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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538.56

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.

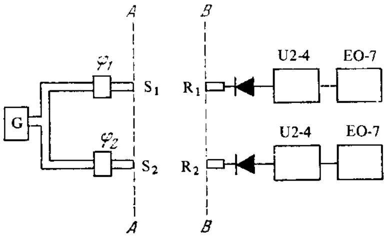

FIG. 1

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 be used to compensate for the resultant phase difference, and a maximum of intensity at the observation point is again obtained.

It is also possible to show that when the phase difference of the interfering waves is changed, a redistribution of the energy in space takes place at the observation point. For this purpose, the two receivers R_1 and R_2 are used. One of them is placed in a position corresponding to a certain intensity maximum, and the other in a position corresponding to a minimum. If the phase at the output of one of the sources is gradually varied, then the receiver previously recording the intensity maximum will show the intensity to decrease slowly to zero, whereas the second receiver, where a minimum was previously observed, will show a gradual increase of the signal to a maximum. The energy has been "pumped over" from one point of space to the other with the aid of the phase control.

II. RESONANT ABSORPTION OF ELECTROMAGNETIC WAVES

As is well known, the passage of electromagnetic waves through a dielectric is always accompanied by a more or less strong absorption of the waves.

The absorption of electromagnetic waves by matter can be simulated to a certain degree by demonstrating the passage of centimeter waves through a grating made up of resonant dipoles (Fig. 2). The grating dimensions are 30 ×30 cm. A sweep generator type XI-24 was used in the demonstration, and delivered an output voltage with a swinging frequency ranging from 8,000 to 12,000 MHz, and with practically constant amplitude. The demonstration setup is shown in Fig. 3.

The sweep generator G radiates in space, through a horn waveguide S, a linearly-polarized wave whose frequency varies periodically at a frequency of 12.5 Hz in the 8,000–12,000 MHz band. The radiated waves are additionally amplitude-modulated at a low frequency (10 kHz). The receiver (R) is a horn similar to the transmitting one, with a broadband detector section. The detected low-frequency signal is fed through an amplifier (U2-4) to the vertical input of the EO-7 oscilloscope. The horizontal sweep of the oscilloscope beam is produced by the sawtooth voltage that controls the frequency of the sweep generator (12.5 Hz). Thus, the horizontal displacement of the beam on the oscilloscope screen is linearly connected with the frequency radiated by the generator, while vertically the beam is shifted in accordance with the amplitude of the oscillations fed to the receiver at the given frequency.

If there is no absorbing medium between the source and the receiver, then the amplitude of the received oscillations is approximately equal in the entire range of emitted frequencies (Fig. 4).

A grating Gr of metallic dipoles is then placed between the source and the receiver in such a way that the dipoles are parallel to the electric vector of the radiated electromagnetic wave. The length of the dipoles of our grating (6 cm) is a multiple of the wavelength (λ = 3 cm). Therefore the alternating electric field of the wave incident on the grating, at the frequency corresponding to the given wavelength (f = 10,000 MHz) causes intense excitation of the dipoles. Consequently a noticeable energy loss will take place at frequencies close to this frequency.

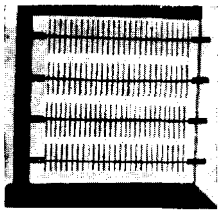

FIG. 2

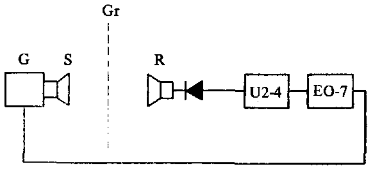

FIG. 3

FIG. 4

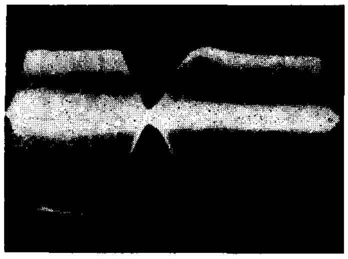

FIG. 5

Because of the unequal change of the signal amplitude at different frequencies, the electron beam will trace on the oscilloscope screen an absorption curve (Fig. 5) superimposed on the subcarrier of frequency 10 kHz.

The largest absorption occurs at one resonant frequency. With increasing deviation from this frequency, the absorption decreases, and for frequencies far from resonance, the absorption is practically nonexistent. By varying the frequency variation interval, it is possible to shift the extremum of the curve to the right or to the left.

III. TRAVELING-WAVE RESONANCE

According to the de Broglie theory, a moving electron can be set in correspondence with a wave process of wavelength λ. Then, to select the stationary circular orbits in the simplest Bohr model of the atom, it is necessary to satisfy the following condition. The perimeter of the stationary orbit must be equal to an integer number of de Broglie wavelengths. In other words, of stabler orbits there should be a resonance of the traveling wave propagating along the closed loop.

This conclusion can be simulated with the aid of 3-cm magnetic waves. The fact that the resonance phenomenon is indeed observed for a traveling wave propagating in a closed loop, when the length of the contour is suitably chosen, it can be demonstrated in the following manner (Fig. 6).

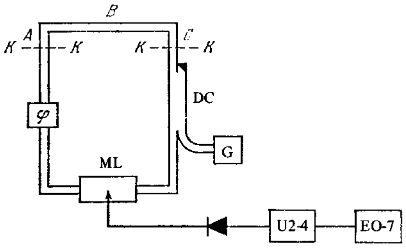

FIG. 6

A waveguide ring is assembled of 3-cm waveguide sections of different shape, connected in series with a directional coupler DC, a three-cm measuring line ML, and a dielectric phase shifter φ. Low-frequency (400 Hz) amplitude-modulated 3-cm electromagnetic waves enter into the ring from a generator G, the waveguide output of which is connected to the input of the directional coupler. A dielectric phase shifter, similar to that described in the demonstration I (Phase Control of the Interference Pattern), makes it possible to vary the electrical length of the loop. The detector in the measuring-line probe registers the amplitude of the wave at the given point of the loop. The detected signal from the probe is fed through a low-frequency amplifier to the input of an EO-7 oscilloscope.

The phase shifter is first set at zero. A signal of small amplitude is observed on the oscilloscope screen, since a loop of arbitrary length does not span an integer number of waves, and the waves concel eath other. By rotating the knob of the phase shifter, a position is found such that the signal amplitude passes through a maximum. This corresponds to the case when the loop spans an integer number of waves. It can be verified that a traveling wave exists in the contour in both cases for the variations of the signal amplitude are negligible when the probe is moved along the line. They are due to the non-ideal joining of the individual parts of the loop. Thus, the experiment has shown that resonance can occur for a traveling wave under certain conditions.

Let us open the waveguide loop, removing from it the section ABC, and let us short the open outputs of the waveguides with metallic plates KK. A standing wave is established in the line. When the probe is moved along the line, the signal on the oscilloscope screen changes periodically from zero (nodes of the standing wave of the electric field) to a maximum (antinodes of the standing wave).

Of course, during the demonstration it is necessary to describe carefully the difference between de Broglie and electromagnetic waves, and to state that the task of the experiment is only to present a model of de Broglie's ideas.

The authors are sincerely grateful to Professor N. N. Malov for valuable hints and for help with the work on the demonstrations.

ILLUSTRATION OF X-RAY PHOTOGRAPHY OF A ROTATING CRYSTAL WITH THE AID OF CENTIMETER ELECTROMAGNETIC WAVES

538.56

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WE describe in this paper two variants of a lecture demonstration that illustrates with the aid of centimeter waves the production of an x-ray pattern by the rotating-crystal method. The validity of the Bragg law for these waves was first experimentally demonstrated in the early Twenties by N. A. Kaptsov.[1-2]

The setup (Fig. 1) comprises a commercial 3-cm generator 1 with a power supply 2, a receiving horn antenna 3 connected to an oscilloscope S-1, and a crystal model 4, consisting of 477 copper dipoles, the natural frequency of which coincides with the radiation frequency of the generator.[3] The dipoles are made of 2-mm copper wire and are 60 mm long. The emitter, like the x-ray tube, is permanently mounted on the demonstration table. The horizontal axes of rotation of the "crystal" is mounted with the aid of bearings on two vertical posts 6 made of transparent plastic. An arm 7, which carries the receiving horn antenna 3, is secured on a separate bearing behind the sample, on its rotation axis. To observe the scattering at all possible angles, the receiving antenna can be moved together with the arm in a vertical plane along a circle with center on the rotation axis of the sample. The rotation of the receiving antenna 3 can be synchronized with the aid of a pantograph 8 with the rotation of the sample 4 in such a way that rotation of the antenna through an angle θ causes rotation of the