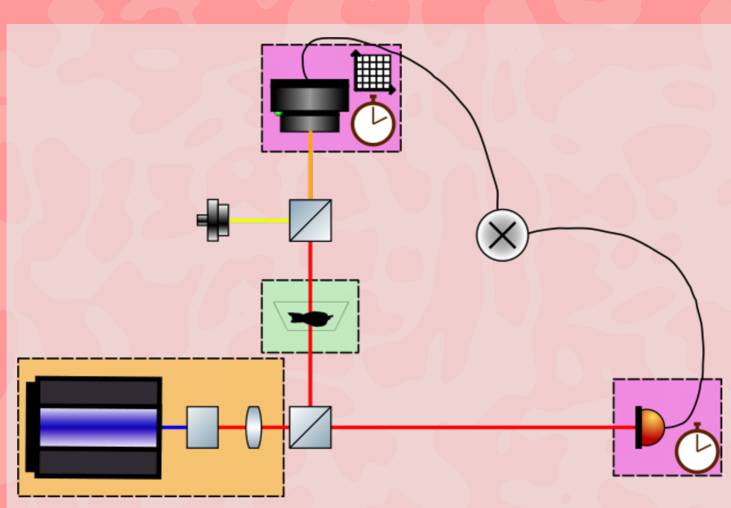
Motivation

Ghost imaging (GI) is a method of imaging an object indirectly via timing and momentum correlations between a signal and idler beam[1]. GI has been shown to be **robust against post-object scattering**[2].

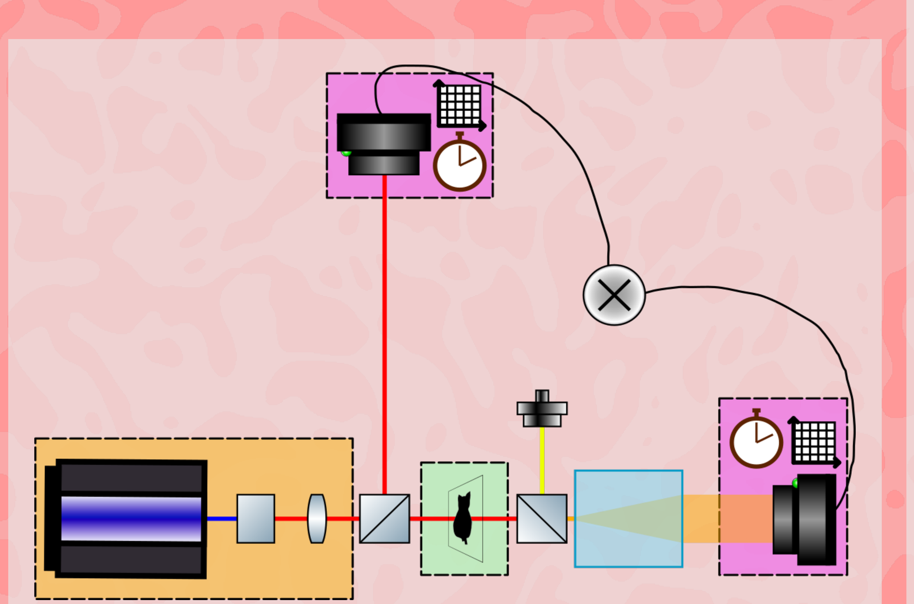


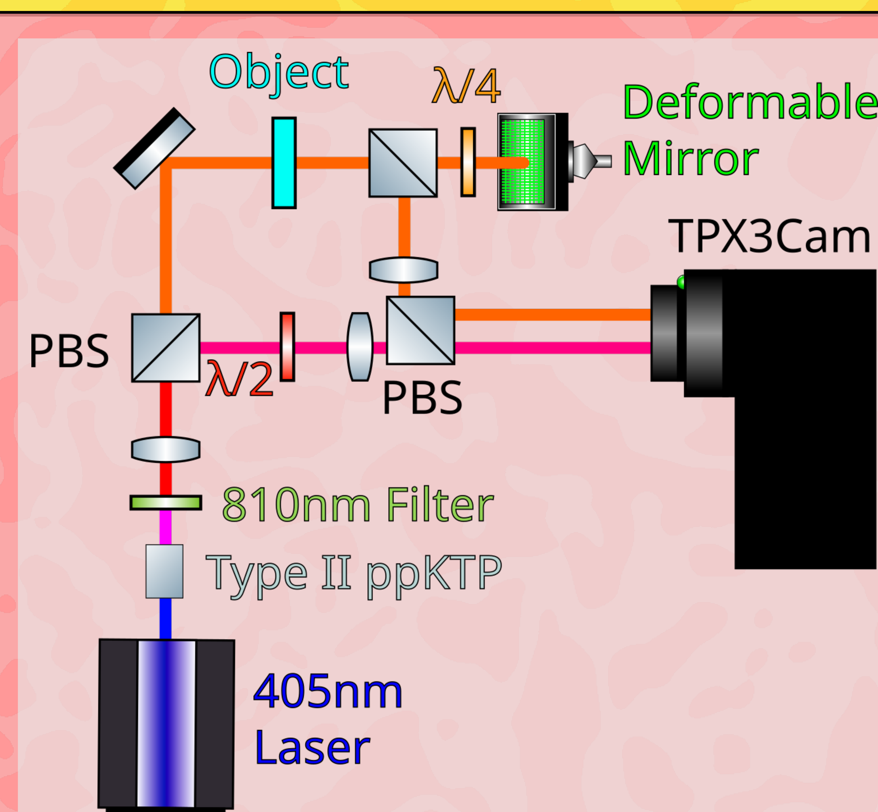


Quantum illumination (QI) is a method of distinguishing light which interacted with an object by taking advantage of timing (and optionally momentum) correlations between a signal and idler beam[3]. QI has been shown to be robust against noise in the object arm[4].

Can the scattering robustness of GI be combined with the noise robustness of QI?

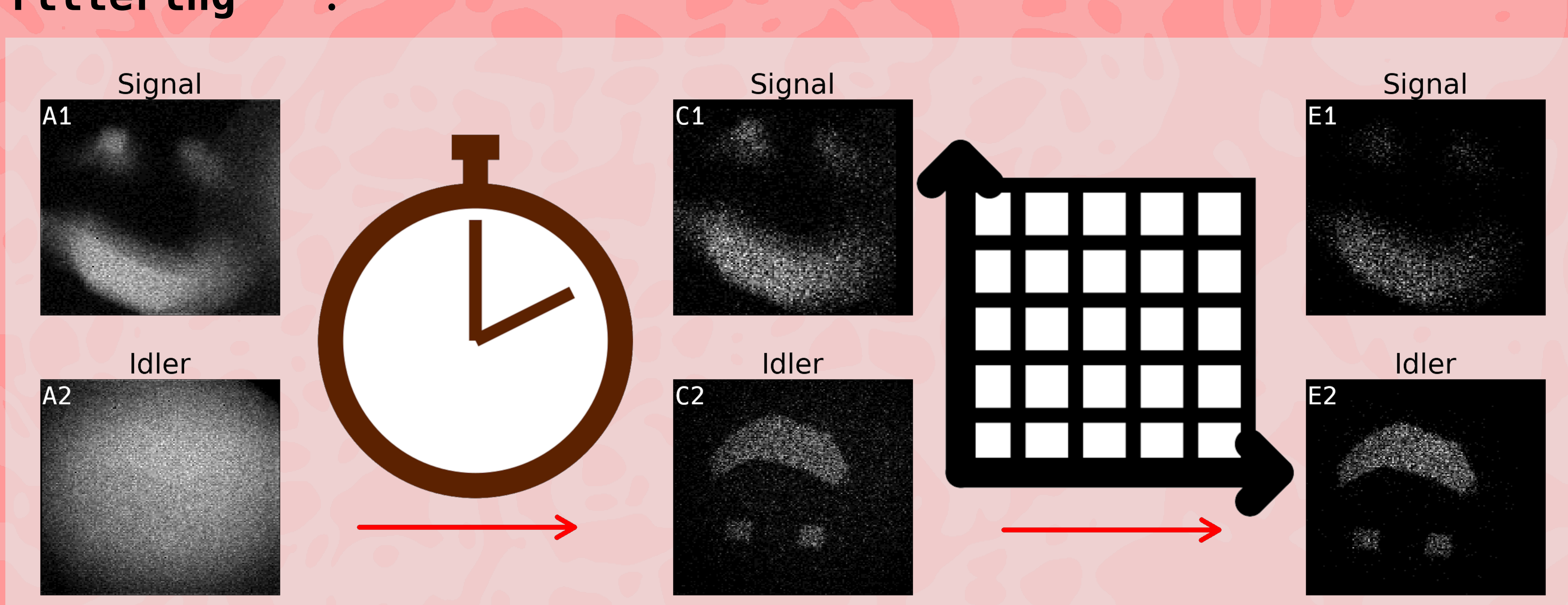
Design

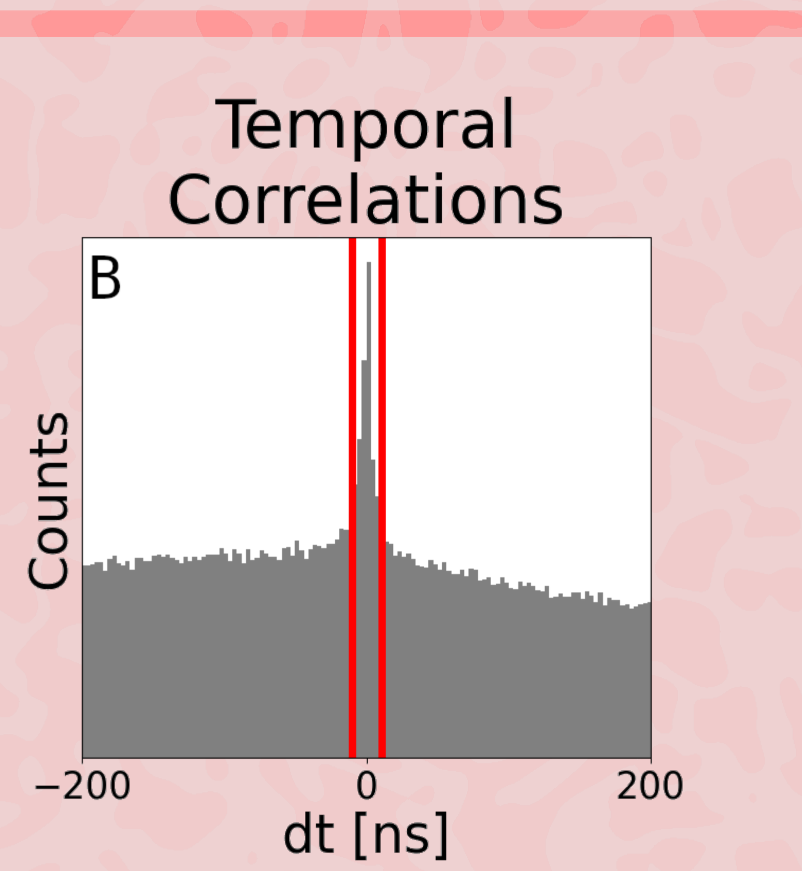


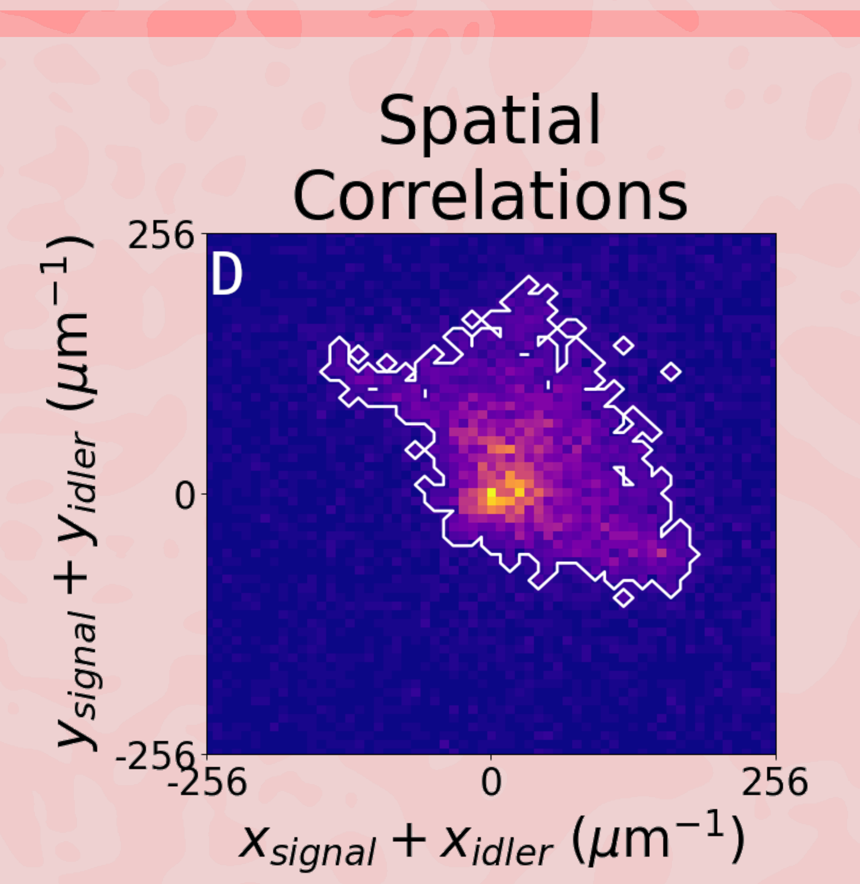


High SPDC flux and **room lights** used as source of **noise**. **Scattering** is caused by a **deformable mirror** which emulates turbulent media.

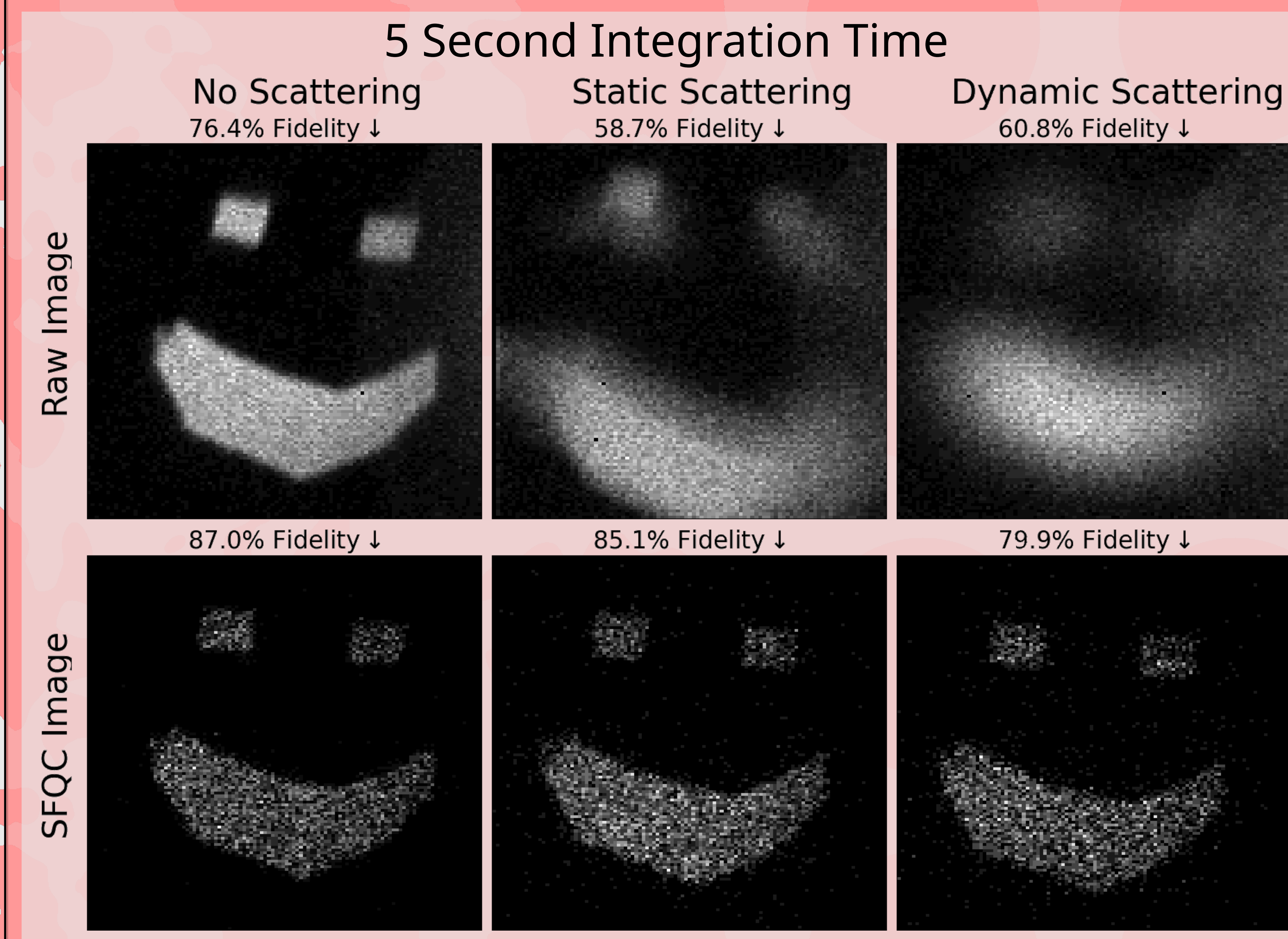
Two steps are required to perform spatially-filtered quantum correlated (SFQC) imaging: **time filtering**, and **space filtering**[4,5].



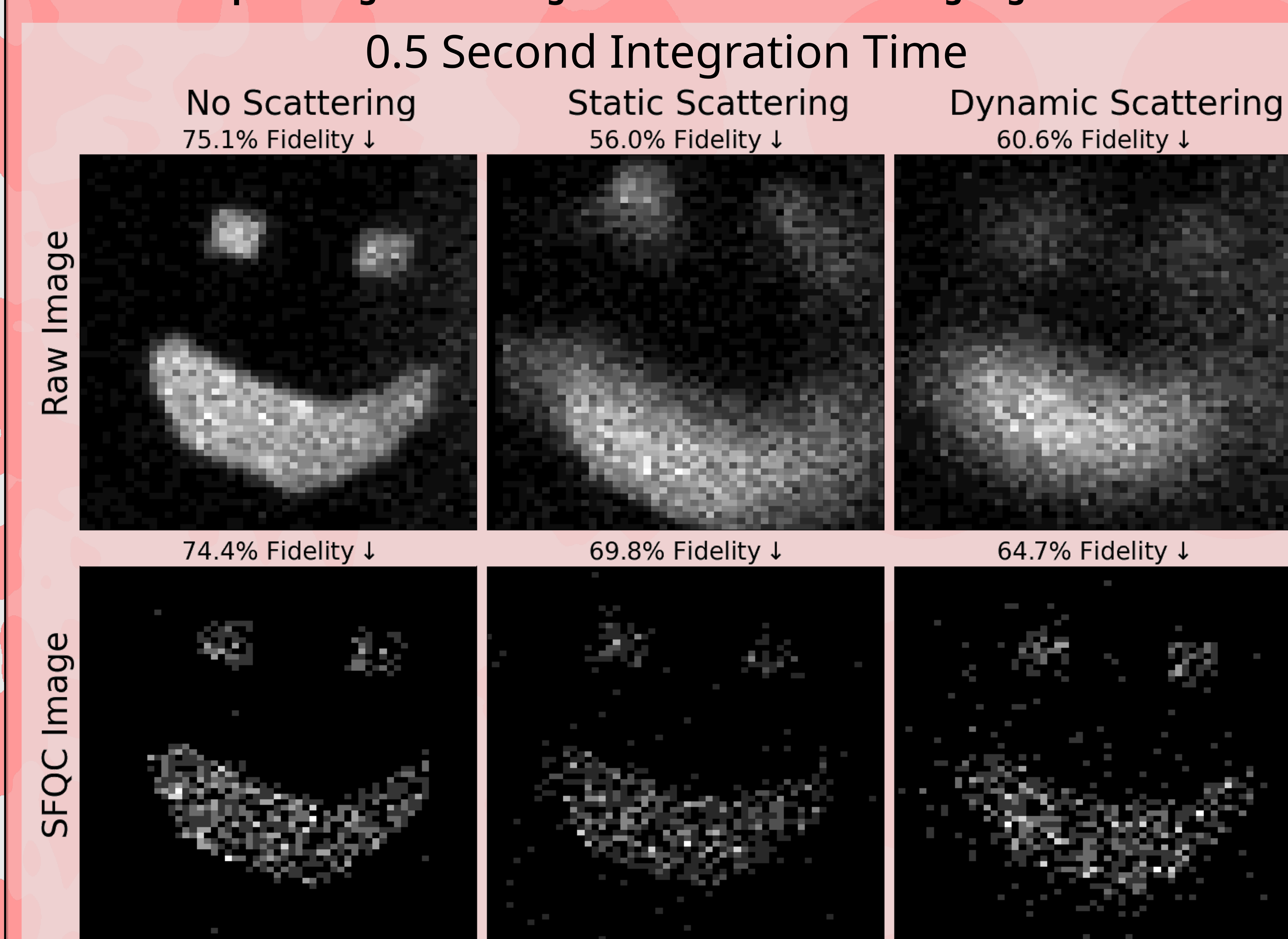




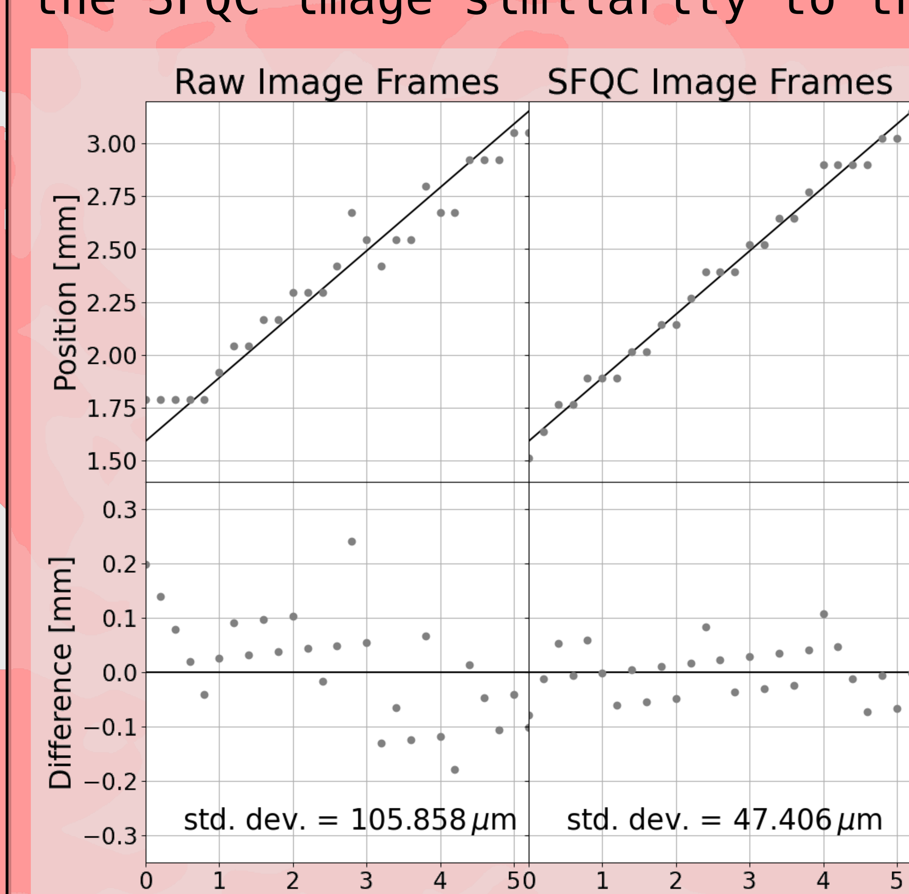
Results



Results from **5 second integration time**. Fidelity measurement comes from the maximum of a cross-correlation measurement, where the reference image was taken classically from a 30 second integration time exposure. **The fidelity of the SFQC images were consistently significantly higher than the corresponding raw image in all three imaging schemes.**



Results from **0.5 second integration time. The fidelity measurement increase were either insignificant or small.** Qualitatively, however, **there appears to be an improvement** in the SFQC image similarity to the reference.



An alternative **object tracking metric** (location of the maximum of the cross-correlation measurement) was used to quantify this improvement for short integration times. The target was translated across the transverse beam profile. **The SFQC recording showed a less than half the uncertainty in object location** compared to the raw recording with **0.2 second integration times.**

Link to real-time video:

References and Acknowledgements
[1] Pittman T. B. et al., Phys. Rev. A, Vol. 52, R3429-R3432, 1995.
[2] Chan J. et al., Opt. Express, Vol. 17, 7916, 2009.
[3] Gregory T. et al., Sci. Adv., Vol. 6, 2020.
[4] Gregory T. et al., Sci. Reports, Vol. 11, 2021.
[5] Defienne H. et al., Phy. Rev. A, Vol. 99, 2019.
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