Recursive Bayesian estimation of atom numbers

Article: Generation and detection of sub-Poissonian atom number distribution in a one-dimensional optical lattice

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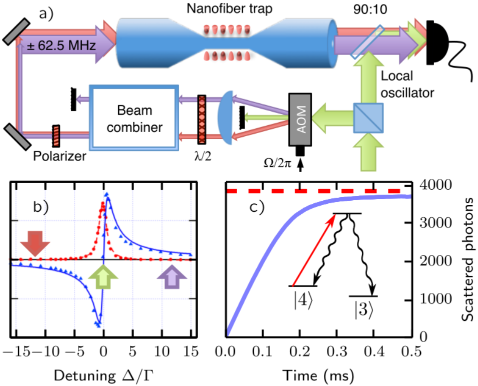
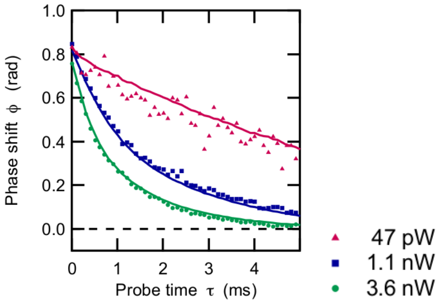
Introduction to the problem

- 1D atomic trap with cesium atoms
- Measuring number of atoms non-demolishing
  - QND
  - Calibration $\phi = N_{at}\bar{\phi}_1$



Introduction to the problem

- Shot noise limited
  $$\delta\phi = \frac{1}{2\sqrt{qN_{\mathrm{ph}}}} \quad , \quad q = \varepsilon(1-l)\mathcal{V}\eta = 0.40 \pm 0.04$$
- Power trade off between precision and lifetime
  - Natural $1/e$ life time: 6.8 ms

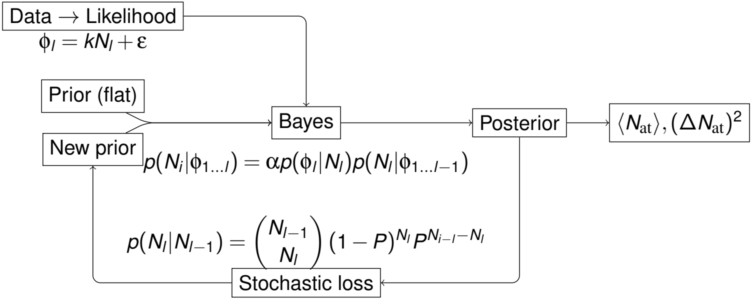


- Red data long lifetime, but noisy.

Goal of the article

- To estimate the atom number evolution with time
- Normal approach:
  - Measure stronger: then we will lose atoms
  - Measure longer and take average: the value we want to measure change in each realization
- Solution: measure weakly and update atom number estimator from previous measurements in each time step.

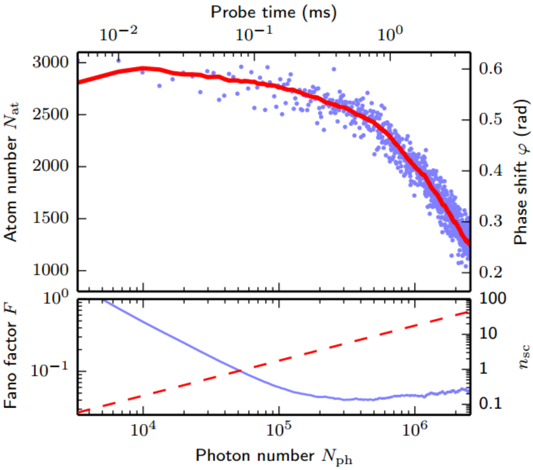
Recursive Bayesian estimation



- Include all losses as Markov process. Binomial
- Likelihood is estimated to be normal, i.e. gaussian shot noise is added to a given measurement.
- Posterior from last time step as prior for current estimation.

Recursive Bayesian estimation

- Fano factor: $F = (\Delta N_{at})^2 / \langle N_{at} \rangle$ =-14 dB $\rightarrow$ sub-poissonian



Recursive Bayesian estimation

- Minimum fano factor is gaussianly distributed - it works!