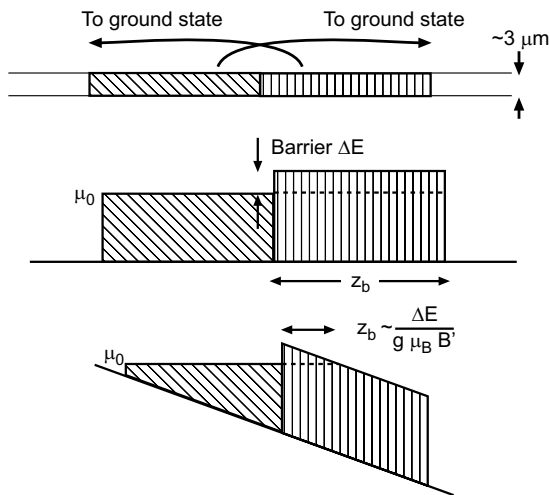


Quantum tunneling across spin domains in a Bose-Einstein condensate

The observation of metastable spin domains in optically trapped $F=1$ spinor Bose-Einstein condensates of sodium [1] raised the question of how thermal equilibrium would ultimately be achieved. Besides thermally activated processes we observed quantum tunneling as equilibration process. For the study of this process, spinor condensates were prepared which consisted of only two spin domains in the $m_F=0$ and $m_F=+1$ states. Those domains are immiscible due to their antiferromagnetic interaction. When a field gradient was added which made it energetically favorable for the two domains to change sides, quantum tunneling was observed. A mean-field description of the tunneling process was developed and agreed well with the measurements [2].

The analysis showed that the tunneling rates are a sensitive probe of the boundary between spin domains, and indicated an unpredicted spin structure in the boundary between spin domains which is prohibited in the bulk fluid.



Study of quantum tunneling in a two-component Bose-Einstein condensate. The $m_F=1$ and $m_F=0$ (vertical hatch) atoms form two immiscible spin domains (upper figure) because the $m_F=1$ atoms experience an energy barrier due to the repulsive mean field interaction (middle figure). When a longitudinal magnetic field gradient is applied, the effective potential for the $m_F=1$ atoms changes to the lower figure, and the spin domains can rearrange themselves by quantum tunneling through each other.

1. H.-J. Miesner, D.M. Stamper-Kurn, J. Stenger, S. Inouye, A.P. Chikkatur, and W. Ketterle, Phys. Rev. Lett. **82**, 2228 (1999).
2. D.M. Stamper-Kurn, H.-J. Miesner, A.P. Chikkatur, S. Inouye, J. Stenger, and W. Ketterle, Phys. Rev. Lett. **83**, 661 (1999).