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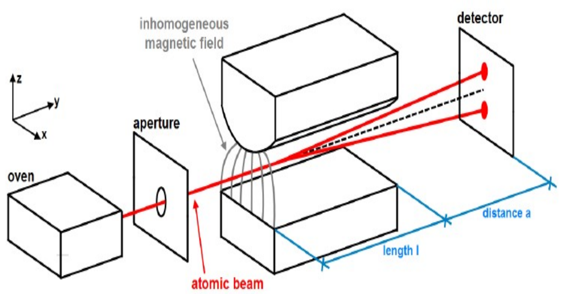
Stern-Gerlach Experiment

Abstract

In 1921 Otto Stern and Walther Gerlach performed an experiment in which they transmitted the beam of Silver atoms through an inhomogenous magnetic field. This was done in order to demonstrate the space quantization of atomic magnetic moments in the magnetic field. A heated oven is a source of an atomic beam of Potassium atoms (instead of Silver atoms used originally) that after collimation passes through the magnetic field. The propagation direction of the atoms is perpendicular to the gradient of the magnetic field. Deflected atoms are detected as two peaks symmetric to the atomic beam. This finding contradicts the classical prediction of a continuous spectrum and is in agreement with quantum mechanical predictions for a spin. The experiment allows determination of the magnetic moment of an atom.



The setup of the Stern-Gerlach experiment. The experiment includes a Potassium oven, a solid magnet with homogenous gradient along the path of the Potassium atoms and the detection system.

Background and Experiment

In the ground state each Potassium atom has one unpaired electron described by quantum number with only two possible values: 'Up' and 'Down'. Due to the interaction of atoms with the magnetic B field an energy splitting

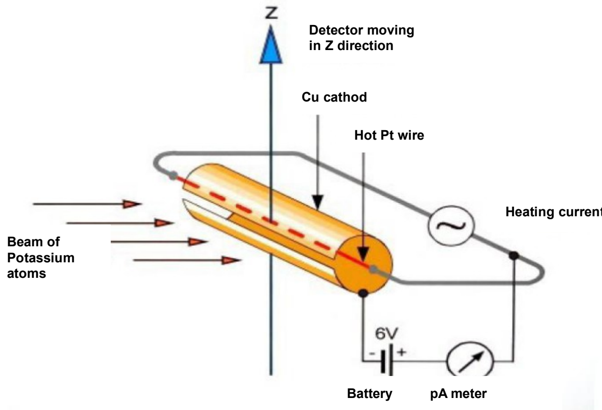
$$\Delta E = \pm \mu B$$

is predicted.

The force in the direction perpendicular to the atomic beam deflects atoms by

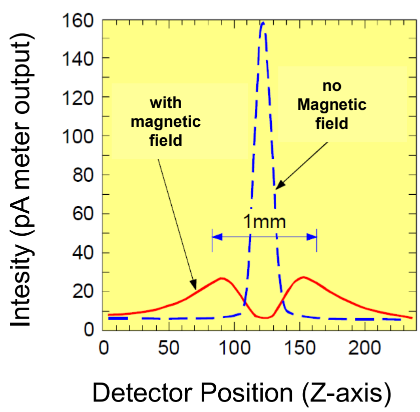
$$z_{max} = \frac{M_J g_J \mu_B}{6 k_B T} \cdot \frac{\partial B}{\partial z} \cdot l\left(\frac{l}{2} + a\right)$$

Based on the measurement of z_{max} the Bohr's magneton can be determined (μ_B).



The surface-ionization detector consists of a hot Platinum wire. The atoms are ionized on the surface and detected on the Cu-cathode. The detector can move along the Z-axis.

Parameters used:
- Potassium oven temperature: T=160ºC
- Length of magnetic pole: l=49 mm
- Distance pole-detector: a=121 mm
- Gradient of magnet I: 18.0 kG/cm
- Gradient of magnet II:19.3 kG/cm



Results

Without the magnetic field the beam of Potassium atoms passes unaffected and is detected as an intensity peak (blue). When the magnetic field is applied the beam is deflected and two peaks (red) are observed symmetrically to the beam line. The distance z_{max} that separates the peaks is close to 0.5 mm and is used to calculate Bohr's magneton. For example, a magnetic field with a gradient of 18.0 kG/cm results in a deflection z_{max}=(0.393±0.037) mm. The calculated Bohr magneton is (10.98±1.03) $\times 10^{-24}$ JT^{-1} (literature value 9.274×10^{-24} JT^{-1}).

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