Experimental detection of discriminating magnetic charge response to light of various polarizations and polarization modulations

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ABSTRACT. The previously reported behavior of ferromagnetic aerosols in a magnetic field (Mikhailov, 1983-1993) is again investigated: under intense light conditions a large number of ferromagnetic aerosol particles move as if possessing magnetic charge. In the present investigations the particles show a discriminating response to various polarizations and polarization modulations of the light inducing the behavior, and an increase in activity under certain polarization conditions. The value and the sign of the increased apparent charge and activity is shown to be correlated with the degree of circular polarization and the polarization handedness (chirality) of the light, respectively. The phenomena reported are novel and are not exhibited by conventional magnetic dipoles.

RÉSUMÉ. Le comportement précédemment mentionné des aérosols ferromagnétiques dans un champ magnétique (Mikhailov, 1983-1993), est à nouveau examiné: en éclairement intense un grand nombre de particules d'aérosol ferromagnétique se déplacent comme si elles possédaient une charge magnétique. Dans le présent travail les particules montrent une réponse spécifique à différentes polarisations de la lumière, et un accroissement d'activité sous certains conditions de polarisation. On montre que la valeur et le signe de la charge apparente et de l'activité sont corrélés respectivement avec le degré de polarisation circulaire et la chiralité de la lumière. Les phénomènes rapportés sont nouveaux et n'ont pas lieu avec les monopoles magnétiques habituels.

1 Introduction

This work continues an extensive series of experiments which have established the existence of an apparent magnetic charge effect (MCE)[1] in ferromagnetic aerosols (Mikhailov, 1983-1993). The present experiments were undertaken in response to Barrett's theoretical investigations of electromagnetic phenomena due to fields the underlying algebraic logic of which obeys symmetries higher than the conventional U(1) symmetry, i.e. higher symmetry fields than those of "Maxwell's theory" or U(1) theory (Barrett, 1989-1993).

Barrett's theory applied to MCE provides an explanation of the apparent appearance of a magnetic charge in ferromagnetic particles. Furthermore, an analysis of the phenomenon from this group theory point of view results in some experimentally testable consequences (Barrett, 1992, 1993).

According to this group theory treatment of radiation-matter interaction by Barrett:
(i) Magnetic monopoles exist in SU(2) symmetry algebraic fields, but not U(1) symmetry fields. There can be positive and negative magnetic charge in SU(2) symmetry fields, but not in U(1) symmetry fields.
(ii) Aerosol particles filled with ferromagnetic solution behave as if their field description is of SU(2) symmetry form, because of the spherical boundary (cavity) conditions, and the large spin exchange coupling offered by the ferromagnetic compounds in solution. The aerosol particle's spherical boundary conditions (SBC) and the spin exchange coupling (SEC) provide the conditions for SU(2) symmetry forms because the resulting compactification of degrees of freedom (i.e. higher transformation symmetry) offers a lower energy state. This compactification of degrees of freedom into SU(2) group symmetries results in particle behavior of a "pseudo" monopole or instanton.
(iii) The result or direction of the interaction between such a particle constrained by SBC and SEC and light is dependent on the polarization handedness (chirality) of the light.

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[1] Previous experiments (Mikhailov, 1983-1993) established that under intense light beam illumination ferromagnetic particles (with diameter $10^{-5}-10^{-6}$ cm) move in a magnetic field along the lines of force (i.e. along coaxial trajectories with respect to the line current). Reversal of the magnetic field, H, causes a reversal of particle motion. An increase in magnetic field strength or light intensity causes a rise in particle velocity, while a decrease results in reduced particle velocity. A reduction below a certain level causes the particles finally to stop moving. This particles thus exhibit magnetic monopole-like behavior and as if they carried a magnetic charge. The value of the apparent magnetic charge calculated from these experiments is $g = e\alpha^{\pm 1}$, where α is the fine structure constant and e is the electric charge.

The existence SBC and SEC conditions in ferromagnetic aerosol particles also provide the conditions for degrees of freedom compactification in the field description of particle behavior, resulting in a substitution of SU(2) for U(1) symmetries in the group rules describing the particle's behavior with respect to external field influences. Therefore, Barrett offered the following predictions. (For ease of referral, a ferromagnetic aerosol particle with SBC and SEC and exhibiting MCE behavior will be referred to as an SU(2) aerosol particle):
A) SU(2) particles irradiated with *linearly polarized* (LP, U(1) symmetry) light will result in no increase in movement of the particles over that detected in the previous series of studies (Mikhailov, 1983-1993). The resulting condition can be referred to as the pseudo-magnetic monopole's *ground state.*
B) SU(2) particles irradiated with *circularly polarized* (CP, U(1) symmetry) light will result in increased movemenet of the particles over that detected in the previous series of studies. The resulting condition can be referred to as the pseudo-magnetic monopole's *excited state.*

In other words, in case [B] the aerosol particles will be attracted or repelled by the external magnetic field more strongly than in case [A]. The prediction is that the effective magnetic charge in case [B] will be larger than in case [A]. These assertions were tested in the present experimental investigations.

2 Experiments

The experiments can be described succinctly as velocity measurements on particles weighted in a gas medium. The experimental procedure and the apparatus - the prototype of which is the well-known Millikan's apparatus originally designed for measuring electron charge and adapted for the present purposes - have been described extensively in earlier publications (cf. Mikhailov, 1983, 1987).

The LP light source was a single-mode laser ($\lambda = 4400$Å, 25 mW) and the aerosols were generated by an electric spark source with iron contacts. The motion of the submicron size (10^{-5}–10^{-6} cm) ferromagnetic particles generated were observed in an homogeneous magnetic field (a Helmholtz coil). The light polarization was changed by conventional methods using a double refraction quarter-wave plate, e.g. for $\phi = n\pi/2$, the light is LP, and for $\phi = (2n+1)\pi/4$ the light is CP, where ϕ is the angle between the polarization axis of the light beam and the optical axis of the quarter-wave plate (Fig 1). Either a double refraction tense rectangular acryclic plastic prism or a mica plate were used as quarter-wave plates in the experiment, and these were changed to test for artifacts.

A quarter-wave plate block permitted both a constant ϕ polarization condition as well as a $d\phi/dt$ continuous polarization modulation (PM) condition. In the case of the latter, polarization modulated light at modulation frequencies up to 200 Hz was obtained. As in previous experiments, the light beam intensity was monitored continuously by a photomultiplier tube.

Previous experiments showed that these particles move in a viscous medium according to Stokes'law with velocity:

$$\tilde{\nu} = \frac{GH}{K} \tag{1}$$

where G is the magnetic charge of the particle, H is the magnetic field strength, K is Stokes'coefficient ($K = 6\pi\eta r$, where η is the viscosity and r is the particle radius).

The average value of the particle'ensemble velocity is:

$$\tilde{\nu} = \frac{1}{n} H \sum_{i}^{n} \frac{G_i}{K_i} \tag{2}$$

Because G_i and K_i are independent random variables, Eq. (2) simplifies to:

$$\tilde{\nu} = \frac{\tilde{G}H}{\tilde{K}} \tag{3}$$

where G' and K' are magnetic charge and Stokes'coefficient, respectively, both ensemble averaged.

Therefore, for the two types of constant polarization (LP and CP):

$$\frac{\tilde{\nu}_{CP}}{\tilde{\nu}_{LP}} = \frac{\tilde{G}_{CP}}{\tilde{G}_{LP}} \tag{4}$$

During the present experiment, the tracks of about 1500 particles were photographed and processed. The average values of particle velocities obtained with LP irradiation ($\tilde{\nu}_{LP}$) and with CP irradation ($\tilde{\nu}_{CP}$) were:

$$\begin{aligned} \tilde{\nu}_{LP} &= (18.00 \pm 0.6) \cdot 10^{-2}\text{cm/s} \\ \tilde{\nu}_{CP} &= (25.50 \pm 0.6) \cdot 10^{-2}\text{cm/s} \end{aligned} \tag{5}$$

whence it follows that:

$$\frac{\tilde{\nu}_{CP}}{\tilde{\nu}_{LP}} = \frac{\tilde{G}_{CP}}{\tilde{G}_{LP}} = 1.42 \pm 0.08. \tag{6}$$

The absolute numerical values of $\tilde{\nu}_{LP}$ and $\tilde{\nu}_{CP}$ in this case have no particular meaning, because particle velocity is a function of the magnetic field strength, H, and the light beam intensity, Φ, (Mikhailov, 1983, 1987, 1990)[2], but the ratio value, $\tilde{\nu}_{CP}/\tilde{\nu}_{LP}$, indicates uniquely that the effect exists as predicted by Barrett.

In order to exclude the possibility of systematic error, multiple periodic changes were made between the LP and CP conditions, the quarter-wave plate was changed from a mica-type to a plastic-type, and new adjustments were made to the apparatus with every experimental run. No systematic error was detected.

In a second experiment, a new interesting effect was discovered using polarization modulauted (PM) light. With the magnetic field strength, $\vec{H}$, constant, the polarization modulation frequency of the light at several Hertz, and with the particles moving either in the same direction or in the opposite direction to $\vec{H}$, particles were observed to oscillate about an equilibrium point. The velocity of the observed particle oscillation is parallel to the direction of $\vec{H}$ and the velocity of the oscillation is equal to the polarization modulation frequency. However, an *increase* in the rotation frequency of the quarter-wave plate beyond about 10-20 Hz results in a *decrease* in the oscillation amplitude of the particles, with the particles ceasing to oscillate at even higher frequencies of polarization modulation. If the modulation is at a low frequency, e.g., 10 Hz or below, the particles oscillate. If then the modulation is stopped, the particles'oscillation ceases. If the modulation is commenced again, the particles again begin oscillating again, etc.

The polarization modulated light induced oscillation effect was examined using an external homogeneous electric field, instead of a magnetic field, but no effect was seen. The effect is observed only with an external magnetic field.

A possible explanation for the observed oscillation effect may be examined as a consequence of the periodic alteration of the sign of the induced apparent magnetic charge of the particles in synchrony with the

[2] In this particular experiment, $H = 12$ Gauss and $= 40$ W/cm2.

polarization modulation frequency of the light. An analysis of the inducing polarization modulated wave into a series of identical polarizations but of opposite signs indicates this. For example, consider a phase retardation of $\phi = \pi/4$, which results in a CP wave with the vector, $\vec{E}$, having an anticlockwise rotation (contrarotating (+)); then consider a phase retardation of $\phi = 3\pi/4$, which results in a CP wave with the vector, $\vec{E}$, having a clockwise rotation (corotating (-)), etc, etc, where ϕ is the instantaneous value of the angle between the polarization plane of the laser light and the optical axis of the quarter-wave plate (Fig. 1). Therefore a correlation between the sign of an apparent induced magnetic charge of a particle and the sign of the handedness (chirality) of the CP wave is apparent (note, the spontaneous magnetic charge exchange observed earlier (Mikhailov, 1987). This interpretation is preliminary and might be revised after further experimentation. Nevertheless, the phenomena reported are novel and are not exhibited by conventional magnetic dipoles.

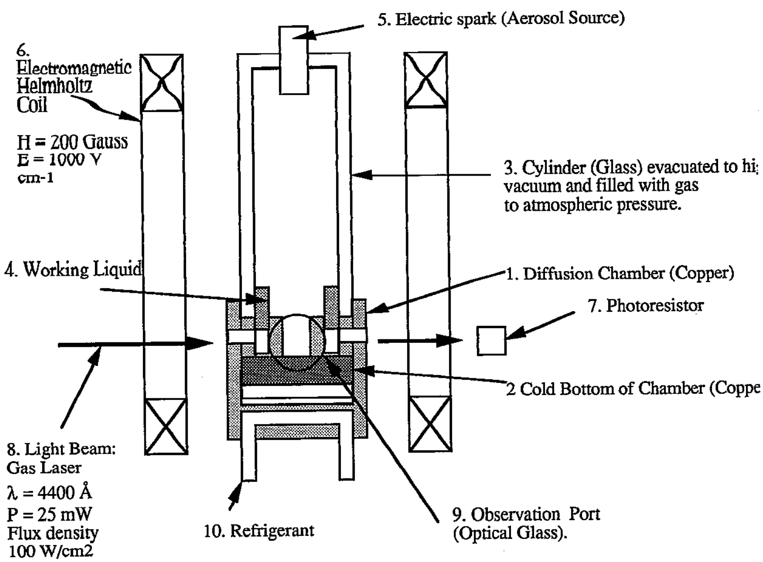

Figure 1. Scheme of the experiment with polarization modulated light beam. 1) is a He-Cd laser; 2) is a double-refracted quarter-wave plate (e-e: optical axis); $\vec{E}$ is the electrical vector of the laser light beam, Φ. $\vec{H}$ is the magnetic field intensity, *amd* are the instantaneous velocity values of the same particle for the two light polarization conditions: $\phi = \pi/4$ and $\phi = 3\pi/4\dot{\lambda} = 4400$Å.

3 Conclusion

1) A discriminating effect induced by circular versus linear polarization light predicted by Barrett's group theory approach to higher symmetry field forms of electromagnetism has been confirmed by experiment.

2) An effect induced by the chirality, or handedness, of polarization modulated light has also been discovered.

3) The experimental results reported here are further confirmation of our discovery of magnetic monopole behavior in ferromagnetic aerosol particles.

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References

[1] Barrett T.W., *Annales de la Fondation Louis de Broglie*, 14, 37-75, 1989
[2] Barrett T.W., *Annales de la Fondation Louis de Broglie*, 15, 143-183
[3] Barrett T.W., *Annales de la Fondation Louis de Broglie*, 15, 253-283, 1990
[4] Barrett T.W., *Annales de la Fondation Louis de Broglie*, 16, 23-41, 1991
[5] Barrett T.W., In *Essays on the Formal Aspects of Electromagnetic Theory*, A. Lakhtakia (Ed), World Scientific Publishing, Singapore, in press, 1993
[6] Barrett T.W., *The Ehrenhaft-Mikhailov effect described as the behavior of a low energy density magnetic monopole-instanton*, *Annales de la Fondation Louis de Broglie*, in press, 1993
[7] Mikhailov, V.F., *Phys. Lett.*, 130 B, 33, 1983
[8] Mikhailov, V.F., *J. Phys. A; Math. Gen.*, 18, 903-906, 1985
[9] Mikhailov, V.F., *Annales de la Fondation Louis de Broglie*, 12, 491-523, 1987
[10] Mikhailov, V.F., *J. Phys. A; Math. Gen.*, 24, 53-57, 1991
[11] Mikhailov, V.F., *J. Phys.: Condensed Matter*, 5, 351-360, 1993
[12] Mikhailov, V.F. et Ruzicka, J., *Acta Physica Univ Comen*, Bratislava, 97-148, 1989
[13] Mikhailov, V.F. et Mikhailova, L.I., *J. Phys. A; Math. Gen.*, 23, 53-57, 1990

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