increasing frequency starts at lower frequencies, while the response at 77 K is constant over the entire frequency range under investigation (0.1–12 GHz). The frequency dependence of the response is described by the formula[77]

$$\Delta V(\nu)=\Delta V(0)[1+(2\pi\nu\tau)^2]^{-1/2}. \quad (27)$$

Using this expression and the experimentally obtained dependence $\Delta V(\nu)$ for various temperatures, the authors obtained the response time $\tau(T)\sim T^{-1}$ over the entire temperature range from 6 to 40 K. It was found that the value of τ does not depend on the substrate material or on the film thickness in the range 0.1–1 μm.

An analysis proved that samples of group A for which oscillations of $\Delta V(I_b)$ and $\Delta V(B)$ are observed display JDM: the peaks on the $\Delta V(I_b)$ curve (see Fig. 18) correspond to Shapiro steps on IVC, which are formed as a result of irradiation of weak intergranular links, while oscillations of ΔV in a magnetic field correspond to oscillations of I_c. The transverse (relative to current) size L of weak links can be estimated from the Josephson interference relation for critical current, i.e., $L=(h/8\pi e)\lambda_L\Delta B$, which gives $L=0.35$ and 1.7 μm (for $\lambda_L=2000$ Å). These values are in good accord with the actual size of microbridges.

As the radiation frequency increases, JDM is replaced by EDM due to electron heating in granules. This can be explained by spectral dependence of JDM sensitivity which varies in proportion to ν^2 for $\nu\sim 2\Delta/h$ in accordance with the theory (see Refs. 11, 24, 77). Since the heating effect remains independent of frequency, upon an increase in temperature, magnetic field, and with decreasing share of granular structure in the films, the frequency of crossover separating these two mechanisms decreases.

Samples of group B were distinguished by a lower degree of granulation and a larger thickness of intergranular junctions. The absence of JDM in group B samples is confirmed by the coincidence of the dependences $\Delta V(I)$ and $dV/dT(I)$, which is typical of the bolometric response. However, the estimates of the EDM time constant give 1–10 ps, which is one or two orders of magnitude smaller than the minimum possible time for a bolometric response defined by the parameter $\tau_{es}=4d/\eta c_s\simeq 10^{-10}$ s, where c_s is the velocity of sound. Besides, the observed response does not depend on the film thickness and the substrate material, which is also typical of a bolometric response. The optimization of EDM is possible for a choice of bias current for which weak links have already been broken, while granules are still in the superconducting state. The resistance at the working point usually amounts to $\sim$10% of the resistance R_n in the normal state. The form of the dependence $\tau(T)\sim T^{-1}$ suggests that the temporal characteristics of EDM are determined by τ_{eph} rather than by the recombination time τ_R of quasiparticles in granules (excluding the temperature region near T_c), which is characterized by an exponential increase upon cooling. A similar dependence for LTS materials has the form $\tau(T)\sim T^{-2}$ corresponding to the temperature dependence of time τ_{eph} in the normal state measured by other methods.[77]

The spectral characteristic of EDM is determined by the frequency dependence of the absorption coefficient α and of the change in the energy gap width $\delta\Delta^*$ ($\delta\Delta^*$ is the mean value of Δ in the resistive state). It is well known that the value of α for YBaCuO changes significantly in the near IR range even in the normal state, leading to a smooth decrease in ΔV with increasing frequency in this range. The absence of singularities in the response for $h\nu=2\Delta$ is associated with considerable inhomogeneity of the resistive state. The ratio of ΔV to the power P_A absorbed by unit volume remains unchanged in a wide frequency range, but was very sensitive to the mechanism of electron energy relaxation. Since the electron–electron interaction dominates in the case of a small mean free path l, energy is redistributed in the electron subsystem, excess quasiparticles are generated, and superconductivity is suppressed effectively for any frequency ν. Besides, the lower value of the Fermi energy in HTSC materials as compared to LTS substances confirms the effectiveness of the electron–electron interaction (along with the electron–phonon interaction), which explained the nonselective nature of the ratio $\Delta V/P_A$.

For $\nu>\tau_{eph}^{-1}$, the response under the electron heating conditions is described by the formula[77]

$$\Delta V=(dV/dT)P_A\tau_{eph}[1+(2\pi\nu\tau_{eph})^2]^{-1/2}C_e^{-1}, \quad (28)$$

which can be used for deriving the temperature dependence of τ_{eph} even in the temperature range inaccessible for measurements. According to (28), $\tau_{eph}\sim T\Delta V(dV/dT)^{-1}$ for $\nu\ll(2\pi\tau_{eph})^{-1}$ and $C_e=\gamma T$. It was found that the temperature dependences of τ calculated by formula (27) obtained from quasistationary measurements coincide with the dependence of τ_{eph} calculated by formula (28) obtained from nonstationary measurements: both times are proportional to T^{-1}. This confirms the uniform nature of energy relaxation and indicates that diffusion of quasiparticles does not play any significant role in relaxation processes. Moreover, the smallness of the film thickness (as compared to λ_L), which ensures a uniform absorption of radiant energy, is an important condition for realization of electron heating.

Lindgren *et al.*[5,6] studied the response of microbridges made of YBaCuO epitaxial films of thickness 100 nm on $LaAlO_3$ substrates to optical radiation with $\Lambda=790$ nm, pulse duration 100 fs, and pulse repetition frequency 76 MHz. A bridge having the size 5×7 μm was placed at the center of a coplanar waveguide of length 4 mm and width 30 μm through which a bias current of frequency $\sim$18 GHz was supplied via a semirigid coaxial cable. The entire sample was coated with a layer of $LiTaO_3$ insulating crystal to facilitate electro-optical measurements made in the ''pump–probe'' technique (see Sec. 1). The incident beam was focussed in the region of the bridge while the probing beam was focussed at a distance of $\sim$20 μm from the bridge in the region of insulating gap. The sample heating estimated from the absorbed power was $\sim$0.2 K.

The current-voltage characteristics of HTSC samples were measured by the four-probe technique in the temperature range 20–80 K. The IVC were characterized by two clearly distinctive voltage modes: the superconducting state (flux flow with zero/low voltage across the bridge) and the resistive state in which the current is almost constant, while the voltage increases abruptly (Fig. 21). With increasing bias current, a transition occurs from the superconducting state to

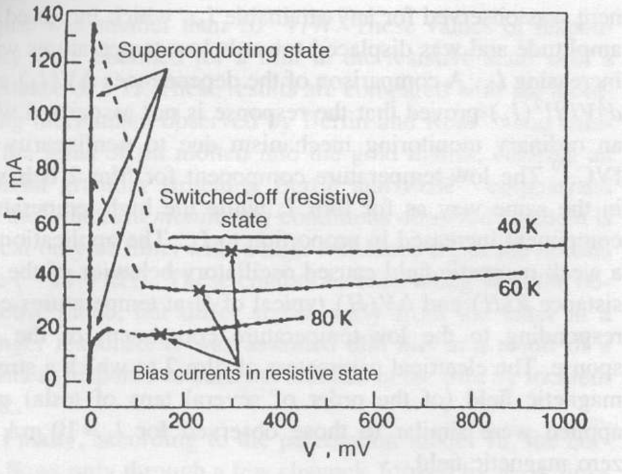

FIG. 21. Current-voltage characteristic of a YBaCuO microbridge measured by the four-probe technique (from Lindgren *et al.*[6]).

the flux flow regime in which the bridge becomes dissipative (dissipates heat). The hot spot increasing with a further increase in I_b gradually transforms the bridge to the resistive state with a low and direct current and a high voltage. In the hot spot region, the temperature is maintained at a nearly constant level exceeding T_c. At still higher values of I_b, the bridge goes over to the normal state, and the IVC becomes linear.

In the resistive state, a transient response has the form of a narrow solitary pulse having a width ~1.1 ps at half height in the entire temperature range 20–80 K. The response was followed by a voltage plateau (~200 μV) associated with a slow bolometric response with a nanosecond fall time (Fig. 22).

According to the model of photoinduced nonequilibrium electron heating, the rise time for a transient pulse is deter-

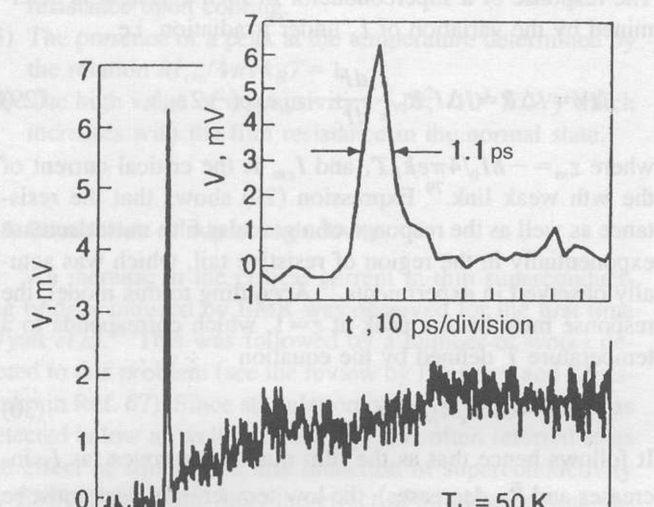

FIG. 22. Transient response of a YbBaCuO bridge in the resistive state at T_b=50 K. Nonzero initial level is due to slow drift of the scanning beam relative to the center of the gap between coplanar waveguides (from Lindgren *et al.*[6]).

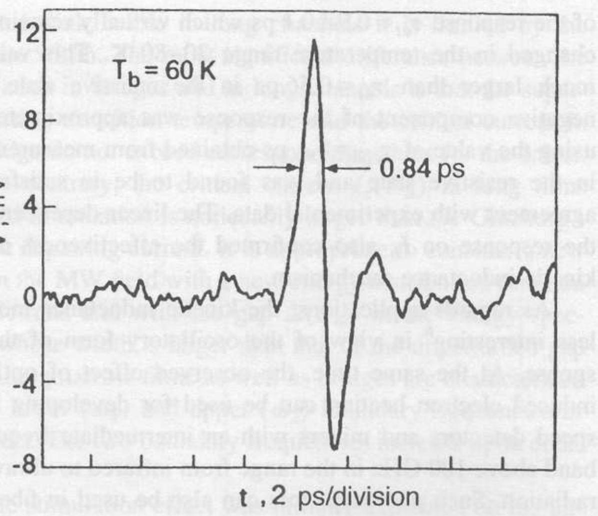

FIG. 23. Transient response of a YbBaCuO bridge in the superconducting state at T_b=60 K (from Lindgren *et al.*[6]).

mined by the larger of two time intervals, i.e., the duration of the laser pulse or by the time τ_{et} od electron thermalization. Since the laser pulse in this case is shorter, and hence does not limit the evolution of the nonequilibrium processes under consideration, Lindgren *et al.*[5,6] who used the model of electron heating managed to determine from the results of measurements the two fundamental characteristics of the samples, viz., the electron thermalization time $\tau_{et} \simeq 0.56$ ps and the electron–phonon relaxation time $\tau_{eph} \simeq 1.1$ ps.

In the superconducting state (for small bias currents), a bipolar shape of the response is observed (Fig. 23) with a time constant ~1 ps typical of the kinetic inductance mechanism. Additional experiments with the removal of the probing beam to a distance ~600 μm from the bridge demonstrated a considerable decrease in amplitude and distortion of the shape of the transient response pulse.[6] Lindgren *et al.*[6] believe that it was the distortion of the shape of a pulse propagating along the transmission line from the bridge to the region of recording, which was observed in early experiments led to erroneous interpretation of the response mechanism as a change in kinetic inductance as a result of uniform heating of the entire region of the bridge. For this reason, the response should be measured as closely to the bridge as possible to reduce pulse distortion effects. Lindgren *et al.*[6] assumed that in this case a nonequilibrium change in the kinetic inductance L_{kin} takes place, in which the variation of the relative fraction of condensate is associated with the electron temperature T_e rather than with the temperature T_b of the thermostat. Lindgren *et al.*[6] attained excellent agreement between the experimental shape of the response in the resistive state and the two-temperature model.[71] The rise time for electron temperature τ_{et}=0.56 ps and the fall time τ_{eph} =1.1 ps were extracted from the approximation of experimental data. Since both times exceed the laser pulse duration, they are regarded as intrinsic characteristic times for photoresponse in YBaCuO. The application of the kinetic inductance model described in Ref. 6 leads to an equally good agreement with experimental results in the superconducting state. This made it possible to determine the rise time of the response $\tau_{el}=0.9\pm0.1$ ps which virtually remains unchanged in the temperature range 20–80 K. This value is much larger than $\tau_{el}=0.56$ ps in the resistive state. The negative component of the response was approximated by using the value of $\tau_{eph}=1.1$ ps obtained from measurements in the resistive state and was found to be in satisfactory agreement with experimental data. The linear dependence of the response on I_b also confirmed the effectiveness of the kinetic inductance mechanism.

As regards applications, the kinetic inductance mode is less interesting[6] in view of the oscillatory form of the response. At the same time, the observed effect of optically induced electron heating can be used for developing high-speed detectors and mixers with an intermediate frequency band above 100 GHz in the range from infrared to ultraviolet radiation. Such photodetectors can also be used in fiber optical transmission lines with a data transmission rate >100 Gbit/s. Another region of application can be high-speed optoelectrical transducers using high-speed single flux-quantum circuits and optical fibers for high-speed data transmission.

Salient features and realization conditions for the mechanism

(1) Thin HTSC films can exhibit both Josephson and electronic monitoring mechanisms, a transition from the former to the latter occurring upon an increase in frequency. With increasing temperature, magnetic field, and radiation power, the value of transition frequency decreases. Besides, this frequency is the lower, the smaller the degree of granulation and the larger the grain size in the film. For films with a granule size $\sim 1\ \mu$m at 4.2 K and low radiation powers, the transition region lies in the submillimeter range.
(2) For the realization of EDM, the film thickness must be smaller than the radiation penetration depth.
(3) The inertia of the response is determined by the time τ_{eph} of the electron–phonon relaxation, which decreases upon an increase in temperature in proportion to T^{-1}.
(4) The EDM is characterized by the lack of selectivity in a wide frequency range, high values of responsivity (10^3-10^5 V/W), and a low noise level ($P_{eq}\sim10^{-12}-10^{-14}\ W/\mathrm{Hz}^{1/2}$).[76]

2.7. Percolation superconductivity

This mechanism of response was proposed for the first time by Afanasyev *et al.*[78,79] who studied the interaction between EMR of the millimeter range and thin YBaCuO films. The same authors[80] studied the response of three different YBaCuO films to mm radiation: (1) multiphase granular film (of thickness $d\simeq1\ \mu$m), (2) polycrystalline film with a granule size $\sim1\ \mu$m ($d\simeq1\ \mu$m) and (3) epitaxial film ($d\simeq0.1\ \mu$m). For film 2, two peaks were observed on the temperature dependence of the response, one of which coincided with the dR/dT peak, while the other was manifested in the region of resistive tail. The epitaxial film had only one high-temperature (bolometric) peak, and a weak low-temperature component was observed only for very large bias currents ($I_b\geqslant10$ mA). For film 1, only the low-temperature component was observed for any attainable I_b, which increased in amplitude and was displaced towards low temperatures with increasing I_b. A comparison of the dependences $\Delta V(I_b)$ and $d^2V/dI^2(I_b)$ proved that the response is not associated with an ordinary monitoring mechanism due to nonlinearity of IVC.[79] The low-temperature component for film 2 behaved in the same way as for film 1, while the high-temperature component increased in proportion to I_b. The application of a weak magnetic field caused oscillatory behavior of the resistance $R(H)$ and $\Delta V(H)$ typical of JJ at temperatures corresponding to the low-temperature component of the response. The electrical parameters of film 2 to which a strong magnetic field (of the order of several tens of tesla) was applied were similar to those observed for $I_b\geqslant10$ mA in zero magnetic field.

Afanasyev *et al.*[79,80] concluded that the monitoring mechanism for epitaxial films is either purely bolometric, or is associated with electron heating,[76] while the model of a two-dimensional (2*D*) network of disordered granules connected through weak links with a wide spread of critical currents I_{ci} is more appropriate for granular films. According to Likharev,[60] the energy $E_{ci}=hI_{ci}/4\pi e$ of the ith link at $T\sim T_c$ is comparable with the thermal energy k_BT, and hence the weak link has a finite resistance $R_i=R_{Ni}F(E_{ci}/k_BT)$, where $F(z)\sim\exp(-2z)$ in the case of weak links with strong attenuation in the limit $z\gg1$. The calculation of electrical characteristics of the film is reduced to determining the resistance of the random network of weak links with an exponential spread of resistance.[81] In this case, R is equal to the resistance $R_m=R_{N_m}F(z_m)$ of the weakest link with highest resistance in cluster formed by weak links with $R_i\leqslant R_m$ to within the pre-exponential factor $(E_c/k_BT)^{\tilde{\nu}}$ ($\tilde{\nu}$ is the critical index of correlation length). Here the resistance R_{N_m} is equal to the resistance R_N of an ensemble of weak links in the normal state to within the coefficient of the order of unity. The response of a superconductor in such a system is determined by the variation of I_c under irradiation, i.e.,

$$\Delta V=I\Delta R\simeq I\Delta I_cR_{N_m}\frac{dF}{dI_c}\sim z_m\exp(-2z_m), \qquad (29)$$

where $z_m=-hI_b/4\pi ek_BT$, and I_{cm} is the critical current of the mth weak link.[79] Expression (29) shows that the resistance as well as the response of a granular film must decrease exponentially in the region of resistive tail, which was actually observed in experiments.[78] According to this model, the response must have a peak at $z\simeq1$, which corresponds to a temperature T defined by the equation

$$T_c-T=2\pi T_c\bar{R}_Ne^2/h. \qquad (30)$$

It follows hence that as the film quality improves (as I_c increases and $\bar{R}_N$ decreases), the low-temperature peak must be shifted to T_c, which was also confirmed in experiments.[78] When the value of I_c is high and comparable with the value of I_c of granules, the bolometric mechanism or electron heating become dominating, and the peak of the response in this case coincides with the dR/dT peak. The responsivity of the low-temperature component was 10^2-10^3 V/W in the temperature range 20–60 K, while that for the bolometric response was smaller than 10^2 V/W. These values of responsivity were obtained for a film in the resistive state with a resistance of 1 Ω. These results are compared with the monitoring mechanism observed by Bertin and Rose[82] who studied the films of tin molten into the gold matrix, creating an artificial granular structure. Bertin and Rose[82] emphasized that the *enhanced monitoring* conditions observed by them is typical only of films with a high resistance R_n in the normal state (~ 11.4 kΩ). These conditions exist along with the bolometric mode, but differ significantly from the latter in a stronger response. It was assumed that this is a result of a nonlinear response to currents induced in the film by incident EMR.

Finally, according to the percolation model 78, the current flows only through a few channels formed by weak links with the lowest resistance in view of strong spatial inhomogeneity of films. These channels are combined into clusters with a certain characteristic correlation length which is in fact equal to the separation between these clusters. Such a pattern was confirmed by laser probing of the film. The dependence of variation of the voltage across the field due to weak local heating by radiation ($\Delta T \ll T_c$) on the coordinate along the film had the form of nearly periodic peaks having different amplitudes (obviously, due to different resistances of various regions of a cluster) with a characteristic period ~ 100 μm. This value is just the correlation length of the cluster being formed.

Salient features and conditions for realization of the mechanism

(1) The presence of a low-temperature component of the response in the region of resistive tail, which increases in amplitude and which is shifted towards low temperatures upon an increase in I_b and to T_c as a result of improvement of the film quality.
(2) An exponential decrease of the response as well as dc resistance upon cooling.
(3) The presence of a peak at the temperature determined by the relation $hI_{\mathrm{cm}}/4\pi e k_B T = 1$.
(4) The high value of responsivity ($\sim 10^2 - 10^3$ V/W) which increases with the film resistance in the normal state.

2.8. Stimulation of superconductivity

An increase in the critical current in thin superconducting bridges induced by EMR was observed for the first time Wyatt *et al.*[83] This was followed by a number of works devoted to this problem (see the review by Dmitriev and Khristenko in Ref. 67). Since stimulation of superconductivity was detected below as well as above T_c, it is often referred to as the effect of stimulation and induction of superconductivity by EMR. For a long time, the effect of stimulation was observed only in weakly coupled superconductors, and was detected much later in narrow, thin, and long films (see Ref. 8 in the literature cited by Dmitriev and Khristenko[67]). Manifestations of the effect in weakly coupled structures and in long homogeneous channels are quite similar, although their mechanisms are different. Besides, the stimulation of superconductivity in bridges is limited by the effective volume of the weak link, while in long channels it is limited by the structure width. The most significant difference between the stimulation in bridges and in long channels is that the superconducting transition temperature and the critical current in the bridge do not exceed corresponding values for the banks. On the contrary, the critical current $I_c(P_\omega)$ in long films exposed to radiation is noticeably larger than the Ginzburg–Landau depairing current. It is appropriate to consider a new state in the MW field with a new energy distribution function for electrons and with the gap $\Delta(P_\omega)$ in the energy spectrum, whose width is larger than that of the unperturbed gap $\Delta(0)$. Long narrow films as well as bridges are characterized by the lower (ω_1) and upper (ω_2) boundary frequencies of the effect. The two boundary frequencies increase upon cooling.

The stimulation effect was initially explained on the basis of phenomenological models (Refs. 5 and 15–18 in the literature cited in Ref. 67) which described its salient features, but failed to explain some peculiarities of the effect (such as the presence of the upper and lower frequency boundaries of the effect, different manifestations of the effect in weakly coupled structures and in long homogeneous superconducting channels, and the coexistence of the Josephson effect with the effect of stimulation and induction of superconductivity in weakly coupled superconductors). The Eliashberg microscopic theory[66] and the Aslamazov–Larkin theory[84] which appeared later described superconductivity stimulation in homogeneous superconductors and in heterogeneous weakly coupled junctions, respectively.

The Eliashberg microscopic theory[66] is based on the assumption that radiation of frequency $\nu < 2\Delta/h$ does not change the total number of excitations in a superconductor, but can lead to a displacement of the "center of gravity" of the electron distribution function $f(\varepsilon)$ towards higher energies due to absorption of the MW energy by excitations located near the edge of the gap. According to the basic equation of the BCS theory connecting the energy gap Δ with the electron distribution function $f(\varepsilon)$, this must lead to an increase in Δ, and hence to the enhancement of superconducting properties of the sample.[66]

According to the Aslamazov–Larkin theory,[84] the order parameter Δ in the contact region of heterogeneous junctions carrying a direct current becomes smaller than the order parameter Δ_0 in the banks outside this region. The electrons with energy $\varepsilon < \Delta_0$ become "trapped" in the contact and move within the potential well, being reflected by its walls. The application of an ac field causes "quivering" of the potential well, and hence to energy diffusion of electrons. As a result, the electron distribution function becomes nonequilibrium, the deviation from equilibrium being most significant at the center of the junction, where the number of electrons decreases as compared to the equilibrium case due to energy diffusion. This is equivalent to effective cooling of the junction. At the same time, electron diffusion may cause the accumulation of electrons in the region of high energies leading to heating of the junction. The resultant effect depends on the radiation power.

The stimulation of superconductivity in HTSC materials by MW radiation was also observed, but it was studied less

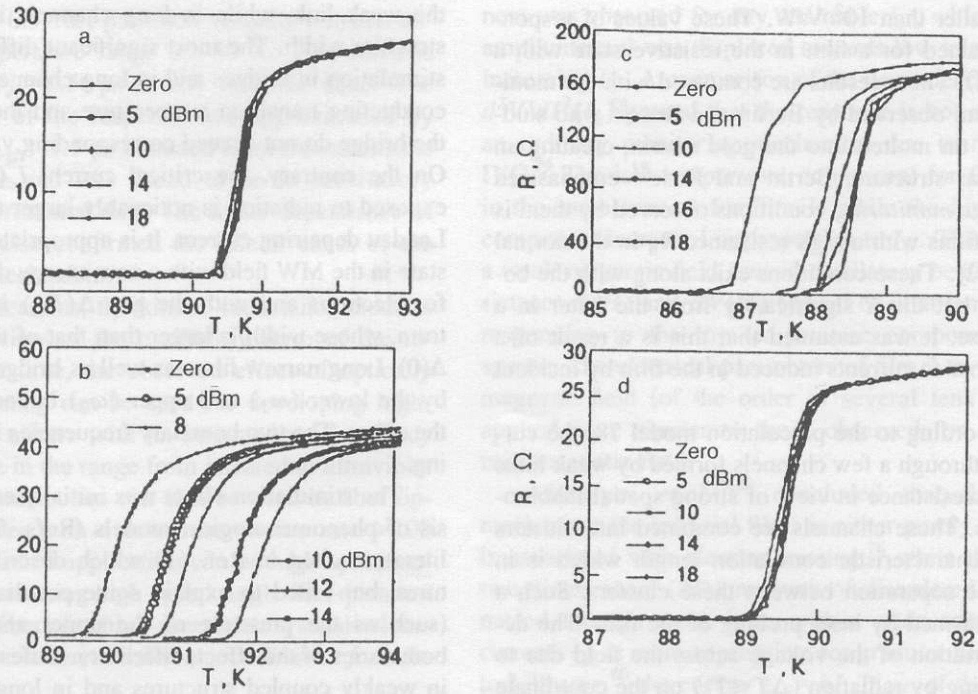

FIG. 24. The $R(T)$ dependence enhanced by microwave radiation for $\theta=24°$ (*a*), 36.8° (*b*), and 45° (*c*). The results for intragranular boundary of a bridge with $\theta=36.8°$ are shown for comparison (*d*). It can be seen that stimulation is significant for weakly coupled junctions (from Fu *et al.*[86]).

comprehensively than in traditional superconductors. This can be explained, above all, by small number of publications in this field, which is due to some peculiarities of new superconductors. For example, the small value of ξ complicates the preparation of weak links with parameters satisfying the conditions limiting the sample size, which must be satisfied to observe stimulation according to the Aslamazov–Larkin mechanism, while the strong electron–electron interaction associated with the small mean free path l hampers the superconductivity stimulation according to the Eliashberg mechanism.[66,67]

First communications concerning the superconductivity stimulation in HTS samples by MW radiation[85] were purely "speculative" and did not lay claims on a detailed description of the observed effect or its analysis. Later, Dmitriev *et al.*[44] reported the observation of nonequilibrium effects in YBaCuO ceramic bridges. Among other things, they observed stimulated excess current in the bridges exposed to MW signal at frequency 13.3 GHz. It was proved that in spite of the emergence of Shapiro steps on IVC as a result of irradiation by MW signal, the dependence of I_c on $P_\omega^{1/2}$ cannot be described by a Bessel function as expected for bridges. On the contrary, this curve consists of two linear regions typical of a long superconducting channel. Dmitriev *et al.*[44] also observed that the passage of direct current for radiation powers higher then the critical value $P_\omega^c(I_c(P_\omega^c)=0)$ leads to a transition from the normal to the resistive state. The transition current I_{tr} increases with the MW power. This effect was observed in HTSC materials for the first time and was attributed to a charge redistribution between "active" CuO_2 planes and the "reservoir" of chains, which is induced by the direct current. This can lead to an increase in the number density of holes in CuO_2 planes, where the holes form pairs. Detailed measurements and an analysis of the results as well as a comparison with available data for low-temperature superconductor led Dmitriev *et al.*[44] to the conclusion that the stimulation of superconductivity in YBaCuO ceramic bridges occurs according to the Aslamazov–Larkin mechanism due to energy diffusion of electrons localized in the constriction region.

Fu *et al.*[86] studied the response of bridges made of YBaCuO epitaxial films on $SrTiO_3$ bicrystalline substrates to MW radiation ($\nu=12.4$ GHz). The typical size of the bridges was 60 μm$\times$20 μm$\times$120 nm. The response of the intragranular as well as intergranular regions was measured simultaneously by using the four-probe technique. The obtained $R(T)$ dependence shows that the normal resistance in a sample region which does not intersect a weak link is an order of magnitude lower, and the transition width is much smaller than the corresponding values for a region intersecting a weak link. Besides, the measurements of IVC for a region intersecting a weak link revealed the presence of steps satisfying the Josephson relation. Fu *et al.* came to the conclusion that the blurring of the transition for a region with a weak link is associated with the formation of PSC.

An analysis of the $R(T)$ dependences for three different disorientation angles θ for the bicrystalline substrate proved that MW power virtually does not affect $R(T)$ for $\theta=24°$, while the value of T_c increases with radiation power for $\theta=36°$ and 45° (Fig. 24). The maximum effect was observed for $\theta=45°$. Since the entire superconducting transition was shifted by 2–3 K above the equilibrium value of T_c, and the value of T_c increases only for the region of weak link, Fu *et al.*[86] believe that the observed phenomenon may be due not only to fluctuations or effects of redistribution of nonequilibrium quasiparticles. It is proposed that stimulation following the Aslamazov–Larkin mechanism takes place in the given case. The measurements of the $I_c(T)$ dependence for weak links with different disorientation angles θ for substrate crystals revealed that it has the form $I_c \sim (1-T/T_c)^2$ typical of weak links of the SNS type for all three junctions. However, a departure (''bend'') from the theoretical dependence is observed for $\theta = 24°$ in a narrow range of low temperatures. Fu *et al.*[86] believe that this confirms the existence of a stronger intergranular coupling inherent in this junction and assume that the difference in the transport properties of the three boundary weak links is due to their geometrical structure; the differences in these structures are also manifested in the $R(T)$ dependences for different values of P_ω (see Fig. 24).

Choudhury *et al.*[87] studied the MW surface impedance of a suspended strip of YBaCuO epitaxial film in a constant magnetic field up to 1000 Oe. The MW magnetic field was parallel to the (ab) plane of the sample, while the constant field was applied along the **c**-axis. It was found that a weak magnetic field (of the order of several oersteds) leads to a decrease in R_s. The maximum effect ($\sim 20\%$) was observed in a field of 5 Oe. while superconductivity suppression (increase in R_s) was observed in a field above 25 Oe. The measurements of the $R_s(H)$ dependence upon sweeping of H from -100 to $+100$ Oe revealed that a hysteresis of the MW response (i.e., the lack of coincidence in the shape of the magnetic-field dependence with the initial curve upon repeated field sweeping) appears even for low radiation powers (by 21 dB·m below 1 mW). It was concluded[87] that the MW field competes with the constant field, leading to the emergence of vortices in the sample, which are subsequently entangled with lattice defects (pinning). It was proposed that the observed decrease in R_s is due to nonequilibrium redistribution of quasiparticles, which is induced by MW radiation and leads to superconductivity stimulation in the presence of direct current I_{dc}. It was also emphasized that since HTSC materials exhibit a nonmonotonic dependence $R_s(T)$ ($dR_s/dT<0$), the manifestation of the effect for which $dR_s/dI_{dc}<0$ is not surprising.

Salient features and conditions for the realization of the mechanism

(1) Superconductivity simulation is observed in heterogeneous and long homogeneous superconducting channels and is manifested experimentally in an increase in superconducting transition temperature and critical current and a decrease in the dc or ac resistance. In bridges and other types of spatially inhomogeneous weak links, the stimulation follows the Aslamazov–Larkin mechanism, while in long and narrow channels it is governed by the Eliashberg mechanism.

(2) Both mechanisms are characterized by the existence of the lower and upper boundaries of the effect, the corresponding frequencies increasing upon cooling.

(3) The decisive role in the emergence of the effect in heterogeneous junctions is played by their volume (which must be smaller than a certain value), while for narrow homogeneous channels the leading role is played by their width (which must satisfy the same requirement).

(4) The main difference between superconductivity stimulation in bridges and in long homogeneous channels is that the critical temperature (or critical current) of the former never exceed the same for the ''banks,'' while the critical current for the channels can not only be larger than the value of I_c in the absence of radiation, but can even exceed the equilibrium depairing current.

CONCLUSIONS

Thus, bolometric and nonbolometric mechanisms can obviously be realized in HTSC materials of any quality. The main nonequilibrium mechanism for granular samples exposed to radiation at frequencies $\nu \ll 2\Delta/h$ is the inverse transient Josephson effect for which the peak of the response lies in the region of resistive ''tail'' of the temperature dependence of resistance and is separated by a considerable temperature interval from the peak of the bolometric response. As the sample quality is improved, the peaks of the nonbolometric and bolometric responses become closer and almost coincide for high-quality epitaxial films. The prevailing mechanisms of the nonequilibrium response are either the radiation-induced flow of magnetic flux trapped in weak links or in granules (in the presence of a strong constant magnetic field), or the phase slip at intergranular weak links and Josephson junctions formed by overlapping segments of adjacent copper-oxygen planes. In spite of the fact that the peaks of the response of the above-mentioned ''high-temperature'' mechanisms almost coincide on the temperature scale with the peaks of the bolometric component, they can be analyzed by using contactless methods of recording (which do not lead to strong nonlinear effects and heating due to a large contact resistance), and the incident radiation with a frequency $\gtrsim 10$ kHz can be modulated in order to eliminate the bolometric effect.

At radiation frequencies $\nu > 2\Delta/h$, electron heating and nonequilibrium variation of kinetic inductance are the dominating nonthermal mechanisms over virtually the entire temperature range below T_c. The fundamental parameters typical of these mechanisms can be observed by monitoring the response by the ''pump–probe'' method in which the signal from the same source (laser) is used to act on the sample and to measure the response (after attenuation and delay). This method is rather effective in the case of short (<1 ps) radiation pulses which do not impose limitations on characteristic times of the response of the picosecond scale. The only drawbacks of the ''pump–probe'' method are its technical complexity and the high cost of the precision instruments. For this reason, monitoring with RF or MW displacement as a simpler economical method can be considered an alternative. However, limitations on the response times as well as the inertia of RF monitoring technique must be determined beforehand.

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