The Quantum Structure of a Dynamic Magnetic Field

Fayang Qiu*

Laboratory of Molecular Engineering, and Laboratory of Natural Product Synthesis, Guangzhou Institute of Biomedicine and Health, The Chinese Academy of Sciences, The Science Park of Guangzhou, 510663, PR CHINA

Email: qiu_fayang@gibh.ac.cn

Abstract The structure of the dynamic magnetic field generated from a pair of rotating magnetic poles is probed through the visualization of the motion of a magnetic needle along a single plane. The quantum transition of the motion and the quantum change of the rotation of the magnetic needle have been observed in this macroscopic system.

Introduction

The structure of the dynamic electric field is extremely important in physics. In a classic paper, Tsien[1] derived the exact parametric equations to describe the electric lines of force of a point charge moving at relativistic velocities along a single plane of motion and to create the pictures of the electric field via the visualization of the electric lines of force. The movement of the point charge is associated with relativistic synchrotron radiation, which tends to bunch into a spiral pattern with sharp kinks. Therefore, the trace of the movement of the point charge to the center of the plane is a spiral line. However, if we can test these predictions through a properly designed experiment, we will be more confident about the structure of the dynamic electric field.

Since a point charge is invisible, it is difficult to visualize its motion in a dynamic electric field. Therefore, it is difficult to confirm the structure of the predicted dynamic electric field. However, it is well known that a magnetic field and an electric field are closely related and are interconvertible under certain conditions. Thus, the visualization of the structure of a dynamic magnetic field may provide useful information about the dynamic electric field. Since a magnetic needle is polarized and it is visible through the naked eyes, the structure of a dynamic magnetic field can be visualized through the observation of the motion of a magnetic needle in the dynamic magnetic field.

When some iron particles are placed onto the plane on top of a magnetic bar, the iron particles form small magnetic needles and they aggregate along the magnetic force lines. What will happen to those magnetic needles if they are placed onto a rotating magnetic field? Herein we report the results of such an experiment.

Experimental

A magnetic stirrer is an instrument that is composed of one pair of magnetic poles driven by an electric motor. The magnetic poles are placed under a thin smooth porcelain (non-ferromagnetic) plate. To make the observation clear and simple, we have just placed a small amount of iron powder on the side away from the center of the plate. When the power is turned on, the speed of the motor is adjusted and the structure of the dynamic magnetic field rotating clockwise is visualized through the motion of the magnetic needles:

1. The small magnetic needles start to move forward through counter clockwise on-plane rotation and then shift to the first orbit, e.g., orbit 1 in **Figure 1**. The motion of each needle along the orbits is in the direction **opposite** to that of the rotation of the magnetic poles. For example, if the magnetic poles are rotating clockwise, then, each of the magnetic needles will both rotate and linearly move forward counter clockwise along the line of the orbit.

2. When the rotation of the motor is set at a certain speed, the rotation frequency of each individual needle is the same in the same orbit. However, the rotation frequency increases as the distance from the center of the plate decreases, i.e., a magnetic needle rotates faster in orbit 2 than in orbit 1 and fastest in the center of the plate (orbit 3). In other words, the linear speed of a needle increases as it moves from orbit 1 to orbit 2.

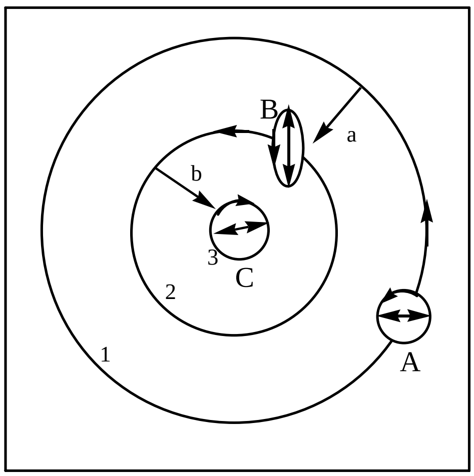

Figure 1 The observed motion of a magnetic needle in a magnetic field rotating clockwise.

A: The counterclockwise **on-plane** rotation of the magnetic needle moving along orbit 1;
B: The counterclockwise **off-plane** rotation of the magnetic needle moving along orbit 2;
C: The clockwise **on-plane** rotation of the magnetic needle in the center;
a: The quantum transition of the magnetic needle from orbit 1 to orbit 2;
b: The quantum transition of the magnetic needle from orbit 2 to the center.

3. A large majority of the needles move into the center through a series of clear **quantum transitions**, such as transition **a** and **b** shown in **Figure 1**. In other words, when an evolving magnetic needle in orbit 1 moves into orbit 2, the process does not occur through a spiral curve, but a straight line. It is a quantum transition! Similarly, transition **b** sends the magnetic needle from orbit 2 to the center.

4. While the magnetic needle is making a quantum transition, e.g., from orbit 1 to orbit 2, it changes the direction of rotation **simultaneously** and, **suddenly,** from

on plane rotation to off plane rotation that is about perpendicular to that of the previous one. For instance, a needle makes on-plane rotation in orbit 1 but off -plane rotation after reaching orbit 2.

5. Transition **b** is faster than transition **a**, though the former involves a larger change in energy. That is, the process with a larger energy change takes a shorter time.

6. If a much larger (e.g., 1 cm in length) and heavier (e.g., 1 gram) magnet bar is used to perform such an experiment, the observed phenomena are very similar. For instance, the magnet makes counterclockwise on-plane rotations in orbit 1; it rotates vertically and counterclockwise in orbit 2. Evidently, as far as it is practicable, the size or the weight of the magnet bar does not affect the observation of the transitional movements.

In summary, two kinds of quantum transitions along with some other unusual phenomena have been observed in this macroscopic system, namely,

1. Movement of the magnetic needle is opposite to that of the magnetic poles;
2. Quantum transitions from orbit 1 to orbit 2 and from orbit 2 to the center;
3. Quantum change of the direction of rotation from on-plane (orbit 1) to off-plane (orbit 2) and then back to on-plane (in the center) but in an opposite direction.

The above observations demonstrate that the structure of a dynamic magnetic field is quantized. It is this structural quantization of the dynamic magnetic field that has rendered the quantum transitions of the small magnetic needles being observable. In other words, the quantum phenomena of the magnetic needles only depict the structure of the dynamic field, rather than being a reflection of the quantum nature of the magnetic needles.

Since quantum transitions are thought to be limited to the microscopic systems, the above observations have demonstrated that quantum transitions can also happen in the macroscopic world! These observations are neither understood nor explained in current physics and thus they will arouse tremendous interest in the science community.

References

1. R. Y. Tsien, *Am. J. Phys.* **1972**, *40*, 46-56.

Acknowledgement

The author is grateful to Professor Robert Kroeger of the University of Mississippi for helpful discussions before the submission of the manuscript.