An E-H gradient spectrometer

An *E-H* Gradient Spectrometer

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We shall in our remarks stress nuclear polarization though it will become evident that the instrument we will describe can be employed for electronic polarization and hence atomic beam magnetic resonance experiments as well. As is well known a beam of atoms is split into $(2I+1)$ $(2J+1)$ beams on passing through a magnetic field H with a gradient ∇H. The deflecting force is $\mu_{eff}\nabla H$ where μ_{eff}, the effective magnetic moment of the atom, is a function of H, the field in the particular region of the gap traversed by the beam. When $H < \Delta W/2\,\mu_0$ (ΔW is the zero field hyperfine splitting) and $J \neq 0$, atoms in different nuclear magnetic substates (m_I) have different effective moments of the order of a fraction of μ_0. Such an inhomogeneous field is therefore in principle a means of producing a polarized beam as has been pointed out by several speakers before me. In practice the two main difficulties are 1) the deflected beam has many times the width of the original beam due to the thermal velocity distribution, and 2) only narrow beams can be used since μ_{eff} is a function of H and H necessarily varies across the gap. These (and other) difficulties can be overcome by applying an electric field E across the magnetic polefaces which must of course be insulated from the magnet yoke. The electric field therefore has a gradient ∇E (proportional to ∇H) and exerts a deflecting force $\alpha E\nabla E$ on an atom with an atomic polarizability α. By satisfying the balance condition $\mu_{eff}(m_I)\nabla H = \alpha E\nabla E$ for any particular state m_I, a beam of atoms in that state suffers no deflection and hence no broadening on passing through the field. Moreover it can have finite width since the balance condition can be satisfied over a wide range of H by choosing an H for which μ_{eff} is nearly proportional to H.

The balance condition in the intermediate field region can be satisfied for most atoms (e. g. alkalis) with fields whose gradients are of the same order of magnitude commonly employed in atomic beam experiments (i. e. $\nabla H/H = \nabla E/E \approx 3\ \mathrm{cm}^{-1}$) with values of E below the breakdown field. For hydrogen whose polarizability is about fifty times less than that of alkalis the situation is unfortunately less favorable and it may be necessary to work in the low field region ($\mu_{eff} \approx 0.1\ \mu_0$) in order to satisfy

the balance condition with feasible E-fields and still retain a favorable geometry and the advantages offered by the E-H spectrometer. Although it has not been tried it seems likely that the resolution of such a system for hydrogen atoms can be greatly increased by running the hydrogen discharge at a low temperature.

An E–H gradient spectrometer has been built at New York University and is being used to measure α of alkalis [1]. Polarized beams with essentially the same width as that of the original beam width and their theoretical intensities have been obtained. This is illustrated in figure 1 where the beam profile of a K^{39} beam with and without deflecting fields

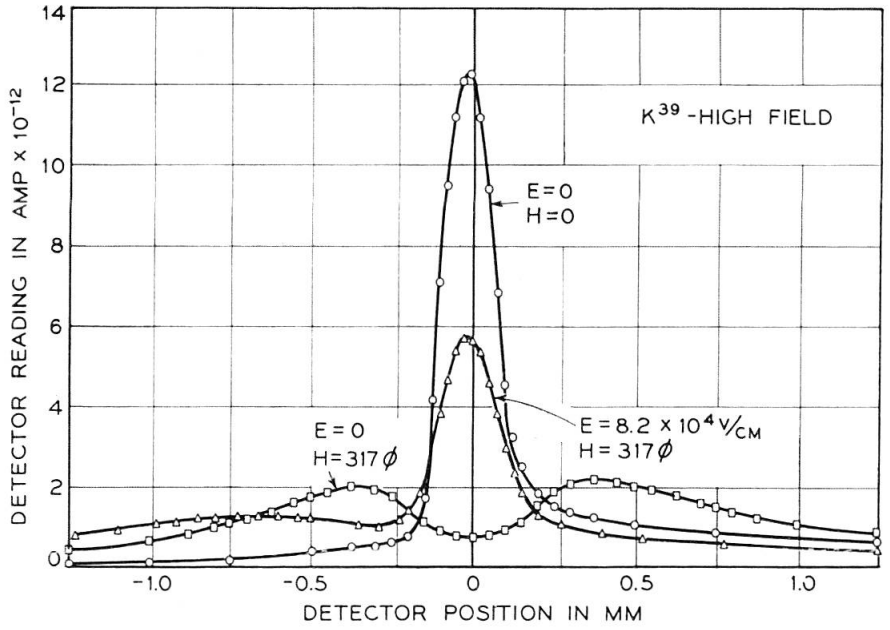

Figure 1

The beam profile of a K^{39} atomic beam at the detector position with and without applied E and H fields. $\nabla H/H = \nabla E/E = 2.6$ cm^{-1}. Note that the beam width with E and H applied is almost the same as the width of the unseparated beam $(E = H = 0)$.

is shown. Note that the H field by itself causes considerable broadening of the deflected beams but that the effect of the simultaneous application of the E and H fields is to re-establish the beam width of the undeflected beam.

We have confined our remarks to dipole fields but it can readily be seen that these ideas are applicable to higher multipole fields as well.

REFERENCE

[1] A. Salop, E. Pollack, B. Bederson, and J. Eisinger, Bull. Amer. Phys. Soc., June 15–17, (1960).