Quantum degenerate gas in a corrugated potential on a magnetic film atom chip

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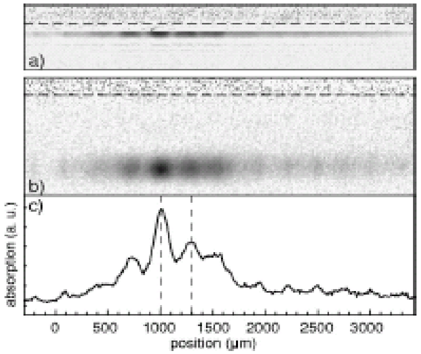
Outline:

- Fragmented atomic clouds on a chip
- Characterisation of the corrugated potential
- Source of disorder
- Our model
- Application of a double-well potential

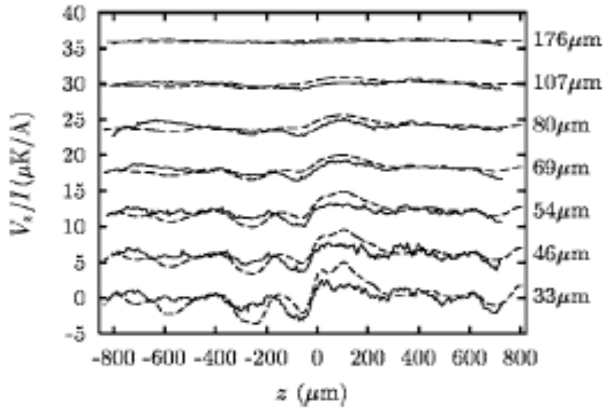
Fragmentation of atomic clouds on atom chips

First observations (2002).



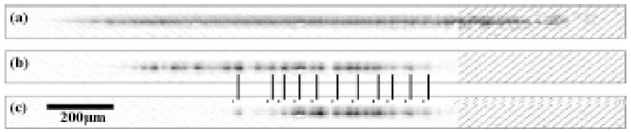
J. Fortagh et al, Phys Rev A. 66 2002
Surface effects in magnetic microtraps

Correlated with roughness of the wire edge (2004).



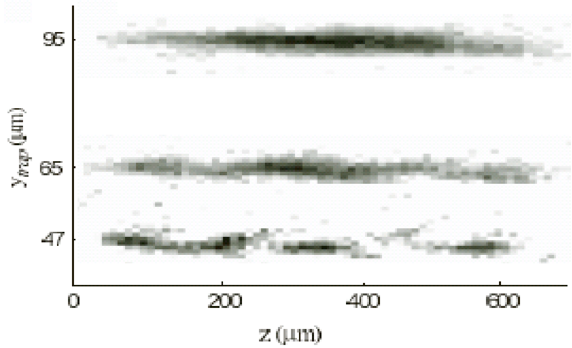
Role of wire imperfections on magnetic microtraps

Characterisation of anomalous magnetic fields



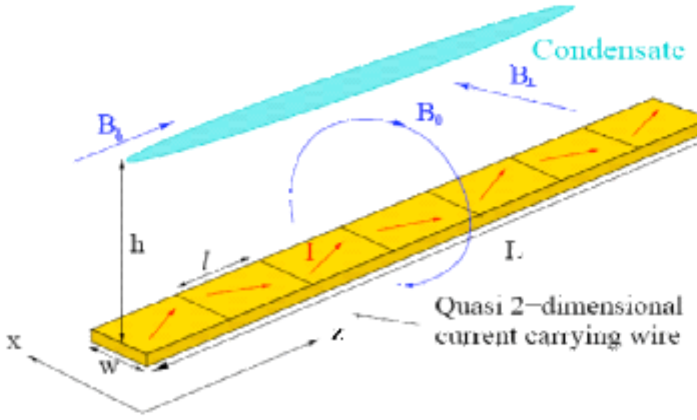
P. Kruger et al, Arxiv: cond-mat/0504686 (2005)
Disorder potentials near lithographically fabricated atom chips

Also observed on a videotape atom chips (2005).



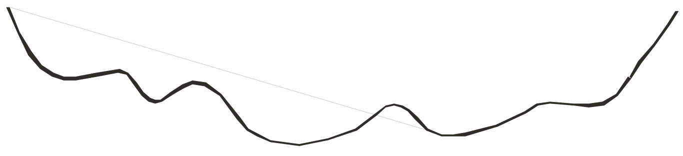
C D J Sinclair et al, Eur. Phys. J. D 35, 105 (2005)
Cold atoms in video tape micro-traps

Disorder potential above microwires



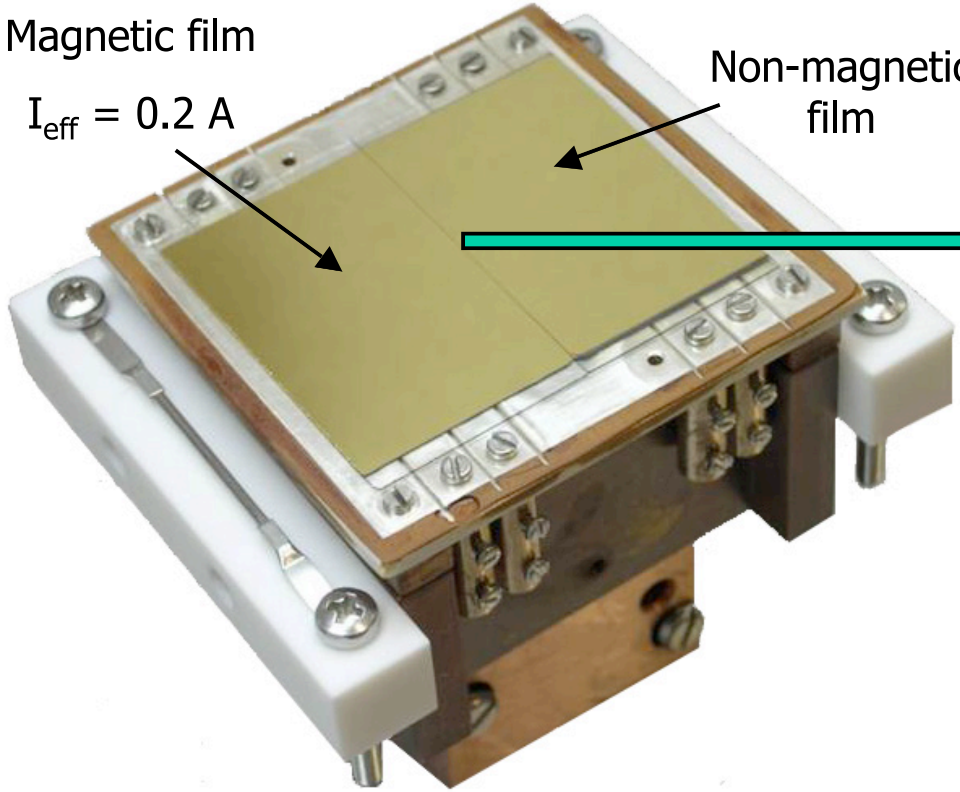
Small deviations in the current path generate a weak, spatially varying magnetic field component along the axis of the trap.

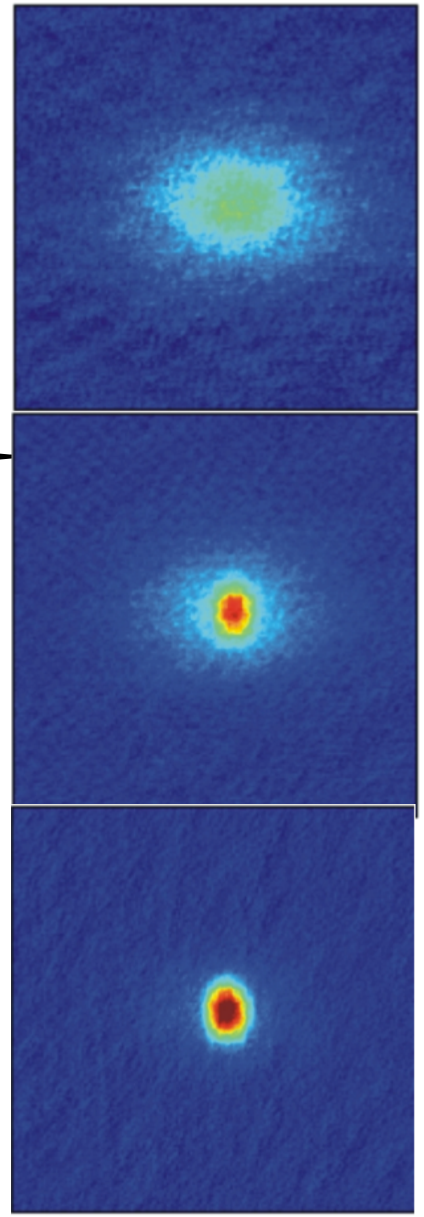
This combines with the axial magnetic field to corrugate the bottom of the trapping potential.



The cloud of atoms exhibits spatial variations in atomic density.

Magnetic film atom chip

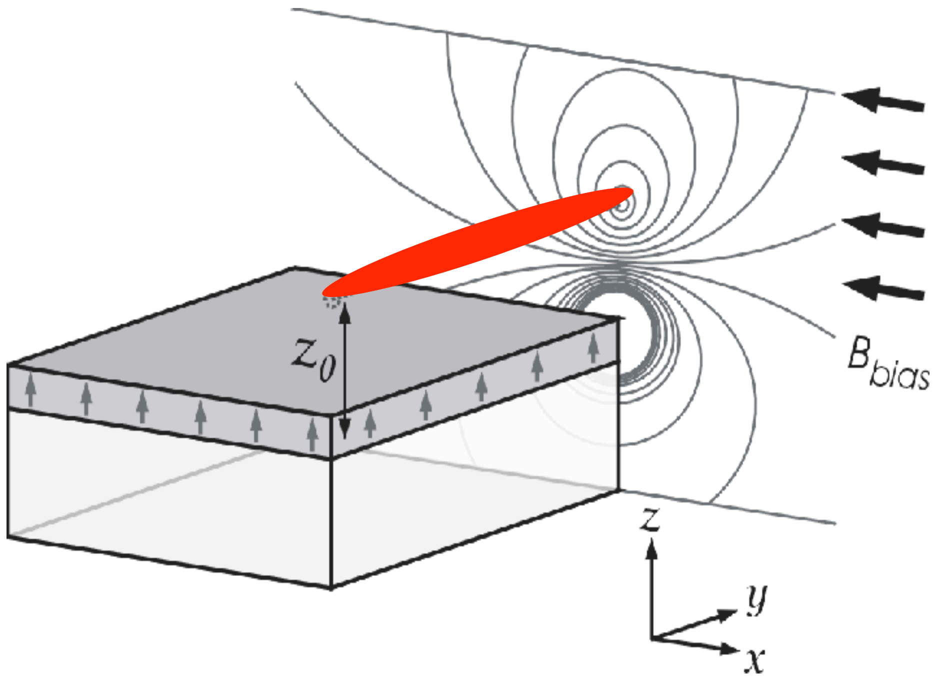


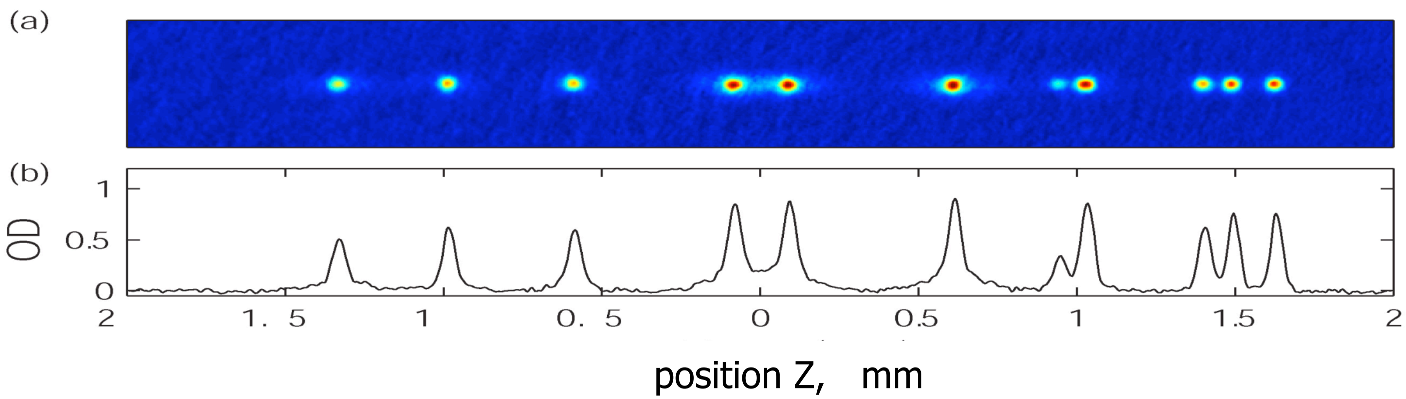


BEC of 2×10^5 ^{87}Rb

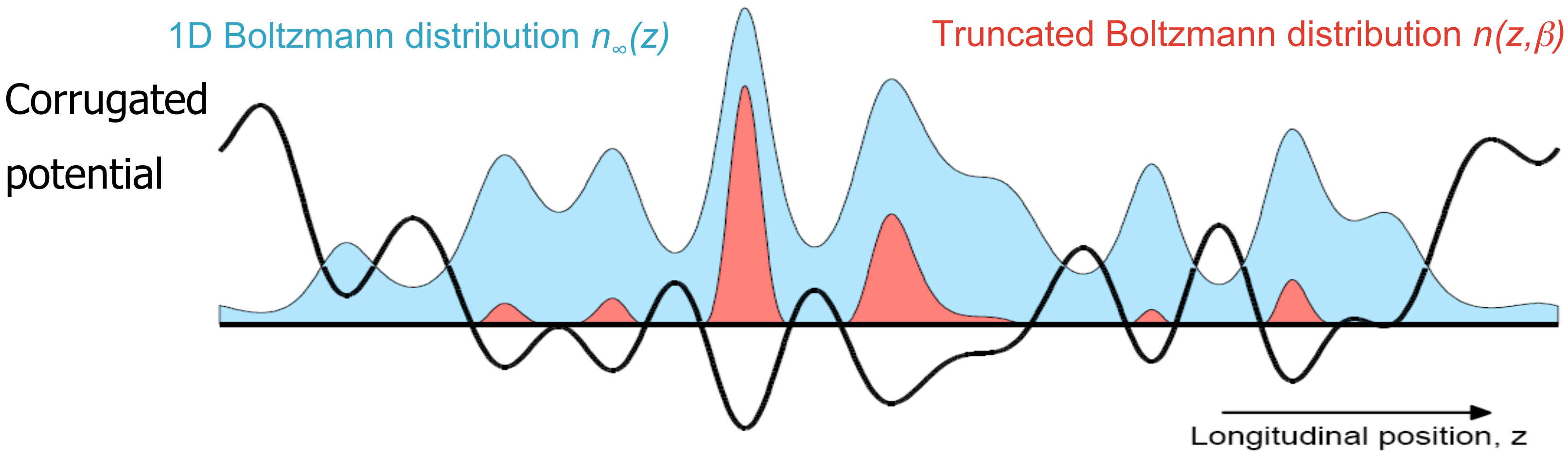
B.V. Hall et al, J. Physics B **39**, 27 (2006)

Expansion of atoms in a waveguide





Quantitative analysis – truncated Boltzmann distribution



Using Walraven's theory (PRA 53, 381 (1996)) we state:

If we know $n_\infty(z)$, the truncated $n(z,\beta)$ and the temperature T then we can evaluate the longitudinal potential $U(z)$ and the disordered component $B_z(z)$ using:

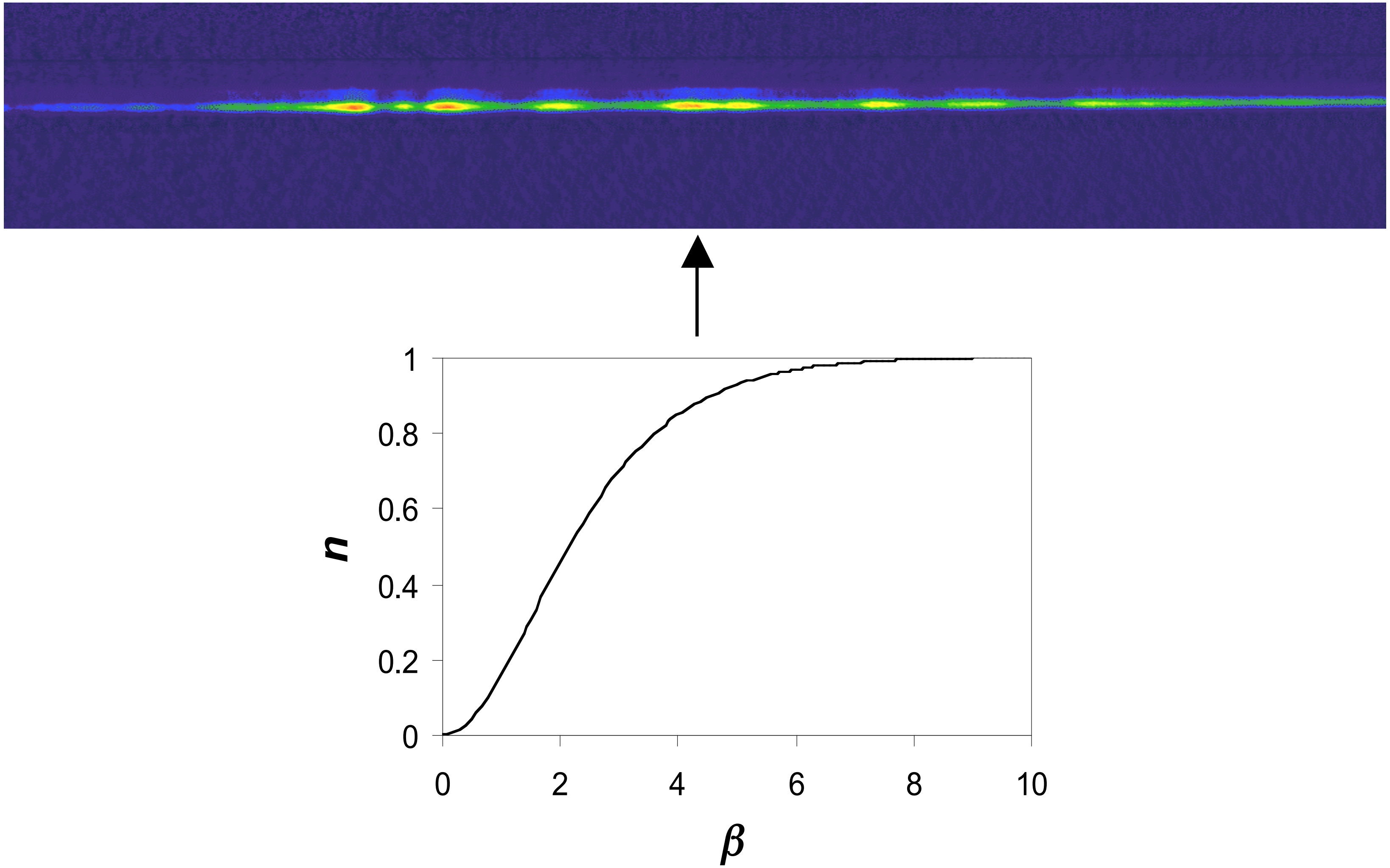
truncated 1D number density distribution

$$n(z,\beta) = n_\infty(z)[\mathrm{erf}(\sqrt{\beta}) - 2\sqrt{\beta/\pi}\mathrm{e}^{-\beta}(1+2\beta/3)],$$

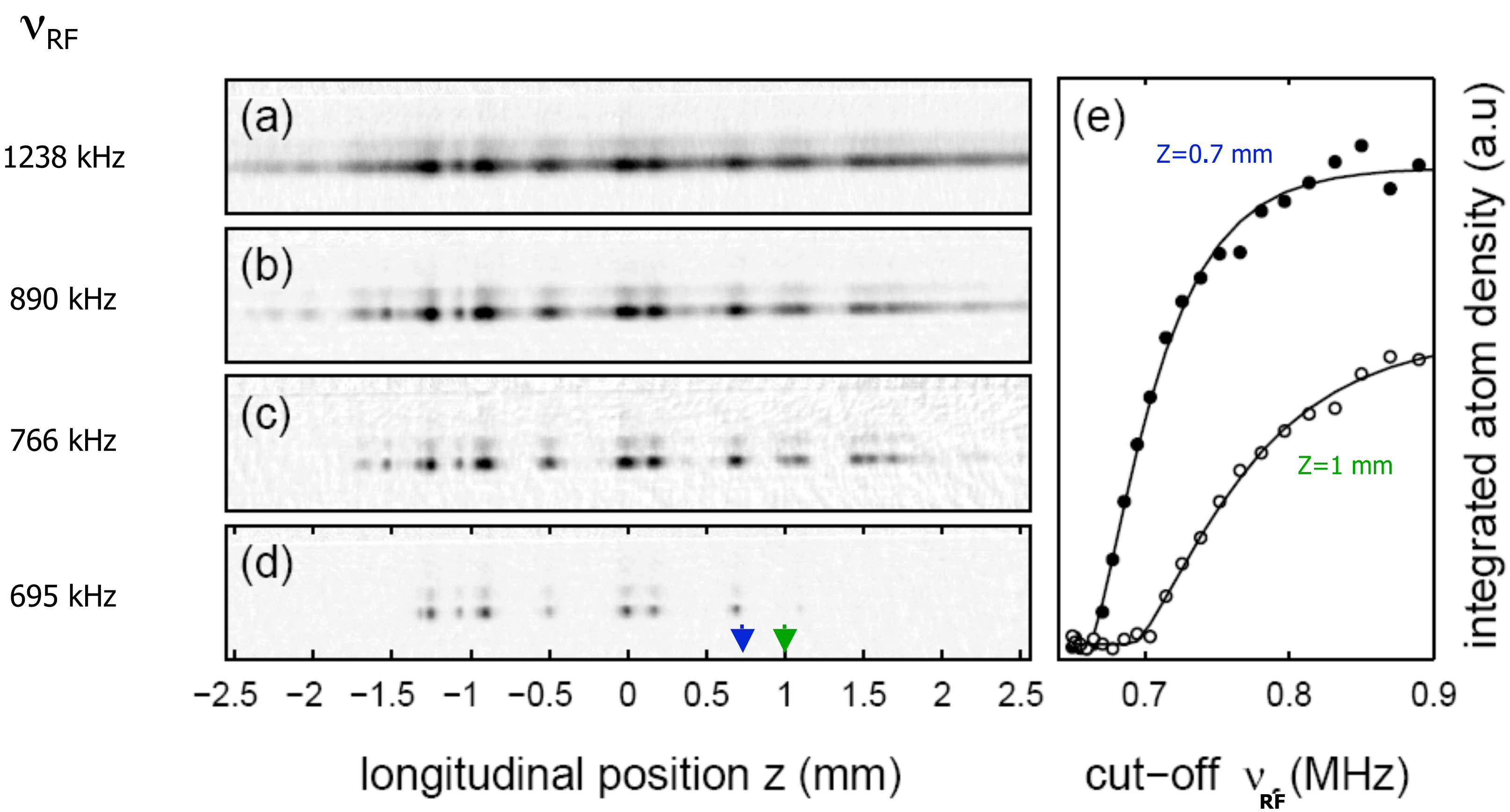
spatially dependent truncation parameter

$$\beta = \left(h\nu_{RF} - g_F \mu_B (B_0 + B_z(z))\right)/k_B T$$

Truncated Boltzmann distribution



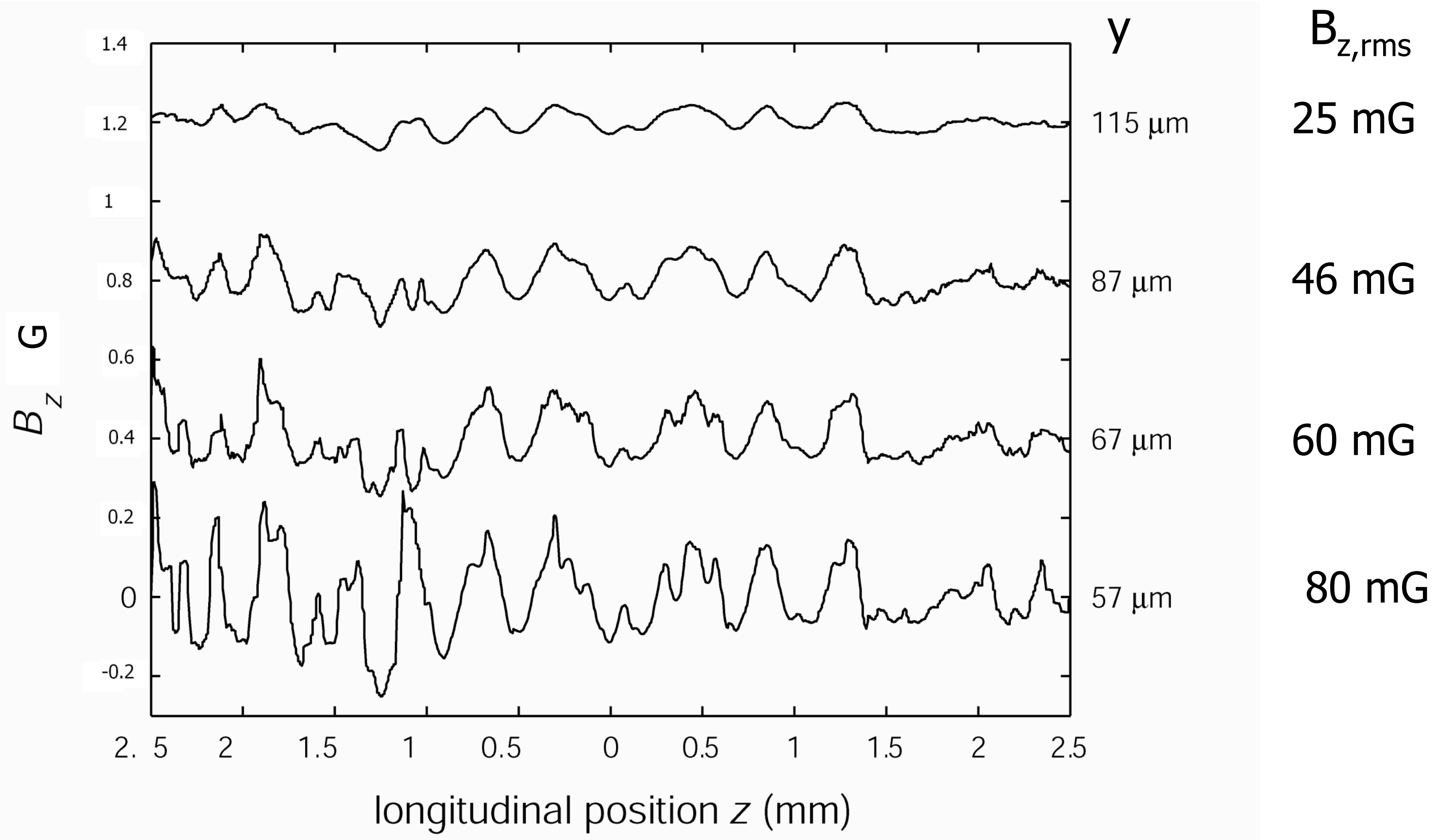
Imaging and RF spectroscopy



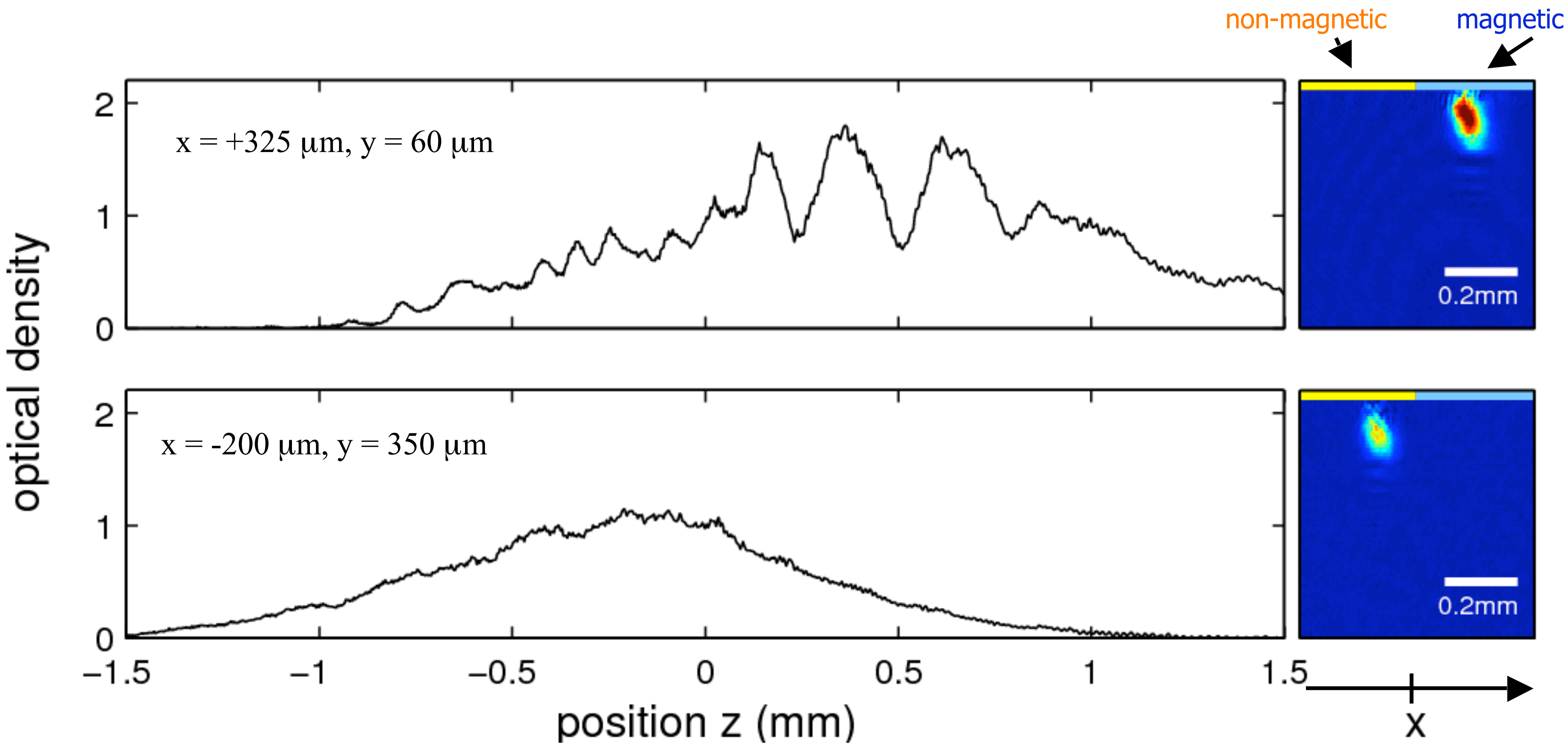
S. Whitlock et al, Phys. Rev. A **75**, 043602 (2007)

Reconstructed disorder potential

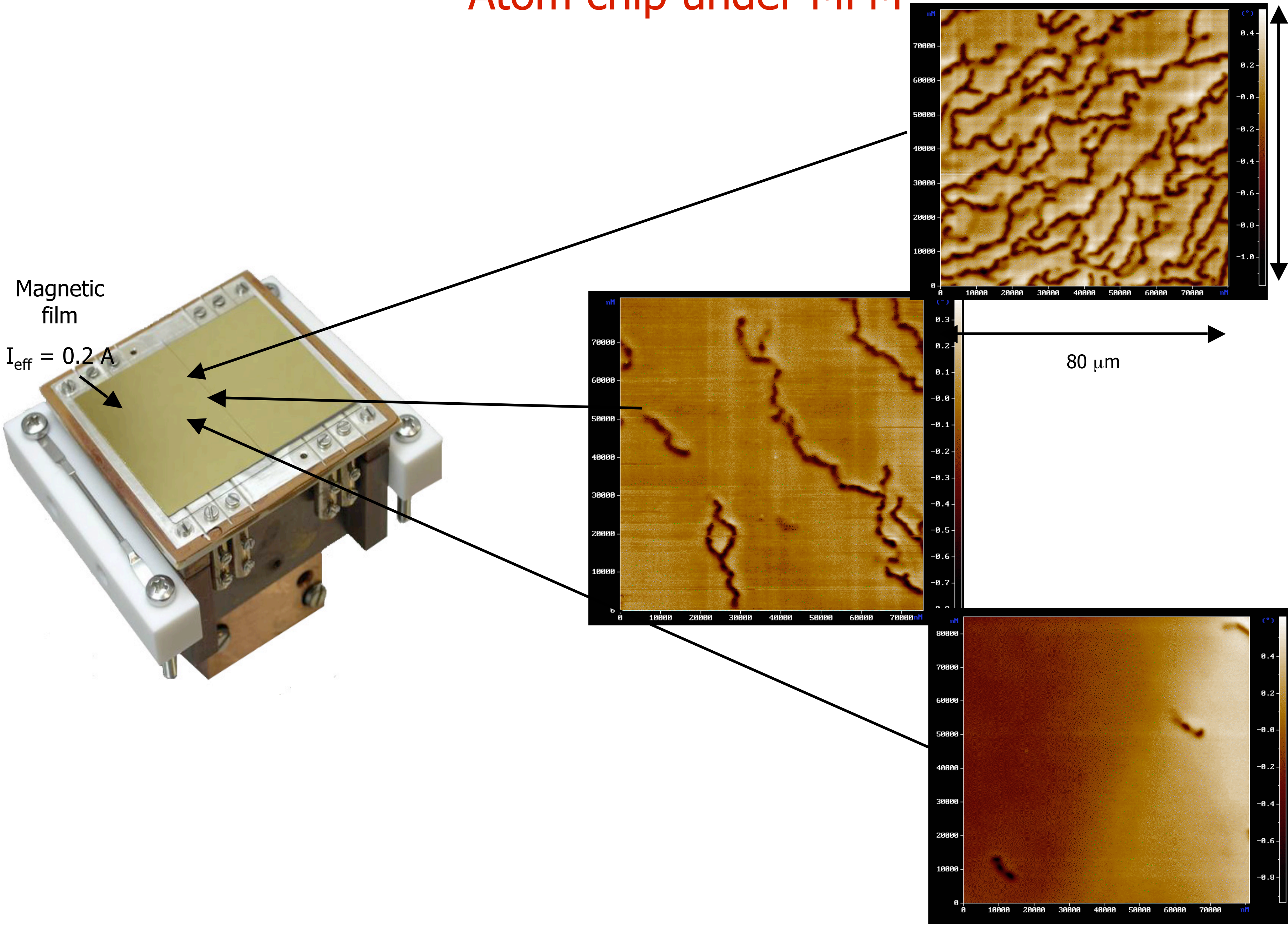
- Amplitude and structure is constant, day-to-day.
- RMS amplitude of corrugation scales as ~ $y^{-1.8\pm0.3}$
- Characteristic period for y>100 μm is ~ 390 μm
- For y<100 μm, higher spatial frequencies appear.



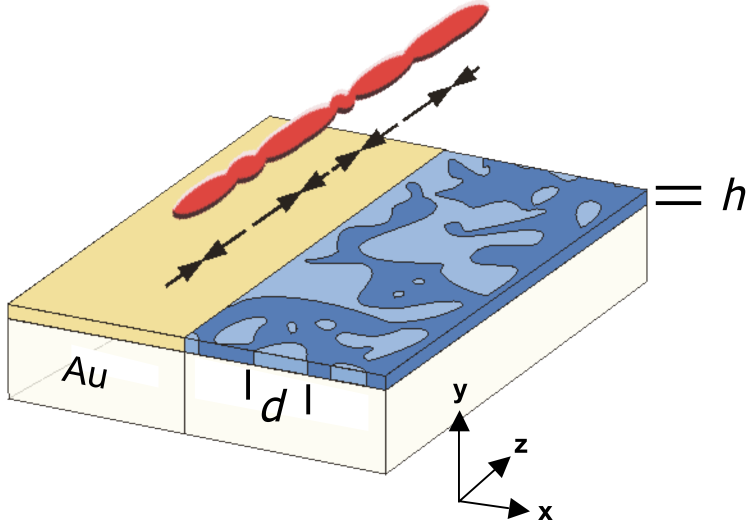
Source of disorder - inhomogeneity in magnetization



Atom chip under MFM



Model of random impurities in magnetization



Evaluate some integrals and obtain an expression for the magnetic field *rms* roughness

$$B_{z,rms} = \sqrt{\frac{3}{\pi}\frac{\mu_0 h \Delta M d}{16 y^2}\sqrt{1+\frac{15}{8}\alpha-\frac{5}{4}\alpha^3+\frac{3}{8}\alpha^5}},$$

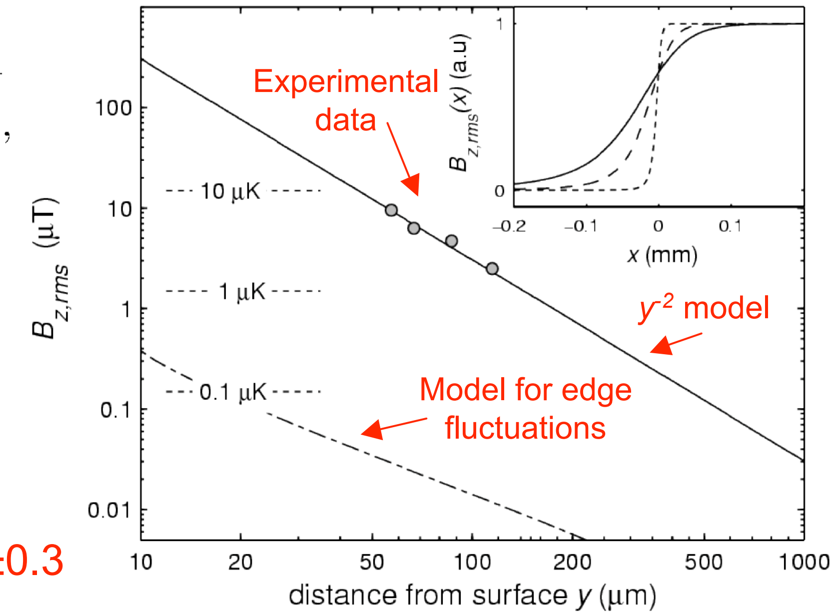
where $\alpha = x/\sqrt{x^2+y^2}$.
and $\Delta M^2 = \left\langle \left(M_y(x,y) - \sqrt{\langle M_y(x,y)^2\rangle}\right)^2 \right\rangle$

Find for x=0 (at the edge)

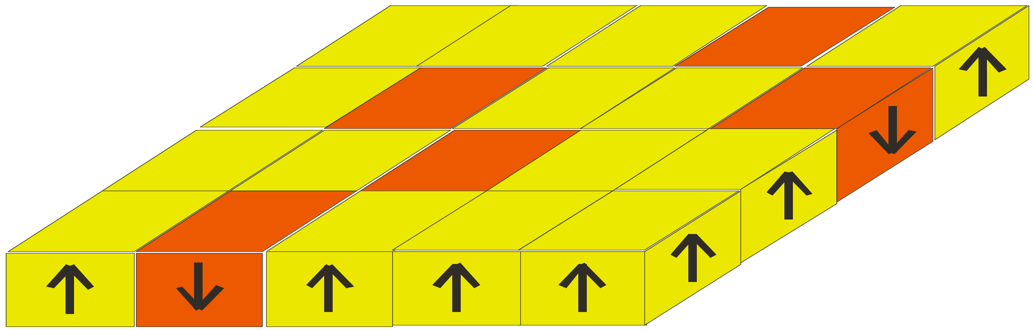
$$B_{z,rms} \propto y^{-2}$$

Experimental result $y^{-1.8\pm0.3}$

S. Whitlock et al, Phys. Rev. A **75**, 043602 (2007)



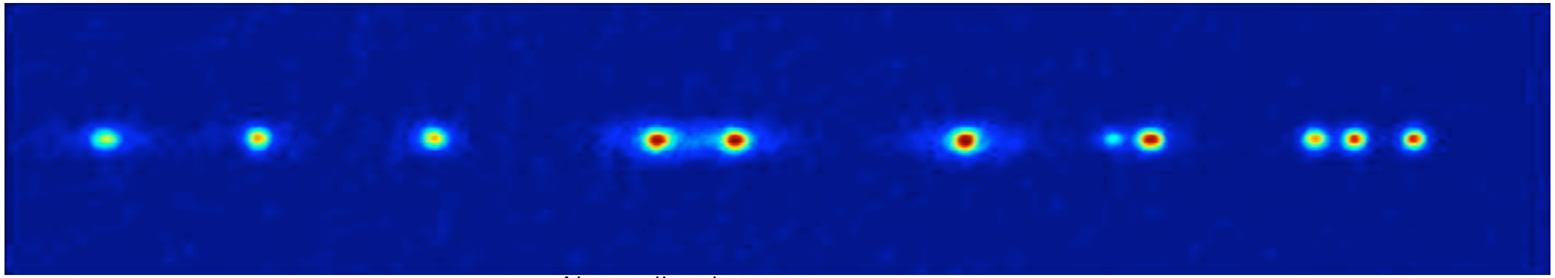
Flipped domains

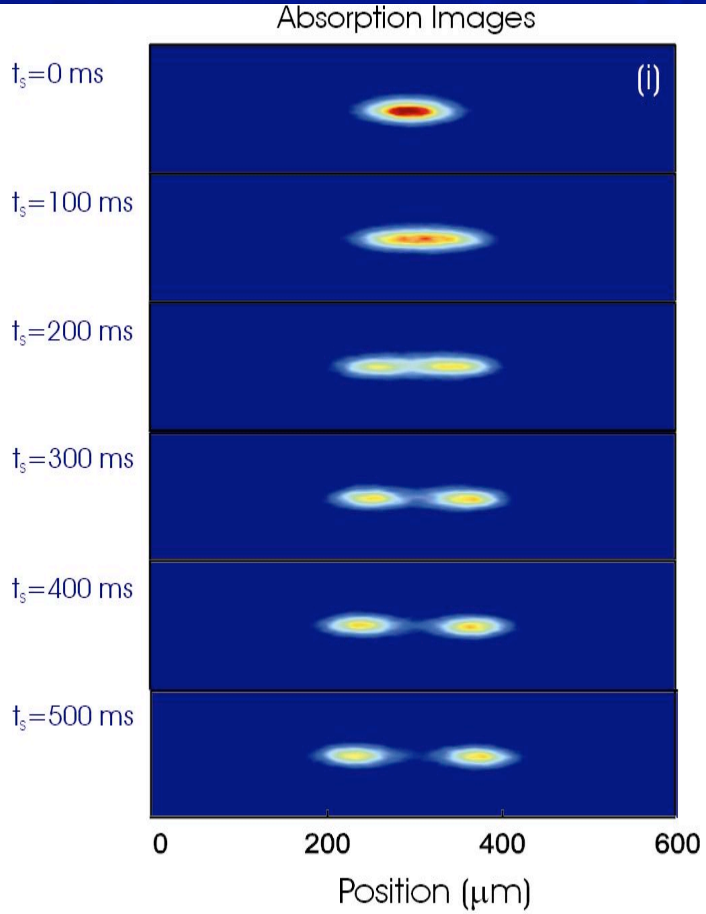


Fit implies the magnetisation inhomogeneity
$\Delta M/M_s \approx 0.35$

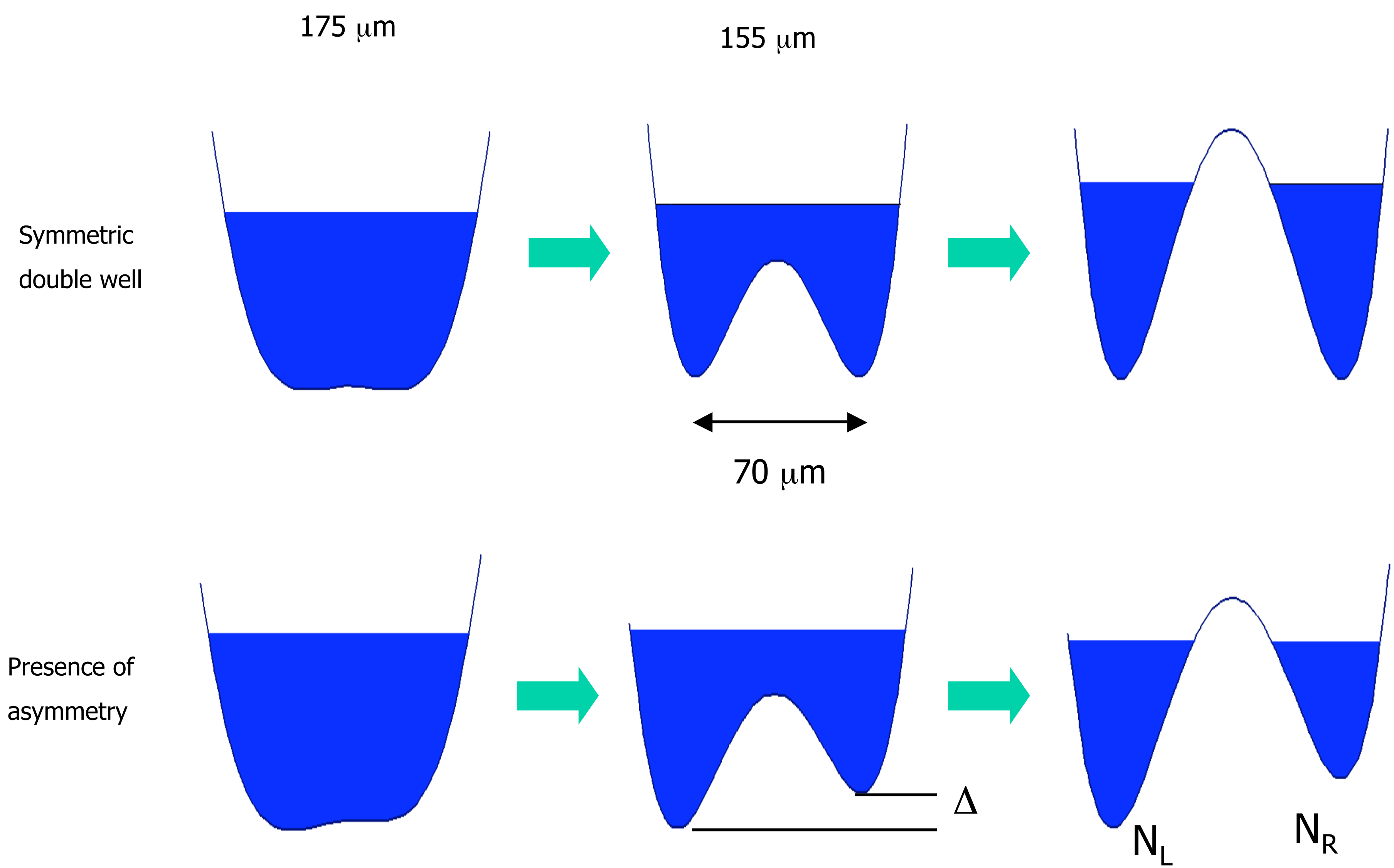
Inhomogeneity due to a small number of reversed domains, ***$\langle M \rangle \approx 0.9\, M_s$***

BEC in a double-well potential



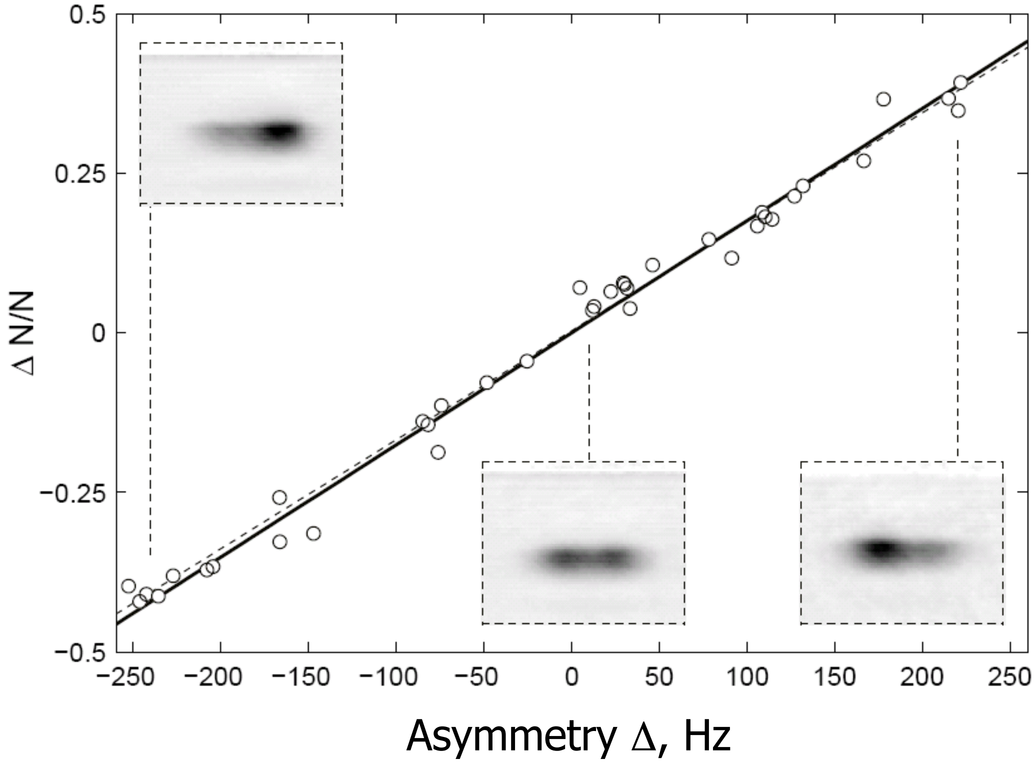


Splitting in a double-well potential



Sensitive sensor of asymmetry

$$\frac{\Delta N}{N} \sim \frac{\Delta}{N^{2/5}}$$



Single shot sensitivity:

16 Hz for 70 μm separation of DW

or 1.5 x 10^{-28} J/m of gradient potential

or $\delta g/g = 2 \times 10^{-4}$

B.V. Hall et al, Phys. Rev. Lett. **98**, 030402 (2007)

Summary

- Source of the disorder potential – inhomogeneity in magnetisation (deterioration during bake-out)

- Our model produced analytical expression consistent with observations

- Applied a double-well section of the disorder potential for sensitive measurements of gradient potentials