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The interference of two-dimensional superconducting induced current in vector potential A field

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ABSTRACT

If a two-dimensional superconducting mental surface is passed through by two infinite straight magnetic flux which is shielded by superconductivity, and it was supposed that the change rate of flux was not equal to zero at the beginning, which would induce two opposite and equal currents on the two-dimensional superconducting mental surface. In this situation, when the change rate of flux changed to zero, and both magnetic fluxes remain constant, new physical interference effect would appear. In this paper, the interference streamline distribution on two dimensional superconducting mental surface are calculated and simulated. We named the new interference phenomenon L-J effect, it is considered as a two-dimensional A-B effect.

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1.Introduction

Scalar potential is indeterminate in physics, but the difference of potential vectors like gravitational potential difference and electric potential difference is determinate and can be measured. While it seems different for magnetic vector potential. Existing theory holds that for the total description of magnetic field, magnetic induction intensity is not enough, vector potential A is redundant. However vector potential A together with its circulation integral $\oint_C A\cdot dr$ is just enough for the description, which can be verified by AB effect [1-3] and L Effect we have recently proposed [4]. Various special physical effects are derived from the potential contribution to momentum, typical examples include cow phase shift [5], AC effect [6], and AB effect. AB effect is essentially one-dimensional interference effects, and this manuscript will explore new two-dimensional interference effects.

We suppose that a two-dimensional superconducting metal surface is passed through by two infinite straight magnetic flux which are shielded by superconductor separately, and the distance between the two magnetic flux is d, as shown in fig. 1. According to the following test procedure.

At the beginning we have $d\phi/dt\neq 0$, and two electric current equal and opposite to each other are induced on two-dimensional superconducting metal surface. Then we make $d\phi/dt=0$, and both magnetic fluxes remain constant ϕ_0. In this paper, the interference streamlines distribution on two dimensional superconducting metal surface are calculated and simulated.

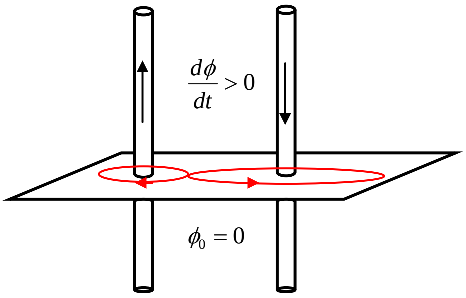


Fig. 1. The physical model.

As the torque function of vector potential A, additional angular momentum which lead to additional phase of cooper pairs would be generated. Then, the two-dimensional interference distribution streamlines of superconducting induced current will appear. The interference phenomenon caused by these induced current with same or opposite direction can be verified by experiments. The two-dimensional interference phenomenon is named L-J effect, and it can be considered the two-dimensional AB effect.

2. The distribution of superconducting induced current without A field

If the effect of vector potential A is not considered, and while the induced current are with the opposite direction, the vector of superconducting induced current of any point (shown in figure 2) in metal surface can be calculated by

$$J_x = j_1\cos(\pi/2+a_1)+j_2\cos(\pi/2-a_2) \quad (1)$$

$$J_y = j_1 \sin(\pi/2 + a_1) + j_2 \sin(\pi/2 - a_2) \quad (2)$$

The symbol $r_i(i=1,2)$ represents the distance between the target point and the ith straight magnetic flux. The symbol $j_i(i=1,2)$ represents the ith induced current value, and $j_i = C/r_i$, $2\pi r_i E_i = -\partial\varphi/\partial t = const$, $j_i \propto E_i$. Then the current streamlines can be drawn, as shown in Fig. 3. It can be found that the value of the current along the horizontal line that connects the two fluxes is zero.

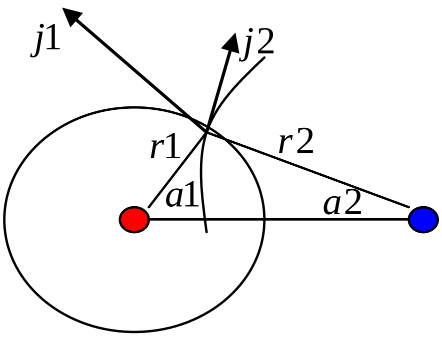


Fig. 2. Superposition of superconducting induced current.

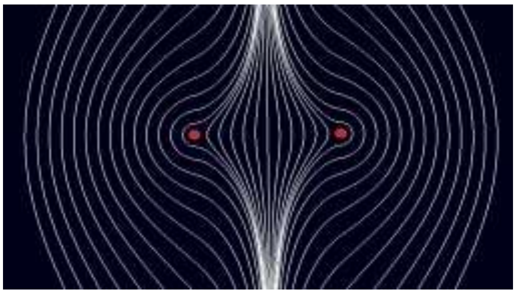


Fig. 3. Superposition of superconducting induced current with the opposite direction.

In contrast, if the induced current are with the same direction, the superposition of induced current can be calculated by

$$J_x = j_1 \cos(\pi/2 + a_1) + j_2 \cos(3\pi/2 - a_2) \quad (3)$$

$$J_y = j_1 \sin(\pi/2 + a_1) + j_2 \sin(3\pi/2 - a_2) \quad (4)$$

The current streamlines are shown in Fig. 4. It can be can found that the value of the current along horizontal line is also equal to zero according to the symmetry.

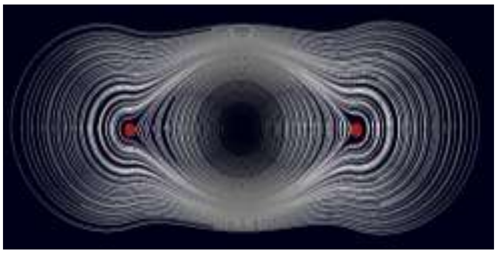


Fig. 4. Superposition of superconducting induced current with the same direction.

3. Interference of superconducting induced current with vector potential A field

After superconducting induced current is produced, to keep $\phi_0 = const$. Then, according to momentum minimum coupling principle or angular momentum minimum coupling principle, the interference in the superposition of currents would occur because of the phase difference caused by vector potential A or its first moment. The previous formulae should be revised correspondingly as follow.

$$J_x = \{[j_1 \cos(\pi/2 + a_1)]^2 + [j_2 \cos(\pi/2 - a_2)]^2 + 2 j_1 j_2 \cos(\pi/2 + a_1)\cos(\pi/2 - a_2)\cos(\Delta\psi)\}^{1/2} \quad (5)$$

$$J_y = \{[j_1 \sin(\pi/2 + a_1)]^2 + [j_2 \sin(\pi/2 - a_2)]^2 + 2 j_1 j_2 \sin(\pi/2 + a_1)\sin(\pi/2 - a_2)\cos(\Delta\psi)\}^{1/2} \quad (6)$$

In which $\Delta\Psi = \frac{m}{e\hbar}(j_1 - j_2) + \frac{e}{\hbar}(A_1 - A_2)$.

For special cases like two-dimensional surface superconductor is replaced by superconducting coil (as shown in Fig. 5), it has

$$\Delta\psi = \int_C \frac{2e}{\hbar}(A_1 - A_2)dr = \frac{4e}{\hbar}\phi_0 \quad (7)$$

$$J = j[1 - \cos(\frac{4e\phi_0}{\hbar})] \neq 0 \quad (8)$$

In which $\phi_0 = \oint_{ring} \mathbf{A} \cdot d\mathbf{r}$.

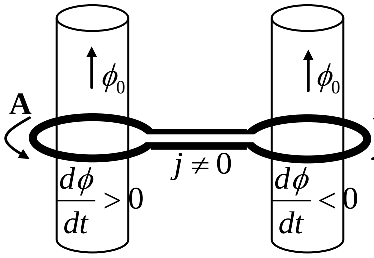
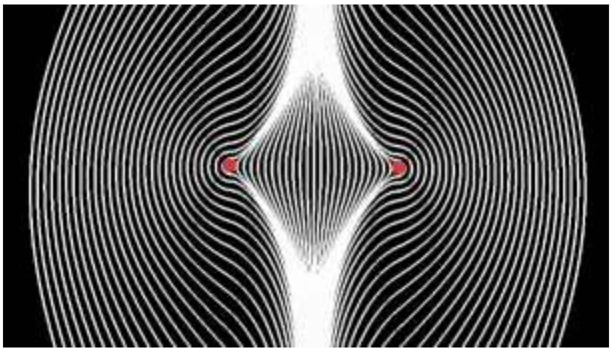
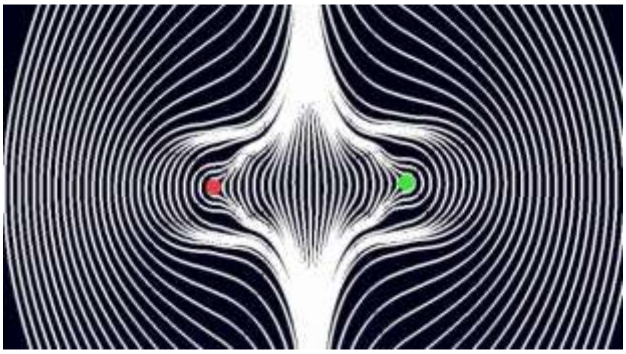


Fig. 5. The special physical model.

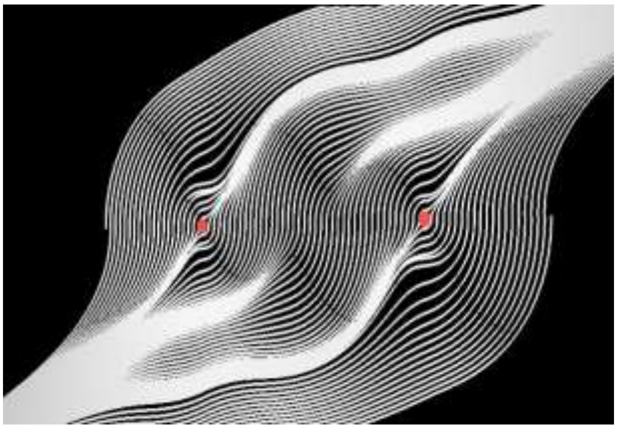
The currents streamlines are shown in Fig. 6.



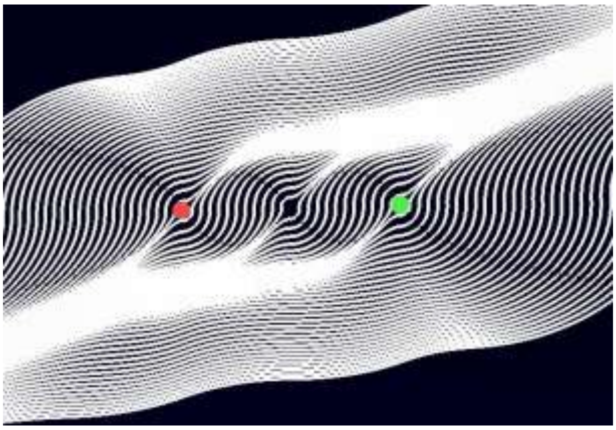
(a) The direction of current j are the opposite, and the direction of vector A are the same.



(b) The direction of current j are the opposite, and the direction of vector A are the opposite.



(c) The direction of current j are the same, and the direction of vector A are the same.



(d) The direction of current j are the same, and the direction of vector A are the opposite.

Fig. 6. Interference of superconducting induced current with vector potential A field

The theoretical research demonstrate that the main factor that affect the distribution shape of the interference streamline, is whether the direction of superconducting induced currents are same. The same or opposite direction of vector potential is the physical reason of interference, but not observably affect the distribution shape of the interference streamlines.

Conclusion

As a conclusion, in this manuscript:

1) A two-dimensional AB effect was proposed, which was named L-J effect.

2) If streamline of interference does exist, a new measurement technique and method is provided, especially for the measurement of the difference value between two vector potential A field.

The most important contribution of this manuscript is the new advance in understanding of magnetic vector potential A, and providing a new method to measure the difference value between two vector potential A field.

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