ON A METHOD OF INVESTIGATING ELECTROMAGNETIC WAVES

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The spatial distribution of electromagnetic radiation flux is registered on a photographic plate. The method proposed and tested here is based on regression of the latent image under the action of the electromagnetic field. It is suggested that the sensitivity of the photographic emulsion to radio waves results from a change in the dark conductivity of silver bromide emulsions as a result of uhf heating. A method of treating photographic materials to increase millimeter wave sensitivity is discussed.

THE spatial distribution of electromagnetic-wave flux density is investigated nowadays with the aid of measuring antennas.[1,2] However, this procedure is sometimes impossible, particularly for the study of fields inside waveguides or resonators. Difficulties are encountered also in performing flux measurements very close to the antennas in connection with problems involving wave propagation in plasma waveguides, and with radio wave diffraction near conducting bodies having dimensions that are commensurate with the wavelength. It is especially important at the present time to investigate the "topography" of the electromagnetic-wave flux when analyzing plasma by microwave methods.[3] The dimensions of an investigated plasma are usually commensurate with the wavelength of the probing oscillations; this results, as we know,[4] in diffractive effects that hinder the measurement of radio-wave absorption coefficients in plasmas. In connection with this problem one must know the geometry of the radio-wave beam that is directed to the plasma surface by the focusing antennas. Certain difficulties are encountered in determining the geometry of a beam formed by these antennas; it is here impossible to determine the geometry of the field by means of measuring antennas because the beam diameter is commensurate with the wavelength. It is shown in the present work that the spatial distribution of electromagnetic-wave flux can be recorded in this case by a photographic method.[5,6]

The photographic process in silver halide (AgBr, AgCl, and AgI) emulsion films is divided into two stages, the production of the so-called (invisible) latent image and the production of the visible image.[6] According to the most recent theories,[7] the latent image represents the topography of the potential wells in the crystalline lattice of an emulsion. The potential wells are produced by electromagnetic radiation, which destroys the regular ordering of lattice ions. We now possess reliable information proving that the final result of the action of light on silver halide crystals is the production of silver through its recovery from the halide. It is interesting to determine the degree to which silver is freed in the millimeter wave region, and the possibility of using some other method to register the spatial distribution of the flux density in a photographic emulsion.

1. DESCRIPTION OF EXPERIMENTAL APPARATUS

Figure 1 is a schematic drawing of the apparatus used to investigate the flux density. Here 8-mm oscillations from the microwave generator 1 pass through the calibrated attenuator 2 to the focusing antenna 3 that directs them to the photographic plate 4, which is oriented to receive the impinging electric vector parallel to the emulsion surface.

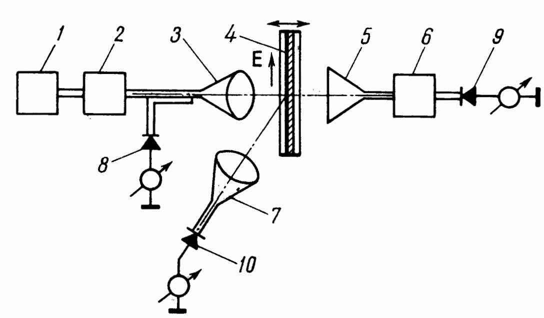

FIG. 1. Block diagram of apparatus for measuring microwave flux density. 1 – microwave generator of 8-mm waves, 2 – calibrated attenuator, 3 – transmitting horn-lens antenna, 4 – photographic plate, 5 – receiving antenna, 6 – attenuator, 7 – movable horn-lens antenna, 8–10 – pickup heads with crystal diodes.

The receiving horn 5 and the calibrated attenuator 6 were used in measuring the uhf absorption by the plate. Reflections from the emulsion were measured from the standing-wave coefficient in the transmitting waveguide in conjunction with a movable horn-lens antenna 7. During its exposure the plate 4 was held in a cassette made of thin black paper. The electromagnetic-wave flux was regulated by means of the attenuator 2.

2. EXPERIMENTAL RESULTS AND DISCUSSION

Photographic paper coated with a silver bromide emulsion was used in the first experiment. The paper was slightly blackened by uhf energy density of about 0.7 W/cm^2 to which it was exposed about 3 sec. The degree of blackening depended slightly on the flux density in the region 0.7—3 W/cm^2. The emulsion was damaged by further increase of the flux.

It was of interest to study the destruction (regression) of a light-induced latent image that was subsequently exposed to electromagnetic radiation. This experiment was performed with a silver bromide emulsion on glass; the developing materials were metol and hydroquinone. The emulsion was first illuminated uniformly during 0.1—0.5 sec; thereupon it was exposed within the paper cassette to microwave radiation for a period of 3—5 minutes. The photographs exhibited bright spots against a general dark background after exposure to a flux of 0.7—2 W/cm^2; this result indicated the destruction of latent images.

The destruction was apparently associated with the fact that Ag atoms at the latent-image centers lose electrons; the resultant Ag^+ ions become interstitial because they cannot be held at the given centers. The sensitivity of the photoemulsion to radio waves can be attributed to a change of dark conduction in a silver bromide emulsion exposed to millimeter waves. In the irradiated areas the emulsion was apparently heated locally, producing a thermal topography and a corresponding change of photoconductivity. The temperature changes led ultimately to changes in the photosensitivity of the emulsion. The high probability of the latter effect was indicated by the experimental observation that with increasing absorption of radio waves in the emulsion or glass of a plate the latter exhibits enhanced microwave sensitivity.

As the uhf sensitivity of emulsions increases it becomes important to select the most suitable emission spectrum for preliminary illumination. Since the experimental emulsions were of different optical sensitivities (ortho-, isortho-, pan-, and infrachromatic), preliminary exposure to long (infrared) wavelengths should modify their sensitivity as a function of temperature. Experimental confirmation was obtained with 0.02—0.1-sec preliminary exposures and a microwave flux $P = 1—2$ W/cm^2. The irradiated portions of the plates exhibited bright spots, thus confirming the hypothesis of emulsion sensitivity change (perhaps the beginning of solarization).

Emulsion blackening was observed as a result of 1—2-sec preliminary illumination and a flux 1—2 W/cm^2. The changes in image color accompanying changes in the length of the preparatory-illumination period can obviously be attributed to solarization. The intensity of this solarization process depended on the duration of radio-wave exposure. For example, in the case of long (8—10 min) uhf exposure following ~1-sec illumination an ~30% increase of flux density resulted in appreciable solarization (transformation of a dark image into a bright image). In the same experimental run only slight solarization resulted from 3—5 min microwave exposure. The lower limit of microwave exposure resulting in appreciable solarization lies in the range 1.3—1.5 W/cm^2 during 10 min when preceded by 1-sec illumination. With 0.4—0.5-sec preliminary illumination, solarization becomes appreciable following 12—15-min exposures.

As already noted, the thermal effect in photographic development can lead to useful results. A maximum absorption of microwave energy is now desirable. For this purpose the emulsions were at first bathed prior to their illumination; this resulted at the same time in supersensitization, which enhances the radio image contrast on the negative. Better results were subsequently obtained by the direct bathing of the photosensitive plates in the developer. In this case when a visible image is produced the speed with which a negative is developed exhibits considerable dependence on the temperature of the developer.

In experimental runs with very brief preliminary illumination (0.01 sec) a very weak radio-wave image was obtained; however, the greatest variation of optical density in a spot was now observed as the uhf flux was varied in the range 0.4—0.7 W/cm^2 for equal 5-min exposures. It was found that the quality of the radio image was improved markedly when the Cabannes-Hoffman effect was taken into account.

Figure 2 shows photographs of the electromagnetic field in the immediate vicinity of a horn-lens antenna operating at $\lambda = 8$ mm. The design and properties of this antenna have been described

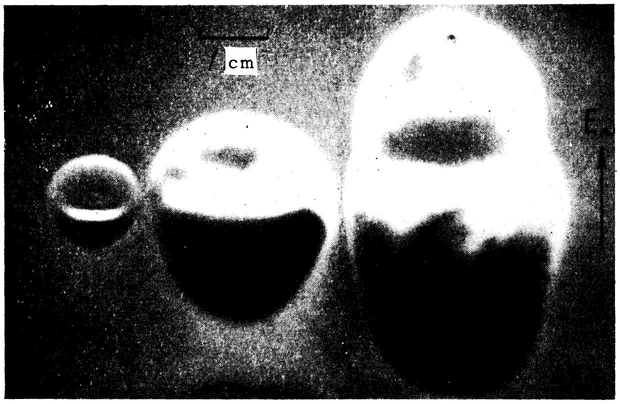

FIG. 2. Photograph of electromagnetic field in the immediate vicinity of the horn-lens antenna.

in[3]. The photoplates were mounted at the focus of the horn-lens antenna as well as at certain distances therefrom; the photosensitive surface of each plate was oriented perpendicular to the direction of radio-wave propagation and parallel to the electric field vector. A series of frames was exposed successively. The first frame (on the left) represents the photographed field at the antenna focus (40 mm from the surface of the dielectric lens). The 8-min exposure followed 0.8-sec illumination. The other two frames correspond to distances of 15 and 5 mm, respectively, from the lens surface. Here 15-min exposures followed 0.5-sec illumination.

For the purpose of investigating an emitter it was desirable to determine the geometric size of the beam at the antenna focus. For this purpose the field was monitored by photographs at different uhf flux densities. (The intensity was moderated by the attenuator 2.) The physical conditions remained the same as when the field at the focus was photographed.

A 10-min exposure to 0.15 W/cm^2 yielded traces of uhf action on the emulsion. The outline of the spot at the focus was apparent for P = 0.15 W/cm^2; at this uhf level the beam diameter at the focus equals the spot diameter. The diameter of the uhf beam at the focus of the horn-lens antenna was 15.5 mm or $\sim 2\lambda$ (Fig. 2).

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