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Methodological Notes

DEMONSTRATION MAGNETIC-FIELD CONCENTRATION

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Usp. Fiz. Nauk 97, 733–734 (April, 1969)

AT the present time, the most effective method of obtaining ultrastrong pulsed magnetic fields is cumulative compression of the magnetic field by a closed conducting sheath.[1] This method has produced pulsed magnetic fields up to 25 million Oe.[2]

In a lecture demonstration of the cumulation method, use is made of the fact that a pulsed increase of the magnetic field intensity can be produced also by compressing the field between conductors that do not form a closed circuit.

The experiments call for an electromagnet and a fluxmeter that makes it possible to show clearly the pulsed variation of the magnetic field. The fluxmeter consists of a measuring coil, an integrating network, and an oscilloscope with a long-persistence screen. First one demonstrates how such a flux meter registers a field pulse. To this end, a permanent bar magnet is rapidly moved past the measuring coil, and a pulse, corresponding to the pulsed variation of the magnetic flux through the coil, is observed on the oscilloscope screen.

In the first experiment (Fig. 1) one shows that rapid motion of a conducting plate across the force lines of an inhomogeneous field produce in the plate eddy currents that change the magnetic field surrounding the plate. A copper plate is inserted rapidly into the gap of an energized electromagnet, and a pulse corresponding to the field increment at the center of the electromagnet gap, where the measurement coil is located, is observed on the oscilloscope screen. According to the Lenz law, the eddy currents in a plate moving in a strong field are directed in such a way as to restrain the increase of the magnetic flux through the plate. The magnetic field of the eddy currents becomes weaker inside the plate, and intensifies the field of the magnet outside the edges of the plate. After the motion of the plate stops, the eddy currents are attenuated and the stationary field distribution in the magnet gap is restored. The duration of this transient process is determined by the relaxation time of the conductor, which depends on its shape, conductivity, and orientation in the external field.[1]

When the plate is yanked out of the magnet gap, a pulse of opposite polarity is observed on the oscilloscope screen, corresponding to a pulsed decrease of the field in the gap of the magnet. A control experiment with a copper plate cut in the form of a comb should also be demonstrated. When such a plate moves in the gap, the flux meter reveals no changes of the field.

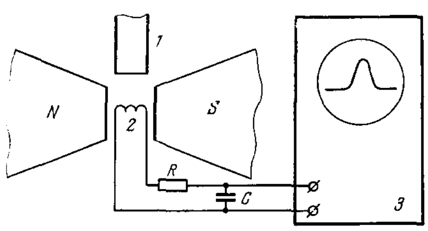

FIG. 1. 1 – copper plate, 2 – measuring coil (4000 turns of PEV-0.06 wire), 3 – SI-13 oscilloscope. Integrating network: R = 40 kΩ, C – 10 μF.

The described experiments can be interpreted also on the basis of the so-called law of conservation of the magnetic flux through a conductor.[3] This law can be used for processes whose duration is shorter than the relaxation time of the conductor. Thus, when the plate moves rapidly in the gap of an energized electron magnet, the small value of the magnetic flux existing in the plate prior to its motion is conserved. In this case the external magnetic field does not have time to penetrate into the plate, is "pushed away" by its front edge, and becomes denser.

The demonstrated effect can be greatly enhanced by compressing the field between three plates that move simultaneously towards the center of the magnet gap. This method is used in the proposed magnetic-field concentrator. Its construction is similar to a central photographic shutter (Fig. 2), the blades of which are duraluminum plates 5 mm thick. The mechanism of the concentrator makes it possible to produce manually, by slight motion of lever 2, a demonstrable sufficiently rapid convergence of plates 1 towards the measuring coil 3, which is secured together with the concentrator on a removable pole piece of the magnet 4.

The compression of the magnetic field by the con-

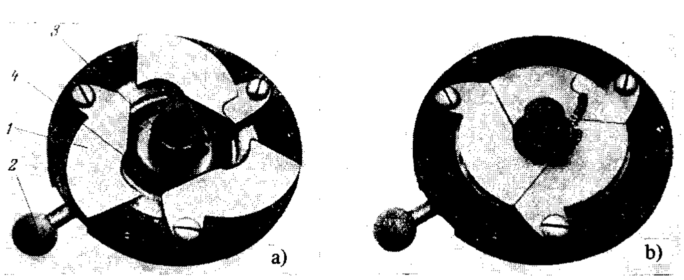

FIG. 2. Concentrator. a) Plates moved apart; b) plates brought together. 1 – Plates, 2 – lever, 3 – measuring coil, 4 – pole piece.

centrator is demonstrated in the following sequence: the magnet is turned on and the plates are moved apart, and then, by smart motion of the lever, the plates are brought together. The pulsed field increment registered by the fluxmeter is much larger than in the first experiment with a single plate. Thus, at a dc field of 3000 Oe, the pulsed increment of the field amounts to 200–300 Oe.

It is possible to demonstrate the ponderomotive action exerted on the concentrator plate by a time-varying external magnetic field. If the plate motion causes a change of the stationary field surrounding the plates, then the inverse effect should also take place, namely a change of the external field should cause the plates to move. This phenomenon is demonstrated with the concentrator by using the following sequence: with the electromagnet de-energized, the plates are brought together, and it is then shown how the plates are pushed apart when the electromagnet is turned on. When the field is turned off, the plates again come together.

This ponderomotive action can also be explained with the aid of the law of conservation of the magnetic flux to the concentrator plates under rapid variations of the external field. Whereas in the field-compression experiment the concentrator serves as a "field generator," in the second experiment it serves as a "field motor." This demonstration illustrates the physical principles underlying the modern methods of producing conducting sheaths in pulsed magnetic fields.[4]

The authors are grateful to M. S. Tikhomirov for taking part in the organization of the described experiments.

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LECTURE DEMONSTRATIONS OF CERTAIN WAVE PHENOMENA IN THE 3 cm BAND

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Usp. Fiz. Nauk 97, 735–737 (April, 1969)

I. PHASE CONTROL OF THE INTERFERENCE PATTERN

As is well known, waves emitted by coherent sources can interfere and the intensity of the resultant oscillation at the point of observation is determined by the phase difference between the interfering waves.

Interference patterns of various types of waves (light, electromagnetic, sound) can be observed in many lecture demonstrations. But to show the dependence of the energy of the resultant oscillations on the phase difference between the initial oscillations in demonstrations with light or sound waves is a very difficult matter. In the case of electromagnetic waves, on the other hand, by using a phase shifter, it is possible to effect phase control of the interference pattern, for example in Young's experiment.

The demonstration setup is shown in Fig. 1. A waveguide tee junction with symmetrical arms is connected to the waveguide output of generator G, which produces 3-cm waves modulated in amplitude at low frequency (400 Hz). The spatially separated outputs of the tee, S_1 and S_2 are coherent sources of electromagnetic waves. To be able to control the initial phases of the oscillations at the output of either source, both outputs of the tee are equipped with dielectric phase shifters φ_1 and φ_2. The phase shifter is a waveguide segment, in the cavity of which a wedgelike dielectric plate is inserted by rotating the handle of the phase shifter.

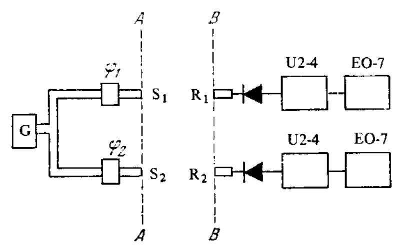

FIG. 1

The interference pattern is observed by moving a receiver with waveguide input R_1 (or a dipole) in the plane BB, which is parallel to the line AA joining the sources. The receiver is connected through a detector section and a low-frequency amplifier U2-4 to the vertical input of an EO-7 oscilloscope. The interference pattern in the BB plane is revealed by the periodic alternation of the maxima and minima of the signal amplitude on the oscilloscope screen as the receiver is moved.

After setting both phase shifters in a zero position, one of the receivers, say R_1, is placed at a point corresponding a certain maximum of reception intensity. One of the phase shifters is used to vary the oscillation phase of the output of the given source. The receiver R_1 registers a gradual decrease of the amplitude of the resultant signal, to a minimum (when the introduced phase shift is equal to π). The second phase shifter can