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On The Experiment of Magnetic Monopoles in a Current Carrying Coil

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Abstract

There are theoretical predictions that when a current going through a coil, there are two magnetic poles appeared at both ends. They are very much like a permanent magnet with two poles. We would like to report the measurements of these two poles directly. It was found that they have incredibly special and unique physical properties. Details of this experiment and results about these two poles will be presented.

Keywords: Magnetic monopoles, Current carrying solenoid, Magnetic dipole, Magnetic charges.

1. INTRODUCTION

One of the basic properties of magnetism is that a magnet always has two poles, north and south, which cannot be separated into isolated poles. However, there are strong theoretical reasons why they should exist, and there are new experiments to prove it.

Dirac's idea (1931) [1] of possible existence of the magnetic monopoles (MMs for short) and quantization of the magnetic flux led to more theoretical and experimental work in recent years. The most extensive experiments are on the so called 'spin ice” at low temperatures [2]. However, their work are not a direct probe of MMs and rely on the theoretical interpretations of the results. We have measured the magnetic clusters (MC's for short) in magnetic materials recently [3,4] and showed that the isolated magnetic charges do exist.

It is a common knowledge that one can produce magnetic field inside a coil by a direct current [5]. And it behaves very much like a permanent magnet, with two poles of opposite sign at each end. Furthermore, in a paper by Kitano [6], using simple electromagnetic theory, he predicted that there are two monopoles of opposite sign in a current carrying solenoid (CCS for short), one at each end. Similarly, Chen [7] also suggested the same thing with a different approach nearly 40 years earlier. Referring to our earlier paper [3], we now know that there were two MMs of opposite signs in all permanent magnets.

It is interesting to point out that in papers by t' Hooft [8] and Polyakov [9], they used unified field theory, predicted that there must exist a point like particle MM with a lump of energy which gives a number just twice that of what Dirac [1] predicted.

In the present work the magnetic poles at the ends of a CCS were measured in detail in order to compared with that of the permanent magnet. The new poles were found to be quite different from that of the permanent magnet in many ways. These poles are point like magnetic charges in the air (or empty space) near the ends of the coil and can be located with a compass or a Gauss-meter. They are macroscopic entities of collections large number of magnetic monopoles. Our measurements allow for both an estimate of the magnetic flux and the interactions between different probes. The details of the new findings will be given in this paper.

NOTE: It is important to define the term 'Single Magnetic Charge' (i.e. Monopoles or MM's) and 'Magnetic clusters' (MC's for short) which is a collections of MM's. The use of these terms has important differences for of all the experimental results so far being published on these subjects. It is understood that MM's are microscopic particles, and MC's are mostly macroscopic entities. (For example, in our earlier papers [3,4], all the MM's should be MC's instead)

2. EXPERIMENTAL METHODS

2.1. Measurements were made with several different size and shape samples of coils, mainly using copper and iron wires. The coils are connected with a DC power supply of five volts. Though higher voltages were also used. However, we will only discuss about the measurements of five volts and 1-2 amps of current in this paper.

A compass and a Gauss meter (Model TD 8620 by Tunkia) were used to locate the MCs of the coil. The magnetic field directions and the intensity near the MCs at the ends of the coil can be measured in detail. The three-dimensional feature of these MCs can also be studied with a small sensor coil connected to an oscilloscope. Video cameras were used to record the events, especially when performing the interactions of the CCS with other probes which will be discussed in sections 2.2 and 2.3 below.

One of the best and frequently used probe is a small coil made of iron wire (size #16 AWG) with a coil diameter of one mm, and about one cm long. This sensor has the advantage of being small in size when used in and around the MC’s of the sample coil. Since this small sensor coil has an axis of its own, it can offer a variety of measurements by orienting the direction of its axis with respect to the directions of the flux lines of a MC.

It should be noted here that the MCs in a CCS are invisible entities in free space, we only know they were approximately located near the ends of the coil. (See figure 1).

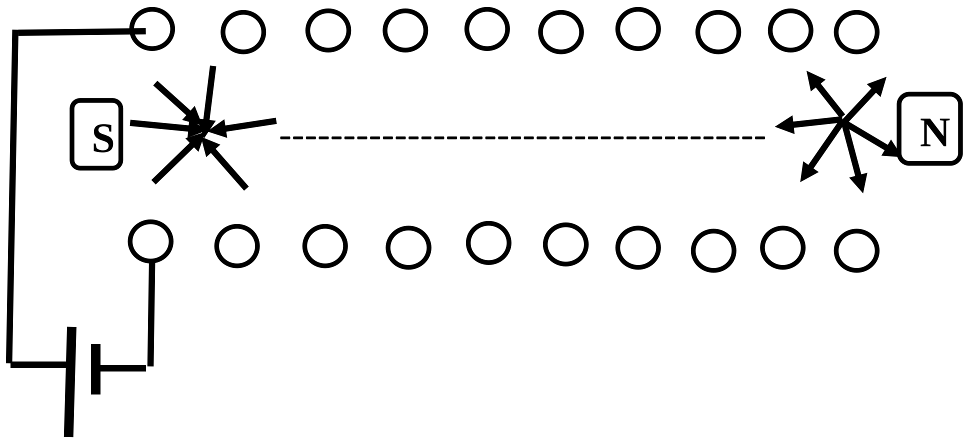

Figure 1. Two magnetic clusters, one on each end of a current carrying solenoid.

The magnetic field lines are not showing outside of the coil here (to avoid too many lines in the drawing).

2.2. The interactions of the CCS and MCs with different probes.

There are mainly two different kinds of experiments performed here: one is moving a probe (e.g. a magnetic material or a bar permanent magnet) with respect to the MCs; the other is to move the sensor across the whole sample while the probe is fixed in position. The changes of signals from the sensor (with respect to the position of the probe) to the oscilloscope can be recorded accordingly with two video cameras.

The change in frequency or period between the receiving pulses are related directly to the changes of magnetic field near the MCs of the empty coils.

The typical change of frequency due to an iron book binder (dimension: 18cm x0.6cm x0.030cm, 3.68 gm in weight, and of approximate 12 G) put into a CCS of 30 turns (dimension: 2.0 cm long and 1.5x1.5 cm^2 in cross sectional area) is approximately 4.87 kHz from a resonant frequency of 26.3 kHz.

One can assume that the CCS as a cavity with both ends made of magnetic charged walls. Therefore, any changes of the magnetic field in the cavity due to the other materials will change the magnetic state of the walls (and so are the inductance and the capacitance of the coil), which in turn cause changes in the frequencies and amplitude of the signals received by the sensor.

The other interesting result is the heat up and the change in the magnetic behavior of the probe. For example, an iron bar or nail can be magnetized by one of the MC's after it was inserted in a CCS which is described in any physics textbook [5]. The surprising part is that the iron bar was made with only one magnetic pole while the other end of the bar has no change. Some sample with only single magnetic poles were made this way [4]. This is quite different from the magnetization of the same sample by a permanent magnet (where both ends were magnetized).

It should be noted that the magnetic history is important for the single MC to be made in the samples. The memory effect can drastically affect the outcome.

2.3. The onset energy of MCs in an empty coil:

It is important to know what sort of energy is used to form a set of MCs in a CCS. It may vary with the coil configurations, the number of turns and the geometric size. The electric energy can be measured from the minimum power required when the MCs were generated. The onset of the movement of a compass needle or the first appearance of a reading of the Gauss meter near the end of coil indicated that MCs were created. For the coil mentioned in section 2.2 above, the onset readings of MC's are 0.5 V and 1.27A of current which gives a power of 0.63 watts. The MC's so produced have about 9 G (which gives an estimated number of about $5\text{x}10^{7}$ unit of magnetic flux, using the formula of Errede [10]) at each end. On the other hand, using the Ampere's law (namely $B=\mu_0$ nI/l, where $\mu_0 = 4\pi$ x 10^{-7} Tm/A, n=number of loops /unit length, I is current in A, and l is the length of the coil) which gives a magnetic field of 42.5 G inside the coil. There is a factor of two difference, if we assume all the energy were applied to the two MC's. Therefore, it may take half the electrical energy to produce the rest of the magnetic field along the CCS. Further measurements should be done to understand this point.

3. RESULTS AND DISCUSSIONS

3.1. General discussion

It is well known that a current in a coil will generate magnetic field within the coil [5]. However, the observation of two MC’s is new. They do confirm the predictions of Chen [7] and Kitano [6].

Furthermore, as the findings in our experiments in section 2, the current carrying coil can magnetizing a sample which was put near the MCs. It can generate a new MC and heat (increased the end about 3 deg C for our sample described in section 2) at the same time. This transfer of magnetic charges and energy is like a torch which can light up another one getting close to it. This is an example of a large energy concentrated at the center of the MC very much like what t Hooft [8] and Polyakov[9] have proposed. (Except the very large number of magnetic charges involved here). It is remarkable that they have predicted MCs this way from a quite different physical concept.

3.2. The heating effect near the MCs may be due to the regular induction heating by the DC current. The high thermal conduction of the materials in question may make it difficult for an accurate reading near the exact location of MCs.

3.3. From the onset of the MC's energy, the amount of power to produce one single magnetic flux unit was estimated approximately 10^{-8} W (which is very large for an elementary particle). But to find out about the quantization of the magnetic particles, one may need further research with different method and much smaller sample.

3.4. The changes in the signals with different probes may provide different information for the MC's as well as the probes themselves. The shape and size of the changing pulses depended very much on the physical properties of the probes. Further research in this area will give more insight of this issue.

4. CONCLUSIONS

4.1. The observation of two magnetic clusters (MC's) in a current carrying coil were made. Some details of their special physical characteristics were presented here for the first time. The theoretical predictions of Kitano [6] and Chen [7] were confirmed experimentally.

4.2 The magnetic clusters were closely related to what t'Hooft [8] and Polyakov [9] described as magnetic monopoles. They are point like magnetic charges with a lot of energy concentrated there. The difference between their theory (microscopic view) and our experiment (macroscopic) is the numbers of MM's involved.

4.3. Further study with other probes is necessary to provide more information about these invisible entities. Such as neutrons, photons, ultrasound or even SQIUD would shed more light for these most interesting magnetic particles.

4.4. It is interesting to note that the mechanical momentum of a CCS may be related to so-called 'hidden momentum' [11]. Whether they are involved in the measurements of the present paper is not clear so far. Further measurements should be done in order to clear this interesting issue.

4.5. There are small quantum mechanical inductors being investigated [12] recently. They might have MC's there also. Further research should be done to find out this interesting possibility.

4.6. It is suggested that the current carrying solenoid made of a superconducting wire should be done to find out the MC's there, if any. This has important consequences in that the magnetic field may not be as uniformed as one believed to be. This may affect the superconducting magnet in the widely used medical devices, such as in MRI coils. Further research should clear this important issue.

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REFERENCES

[1] Dirac, P. (1931) “Quantized singularities in the electromagnetic field”. *Proc. Roy. Soc.* (London) **A 133**, 60

[2] Castelnovo, C.; Moessner, R.; Sondhi, S. L. (2008) 'Magnetic monopoles in spin ice'. *Nature*. 451: 42–45. arXiv:0710.5515

[3] David Y. Chung (2017) “The experimental evidence on direct measurements of Magnetic monopoles in magnetic materials at room temperatures”, Int. J. of Pure and Applied Physics, Vol. 13, No.1, pp.143-154.

[4] David Y. Chung (2018) “On the making and testing of magnetic monopole samples at room temperatures”, Int. J. of Pure and App. Phys. Vol 14, no. 2, pp.87-92.

[5] Giancoli, D.C. (2000) *PHYSICS FOR SCIENTISTS AND ENGINEERS*, (Third Edition) “Magnetic field of a solenoid”. Prentice Hall, Upper Saddle River, N.J. ISBN 0-13-029096-3, p. 723, Fig. 28-22:

[6] Kitano, M .(2006) “Derivation of magnetic coulomb's law for thin, semi-infinite solenoids” arXiv: physics/0611.0900v1.

[7] Chen, H.S.C. (1965) “Note on the magnetic poles” Am. J. Phys. 33, p.563.

[8] t' Hooft, G. (1974) “Magnetic Monopoles in Unified Gauge theories” Nucl. Phys. B79, pp.276-284.

[9] Polyakov A.M. (1974) “Particle spectrum in the Quantum field theory”, JETP Lett. 20, pp.194-195.

[10] Errede S. (2007) UIUC Physics 435, E.M. Fields and Science 1. Lecture Notes 18.

[11] Vaidman, L. (1990) “Torque and force on a magnetic dipole”. Am. J. Phys. 58 (10), 978.
Griffiths, D.J. (1992) “Dipole at rest”, Am. J. Phys. 60 (11), 979.

[12] Omoyuki, Y. (2020) “Emergent electromagnetic induction in a helical-spin magnet”, Nature, 586, 232-236.