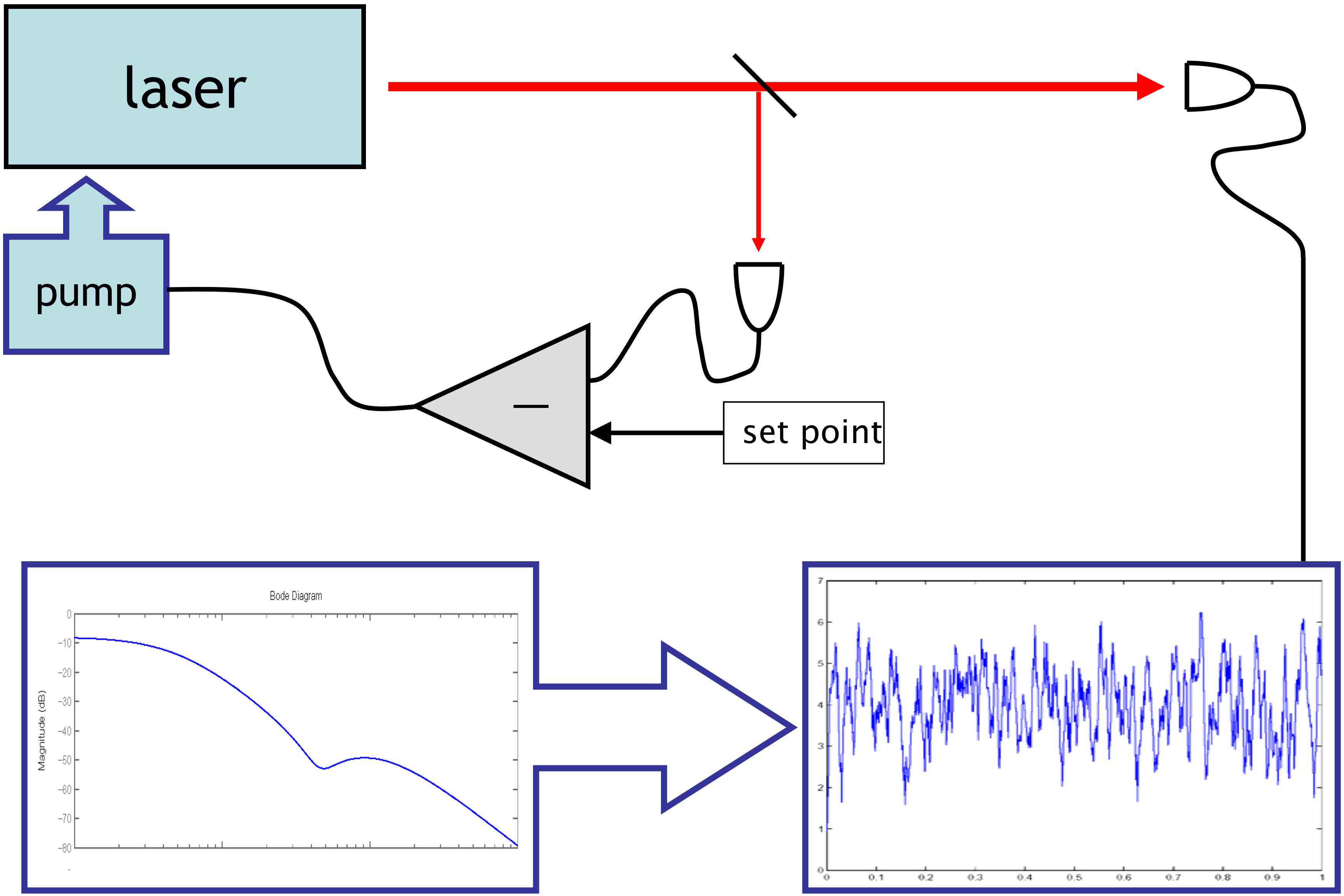
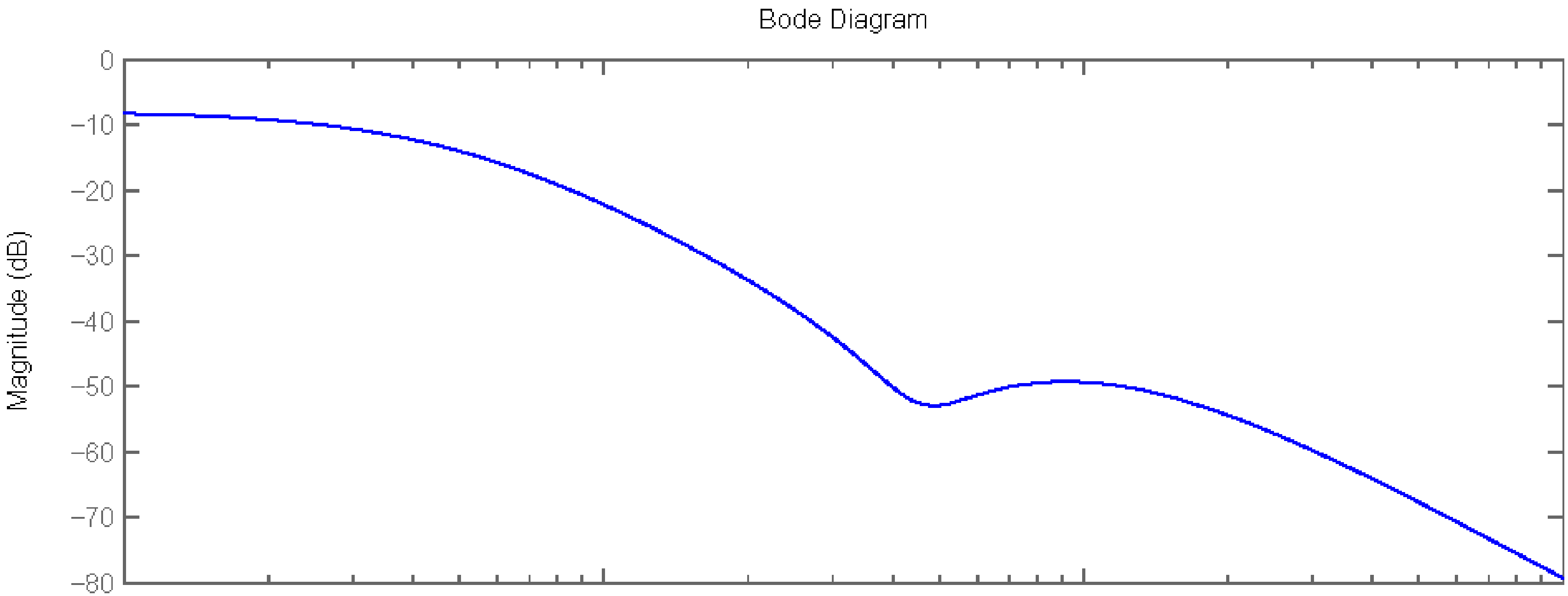
Stabilizing the power of a laser beam via feedback/forward

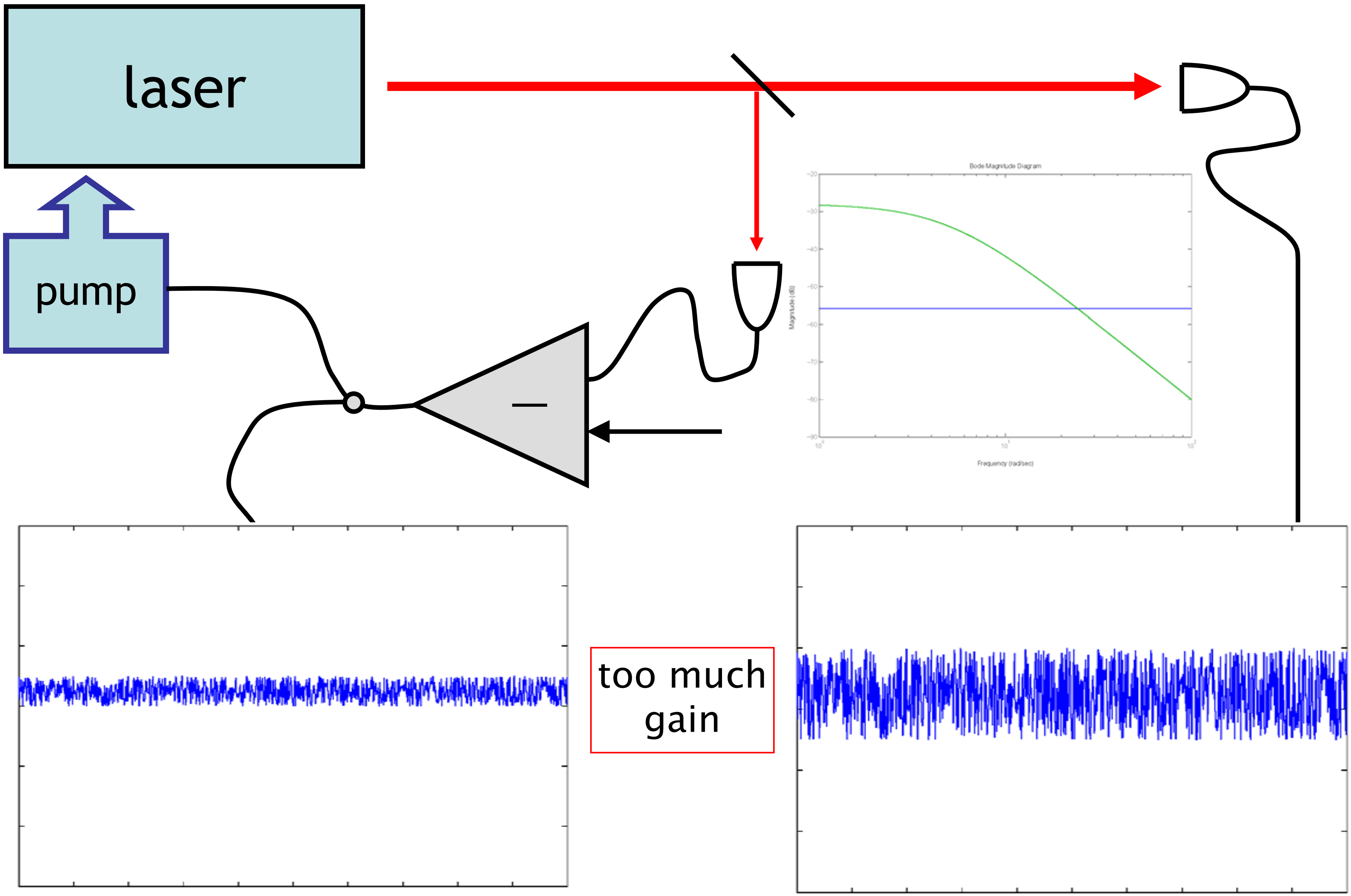


Loop-shaping: put gain where you need it & close carefully

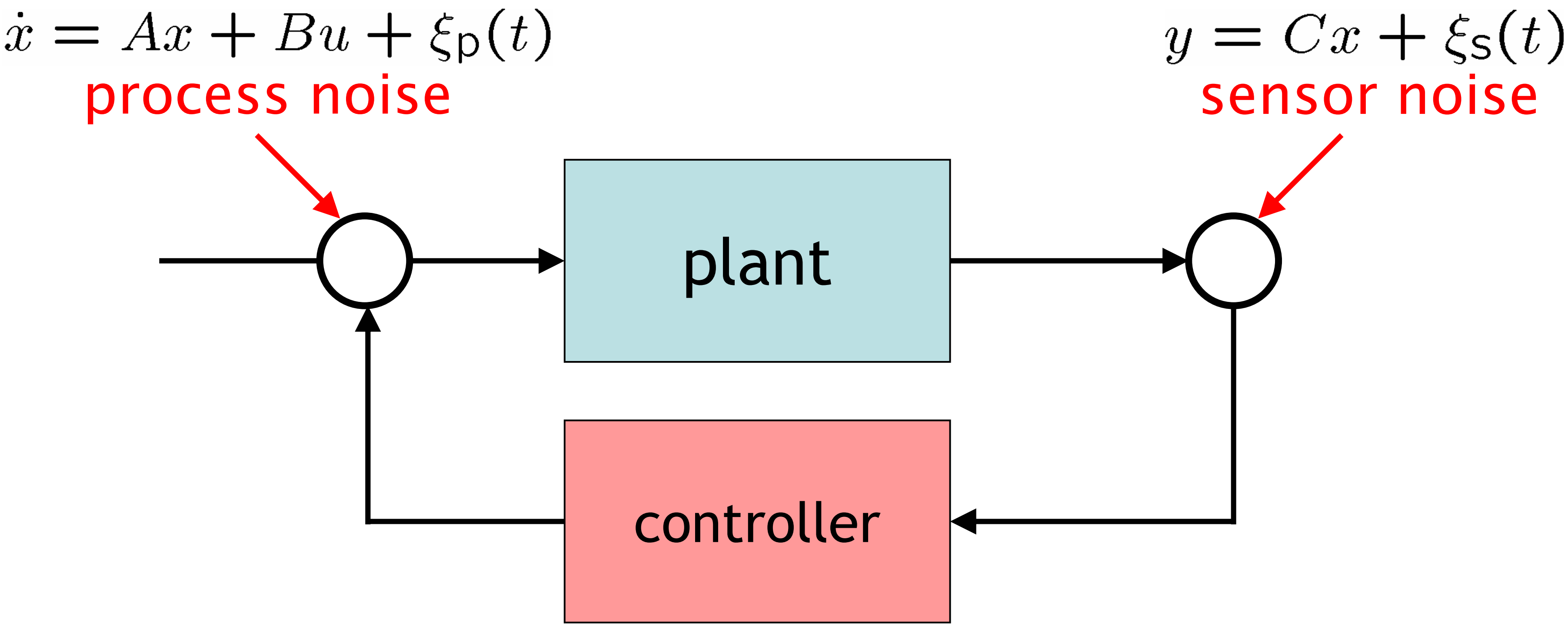


- Higher gain at acoustic, seismic frequencies
- Try not to close in a noise bump with inadequate phase margin

Filter sensor noise and limit gain to SNR bandwidth



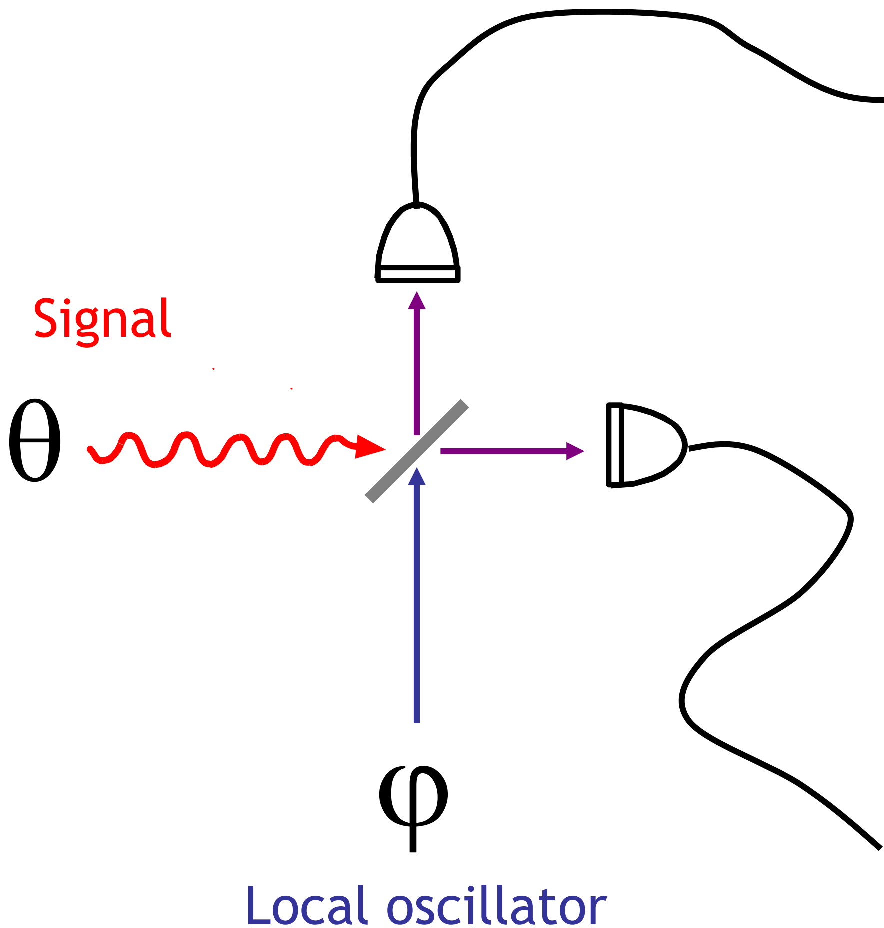
Signal diagram for “general” scenario

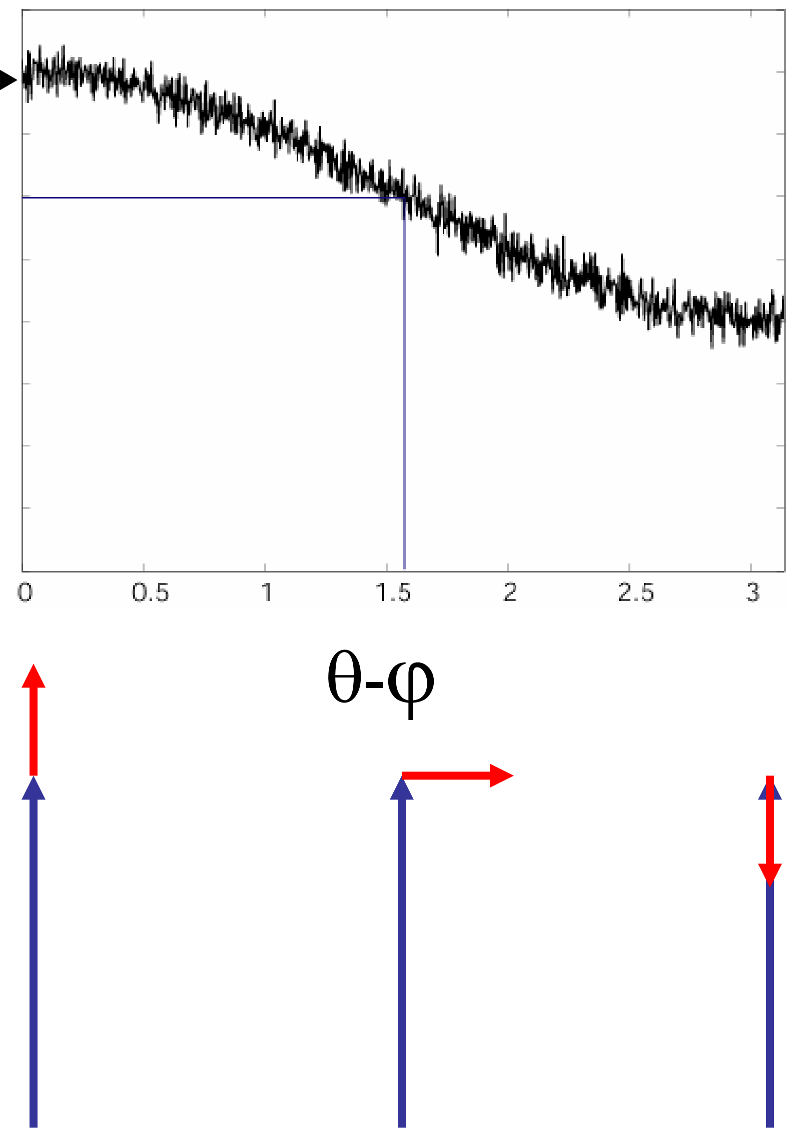


<u>Conclusions</u>

- It’s as important to characterize your noise as to characterize your plant
- Plenty of room for theory to help with optimizing and compromising

Measuring optical phase

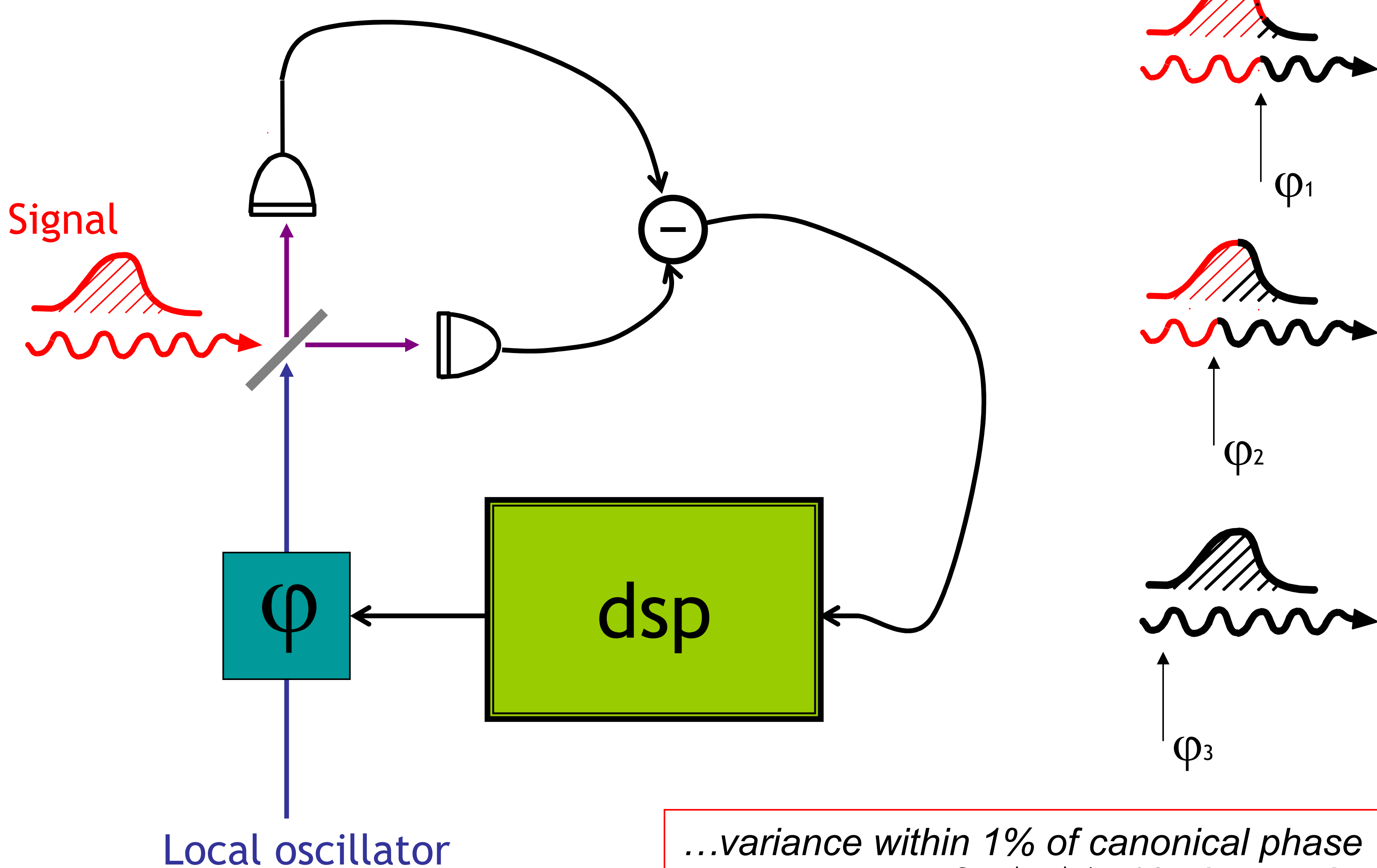




approximates canonical phase measurement,
given prior knowledge of mean phase
and photon number

Adaptive homodyne measurement

(H. M. Wiseman)



…variance within 1% of canonical phase measurement for $\langle n \rangle \gtrsim 10$ *photons !*

Adaptive homodyne feedback algorithms

(D. W. Berry and H. M. Wiseman, PRA 63, 013813 (2000))

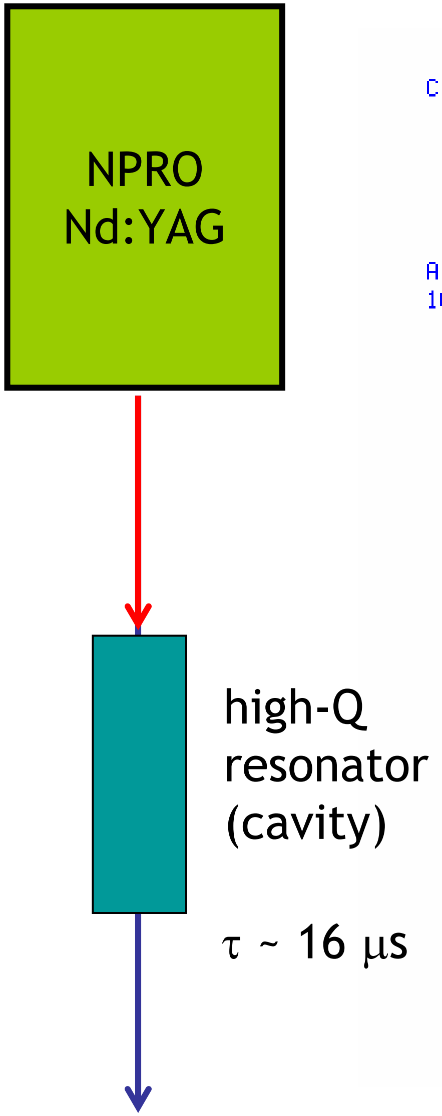
Local oscillator phase: $\Phi(v) = \hat{\varphi}(v) + \frac{\pi}{2}$ $\hat{\varphi}(v) = \arg(A_v)$

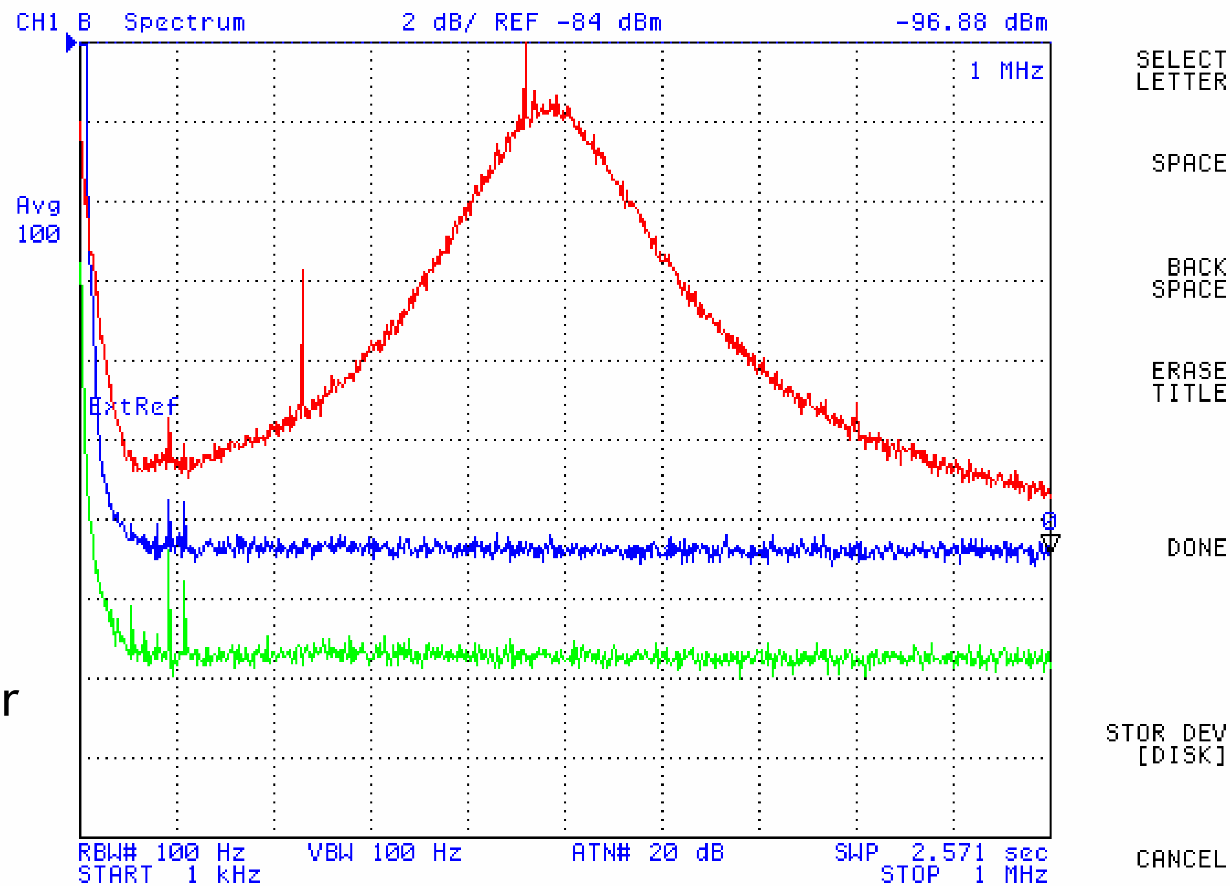
Mark I: estimate = arg(A); Mark II: estimate = arg(C)

$$A_v = \int_0^v I(u) e^{i\Phi(u)} du \qquad B_v = -\int_0^v e^{2i\Phi(u)} du \qquad C_v = A_v v + B_v A_v^*$$

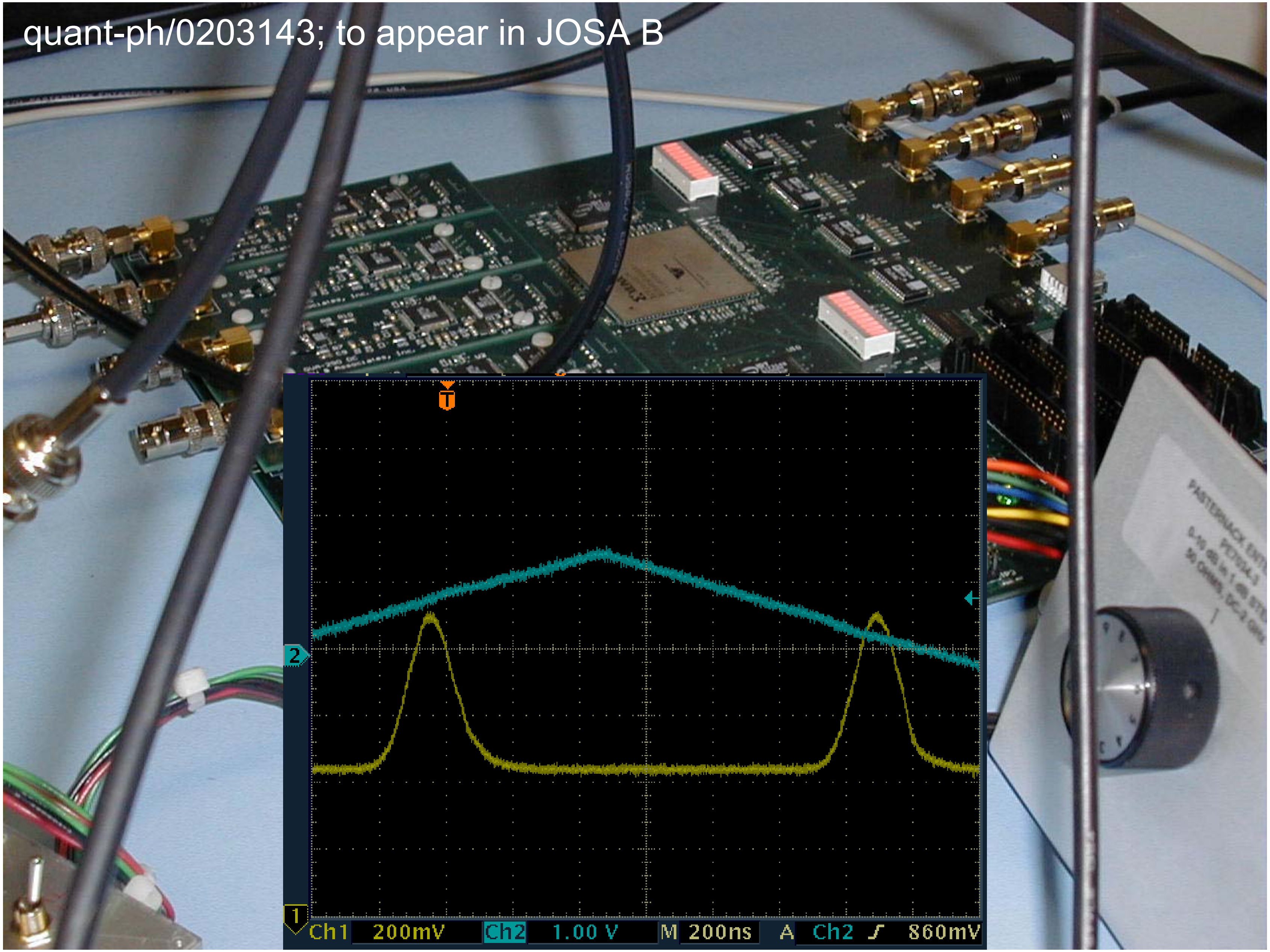
technical effects?

Technical challenges – laser noise

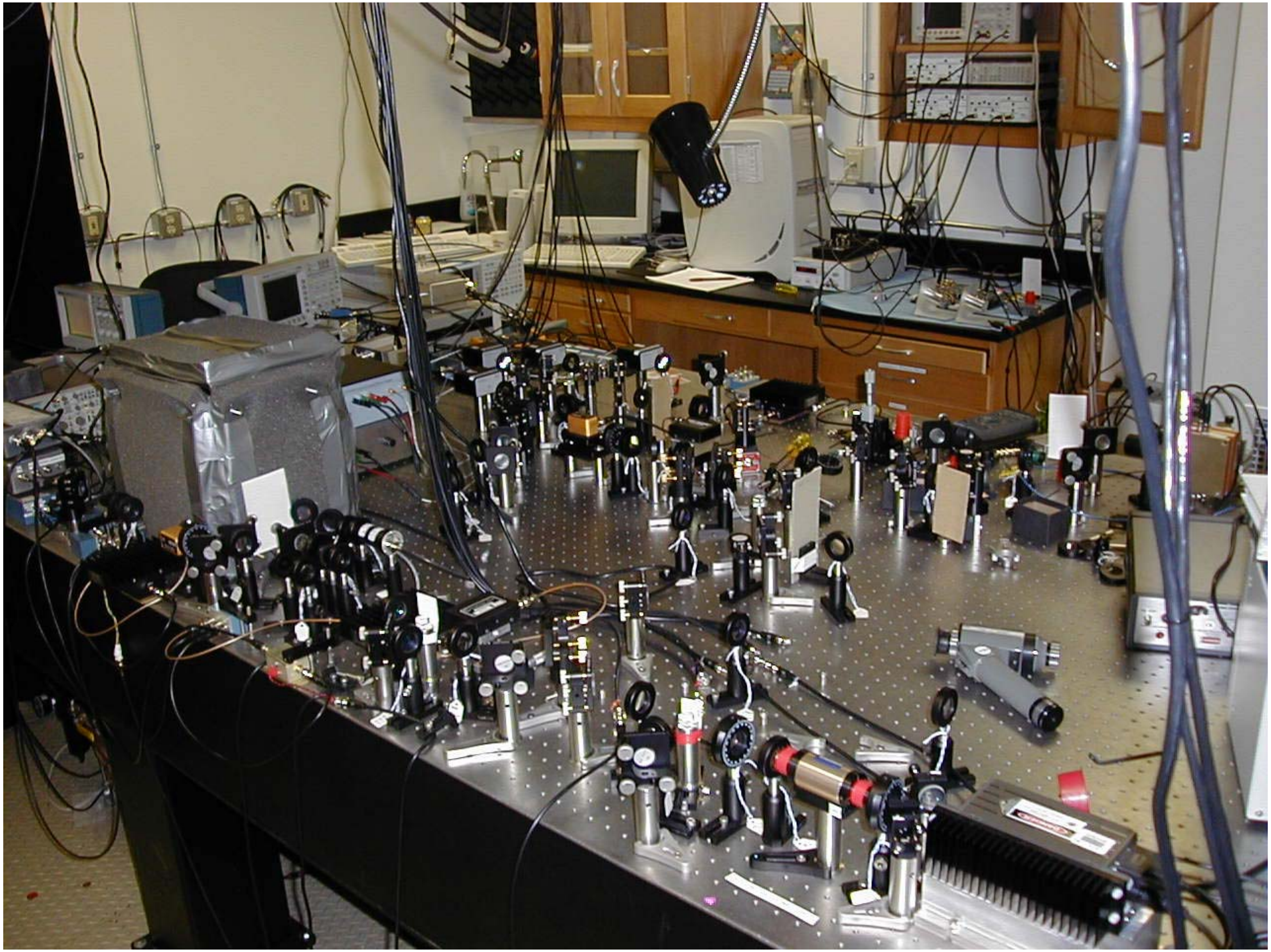




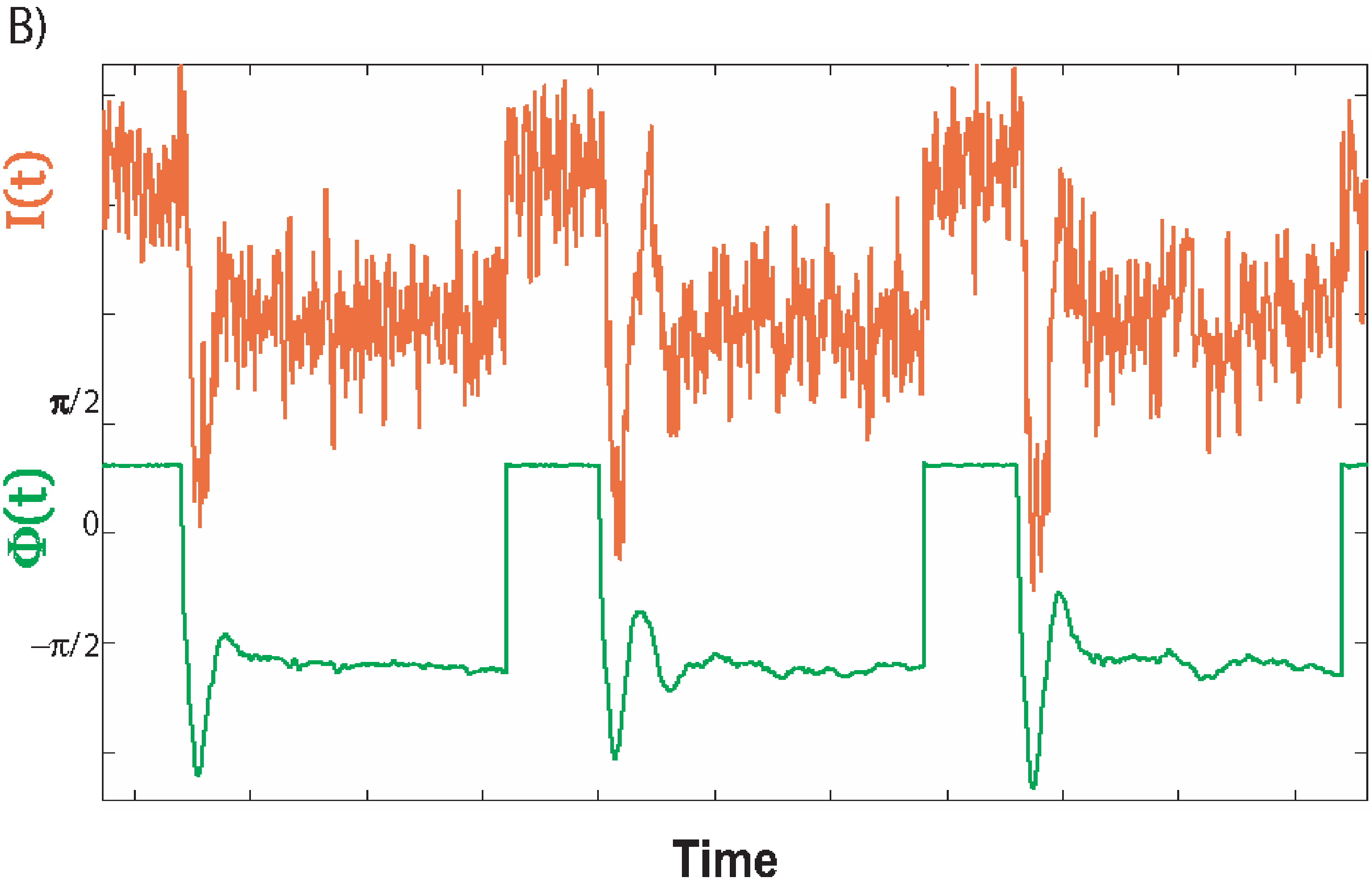
Technical challenges – loop delay



Experimental implementation

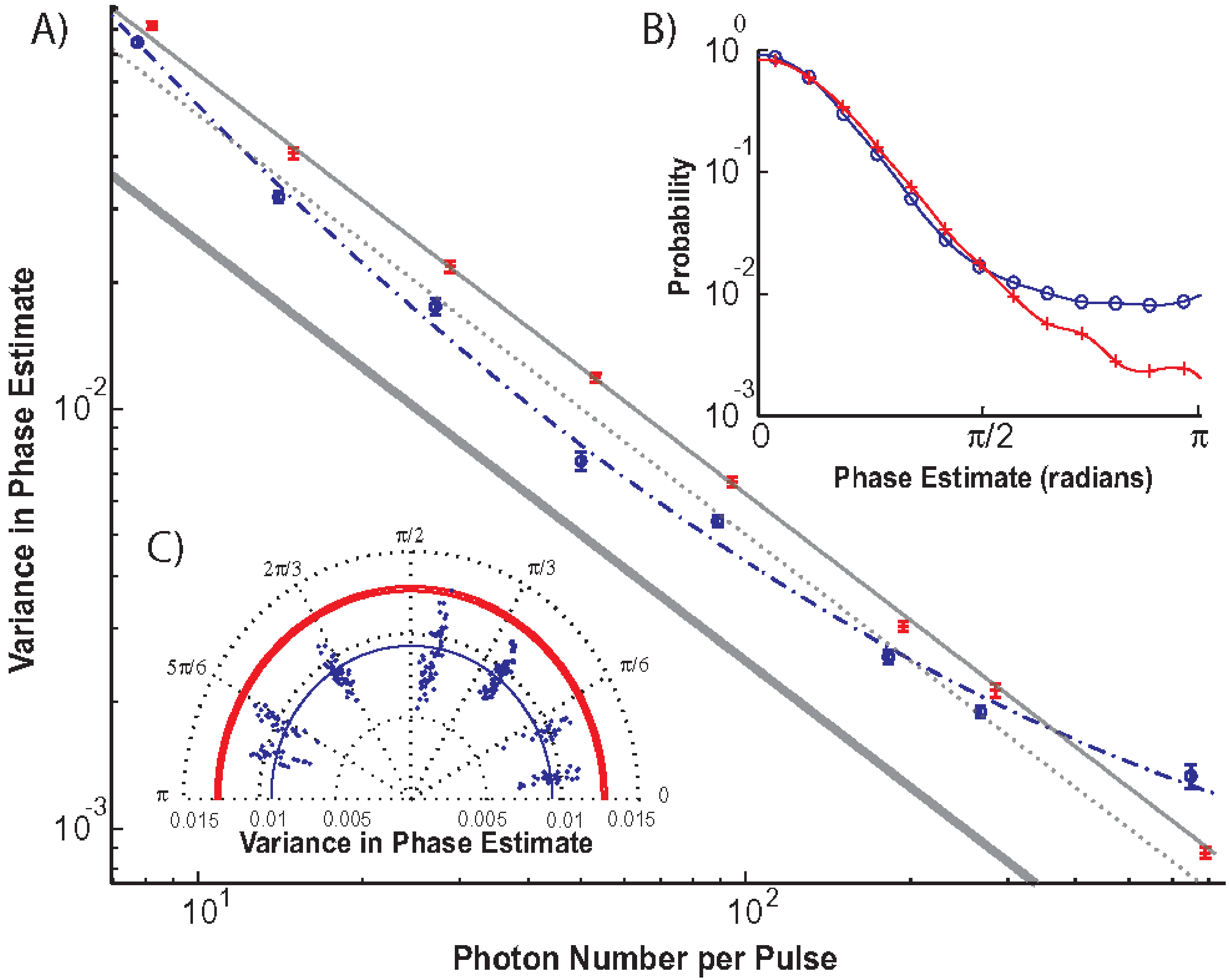


Closing the loop…

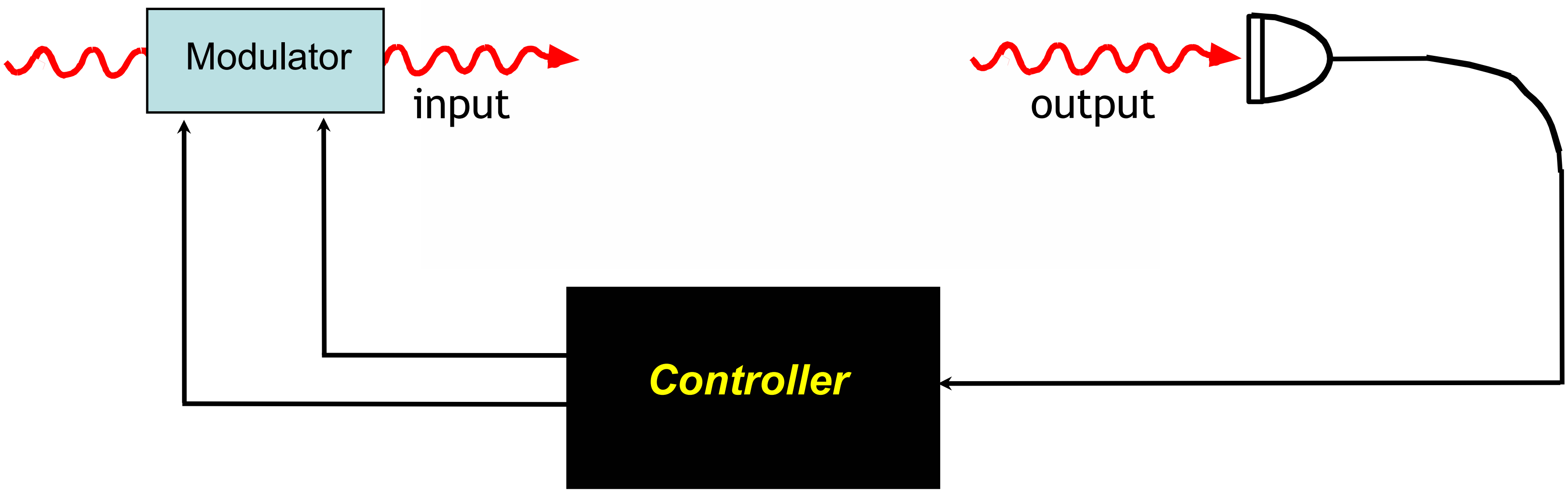


M. Armen, J. Au, J. Stockton, … PRL 89, 133602 (2002)

The power of quantum feedback

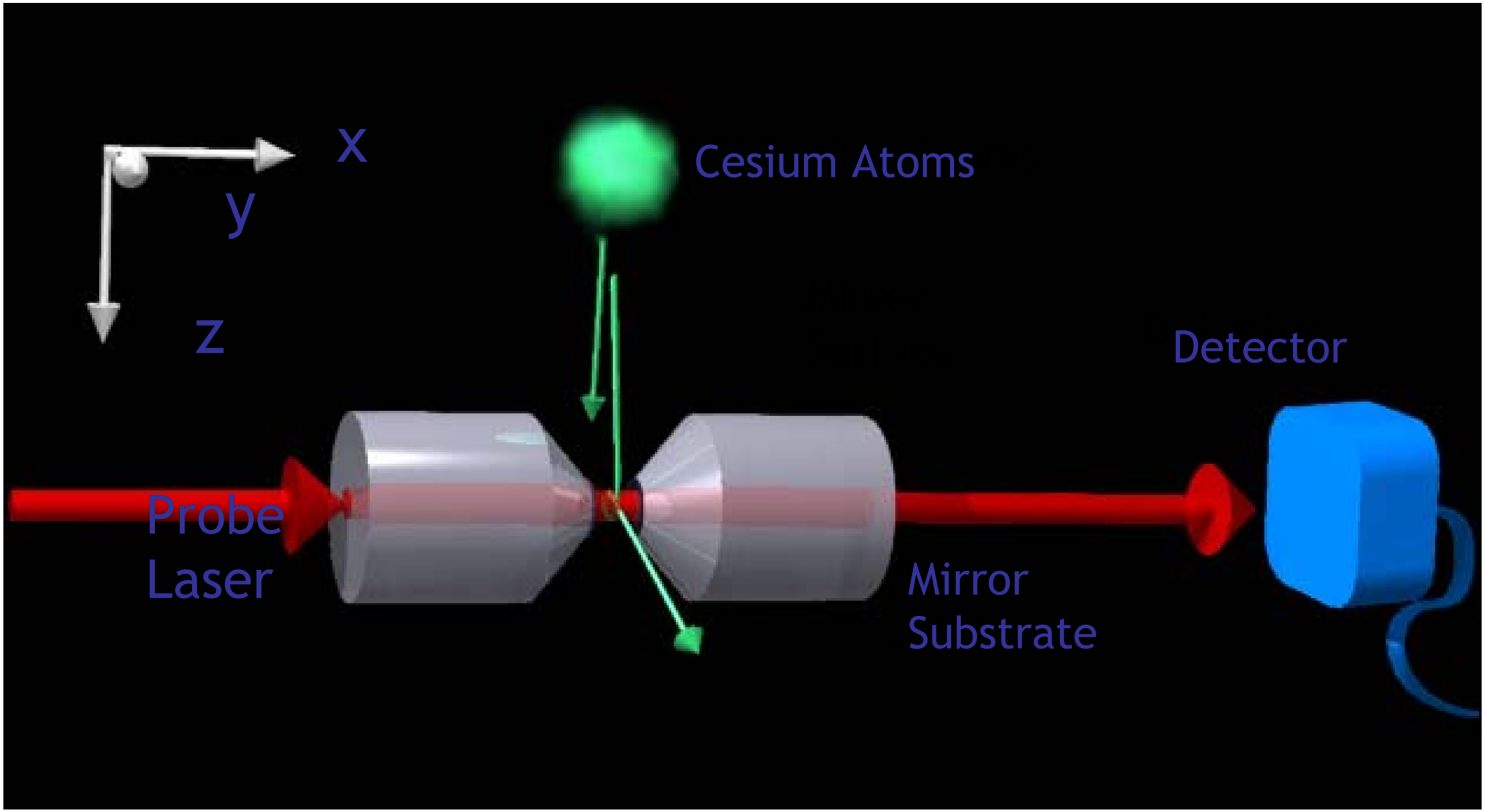


Feedback control of quantum *dynamics*



optical coupling to internal and/or center-of-mass atomic dynamics

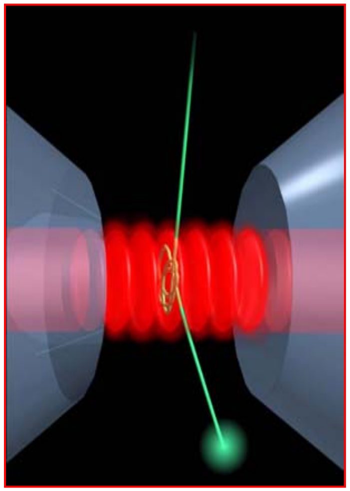
Cavity QED with cold atoms

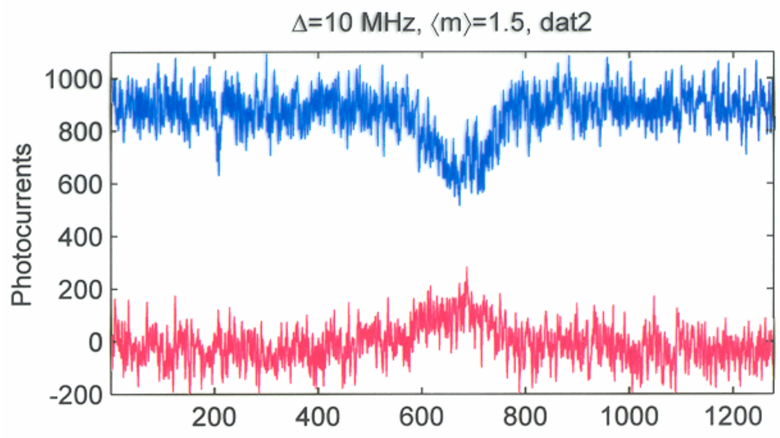


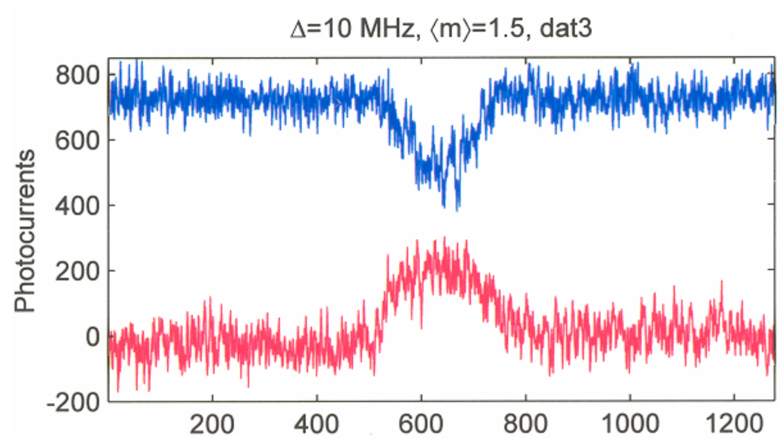
C. J. Hood

Single-atom spatial trajectories

(with J. Ye and H. J. Kimble)



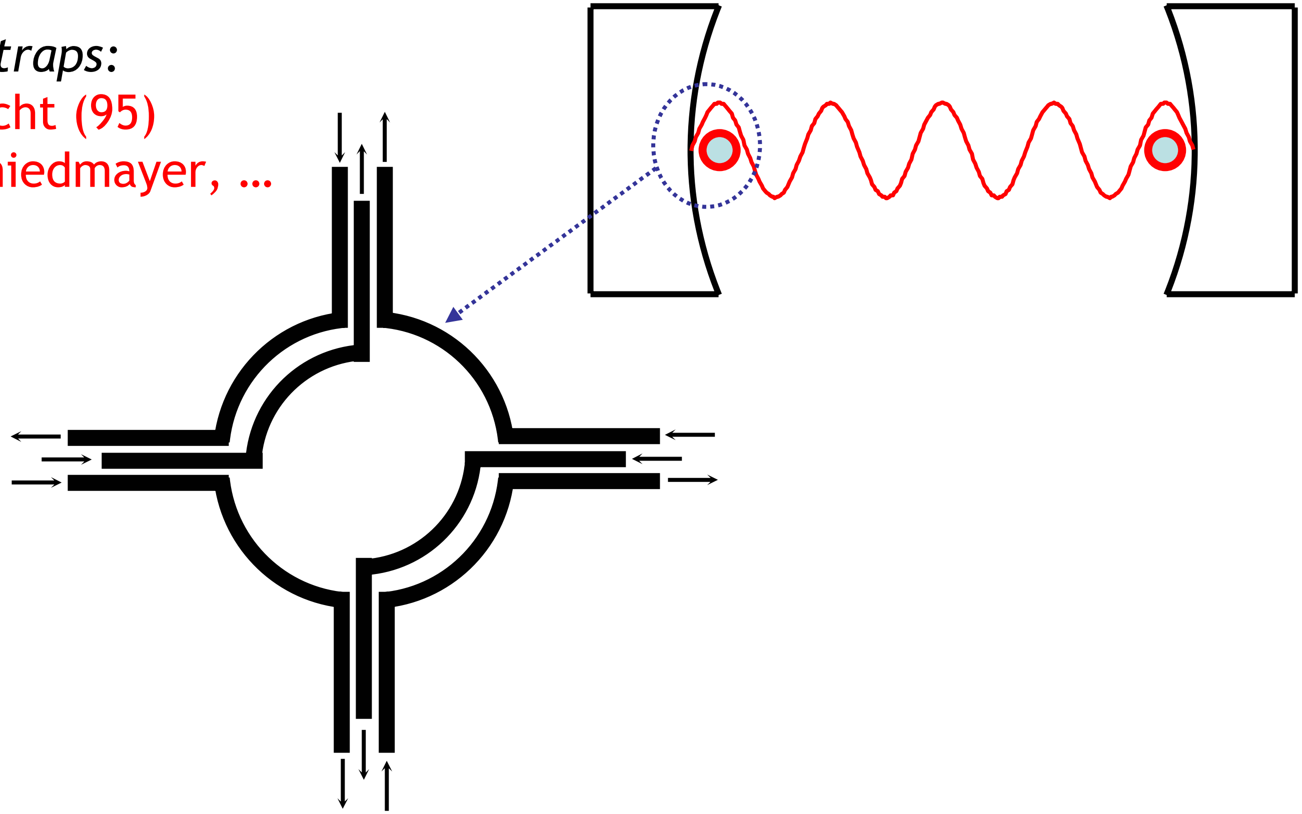




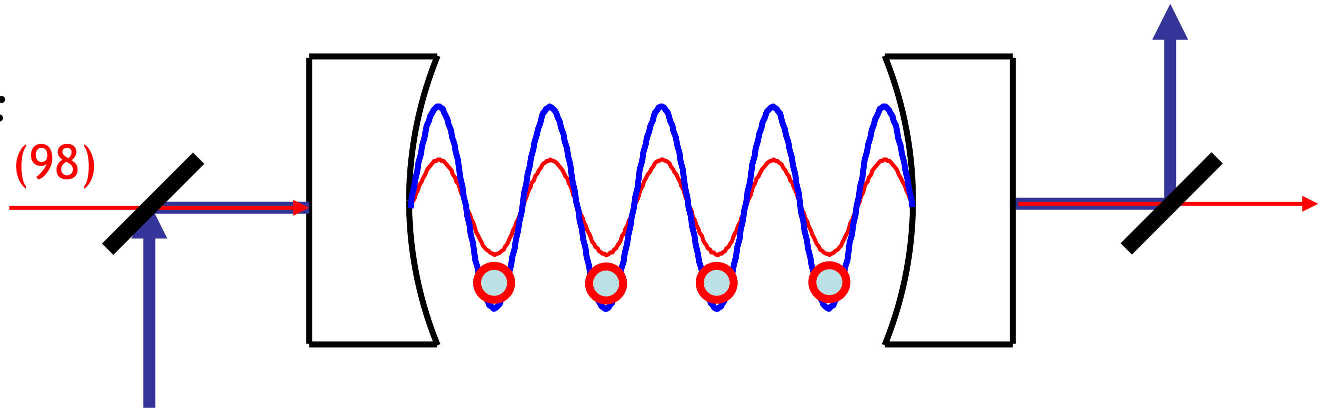
- quantum-limited sensitivity, we believe
- but how to prove it?

Intra-cavity atom traps

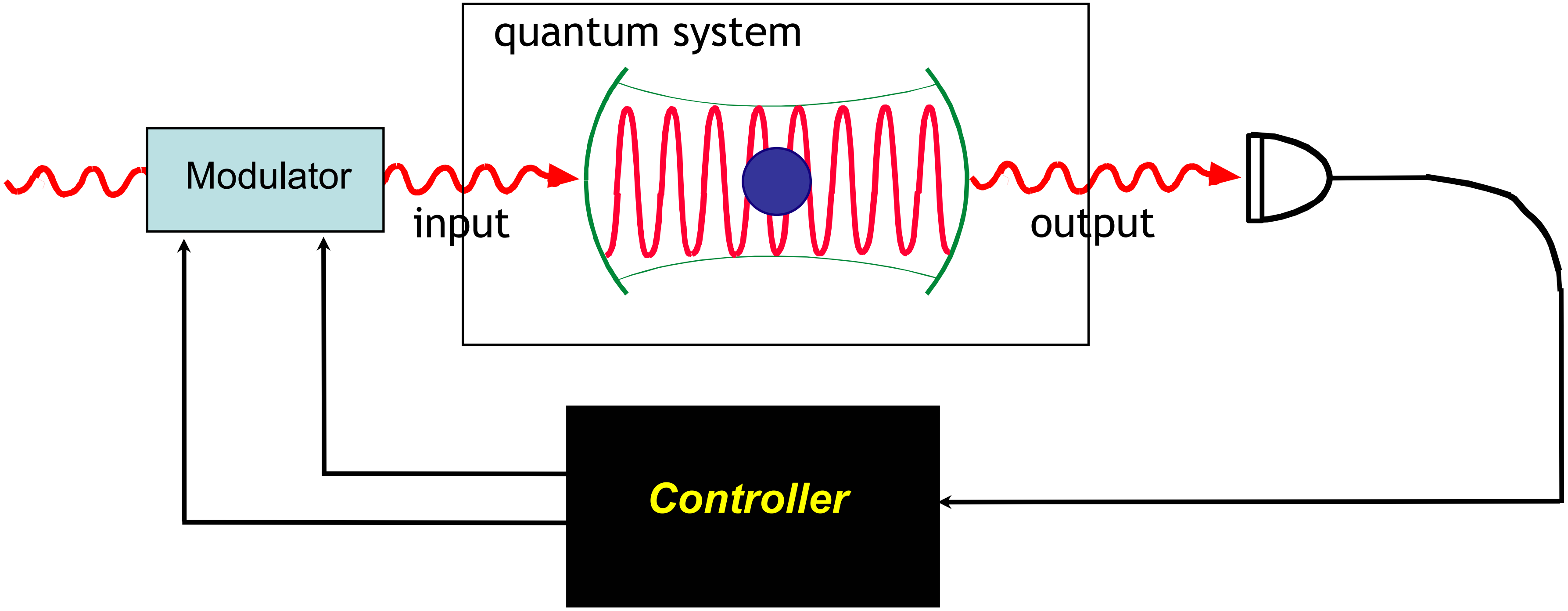
Planar magnetic microtraps:
Weinstein and Libbrecht (95)
Haensch, Hinds, Schmiedmayer, …



Intracavity optical lattice:
Vernooy, Ye, and Kimble (98)
Jessen, Deutch, …

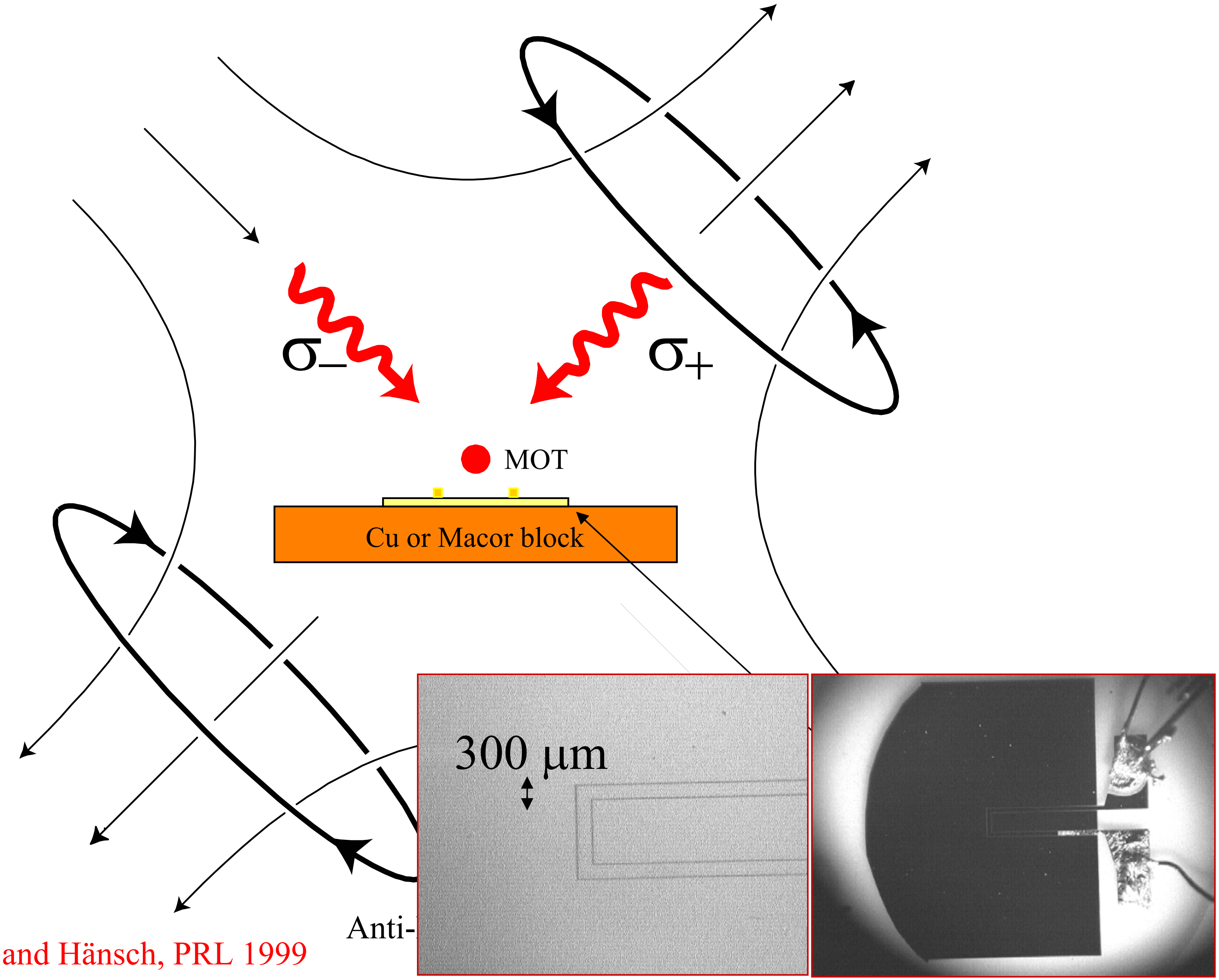


Real-time 'quantum feedback' control



- quantum-limited broadband measurement + low latency signal processing (HW)
- synthesis (bilinear/stochastic/Hamiltonian) & identification methodology (SW)
- explore "applications" with demonstrable, unique benefits of real-time QFB

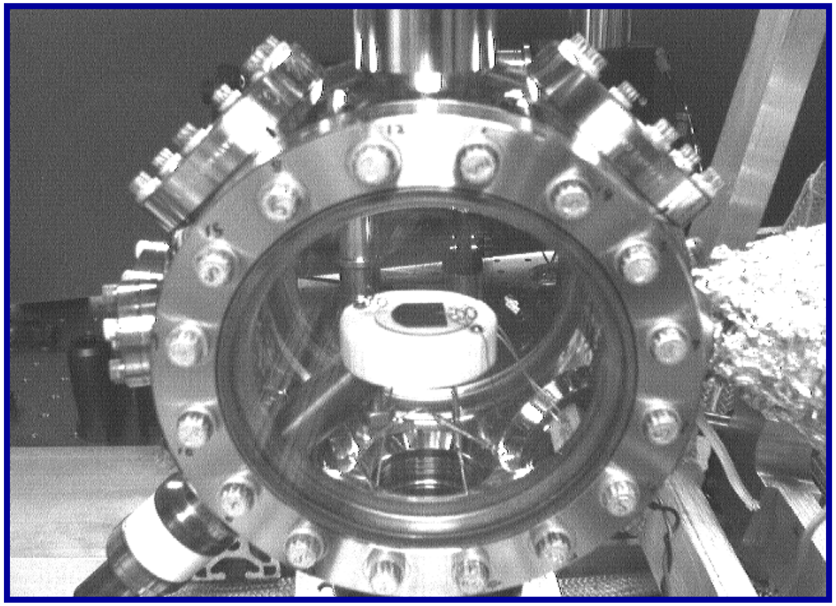
Planar trapping geometries for integrated cQED

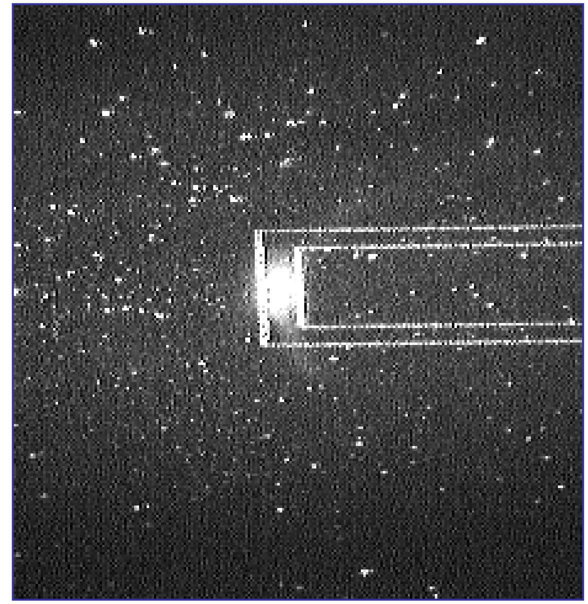


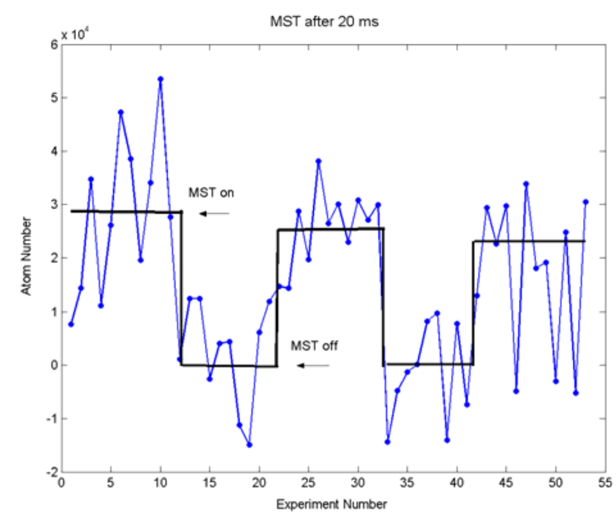
Reichel, Hänsel, and Hänsch, PRL 1999

Loading cold atoms into a surface-MOT, MST

(B. Lev)







http://minty.caltech.edu/MabuchiLab/