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LETTER TO THE EDITOR

Laser enhancement of radiation detection sensitivity of a YBCO film

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Abstract. We report experimental results which demonstrate the laser enhancement of the sensitivity of a $YBa_2Cu_8O_{7-\delta}$ film as a radiation detector and the existence of a non-thermal optical response. The bias continuous wave laser beam enhances the sensitivity at higher chopping frequency range (more than 80 Hz) near the critical temperature of the film. The enhancement shows the non-bolometer response.

In the past few years much effort has been focused on the investigation of optical effects on high-T_c superconductors. In particular, investigations have been made into how superconducting electrical properties have thereby been affected. Much attention has also been paid to the question of whether the non-thermal optical response is included, independent of the thermal (i.e. bolometric) mechanism, in a superconducting film. This is essential to superconducting physics and for potential optical applications of high-T_c superconductors, for example, its application for radiation detection. It can be expected that the non-thermal optical response of a superconducting film as a radiation detector is faster than the bolometer response. Zeldov *et al* [1] indicated that there was a strong non-bolometric response in an epitaxial $YBa_2Cu_8O_{7-\delta}$ (YBCO) film at temperatures below the onset of the superconducting transition. Nieva *et al* [2] and others reported the photo-induced enhancement of superconductivity and transient observations of the optical response in some superconducting materials by short laser pulses [3–5]. In this letter we report a new type of observational method and the experimental results which demonstrate the laser enhancement of the sensitivity of a YBCO film as a radiation detector and the existence of a non-thermal optical response along with the thermal response.

Theoretically, the resistance–temperature (R–T) curve of a superconducting film will change when it is irradiated by laser beams with total intensity I, since its resistance is a function of both temperature $T(I)$ and concentration of laser induced carriers, $n(I) : R = R(T(I), n(I))$. In our experiment we used two laser beams from two He–Ne lasers (632.8 nm) with output powers of 1.2 mW and 40 mW, respectively; a strong continuous wave beam with intensity I_{cw} and a weak chopped beam with intensity I_{ch} at a chopping frequency ν. We have, thus, approximately $T(I) = T(0) + \alpha_{cw}I_{cw} + \alpha_{ch}(\nu, \tau_t)I_{ch}$ and $n(I) = n(0) + \beta_{cw}I_{cw} + \beta_{ch}(\nu, \tau_c)I_{ch}$, where τ_t and τ_c are the thermal relaxation time constant and the life of the laser induced carriers, respectively. The superconducting YBCO film (100 nm in thickness) was prepared by radio frequency sputtering on a $SrTiO_3(100)$ or $ZrO_2(100)$ substrate and patterned into an 'H' structure using photolithography. The central bridge region which linked two pads was 1×2 mm^2. Two silver contacts were vapour deposited onto each pad. The measurement was performed using the four-probe technique. The critical temperature T_c of the films is about 85 K. The sample was adhered to bulk copper

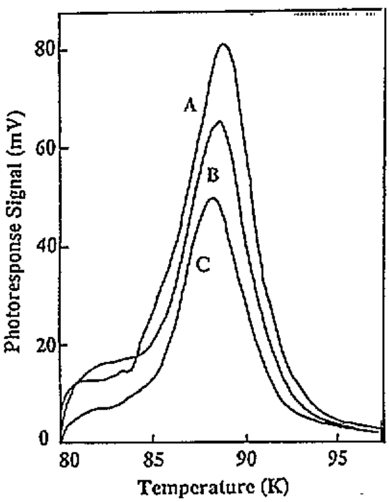

Figure 1. Temperature dependent photoresponse signals of the YBCO sample at the chopping frequency of 25 Hz. Curves A, B and C correspond to the powers of the bias laser beams of 0, 20 and 30 mW, respectively.

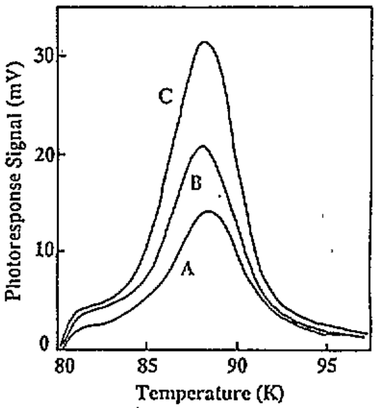

Figure 2. Temperature dependent photoresponse signals of the YBCO sample at the chopping frequency of 500 Hz. Curves A, B and C correspond to the powers of the bias laser beams of 0, 20 and 30 mW, respectively.

in which a Rh–Fe thermoelectric resistor was embedded. The bulk copper was then placed in a Dewar. The temperature of the sample was changed by evaporation of liquid nitrogen to increase the gap between the surface of the liquid nitrogen and the sample. With a constant current (i) supply, the measurement signal $i\langle\Delta R\rangle$ by a lock-in amplifier is proportional to the root of the mean square of ΔR : $\langle\Delta R\rangle \simeq \langle\Delta R\rangle_0 + [a\alpha_{ch}(\nu, \tau_t) + b\beta_{ch}(\nu, \tau_c)]i_{cw}\langle I_{ch}\rangle$ where $\langle\Delta R\rangle_0$ is the value when $I_{cw} = 0$. The power of the probe laser beam was 1.2 mW. In figures 1 and 2, the curves A, B and C correspond to the bias laser power of 0, 20 and 30 mW, respectively. It is obvious that there is a striking contrast between these two figures. The peak value of the photoresponse signal corresponding to $i\langle\Delta R\rangle$ decreases with increasing power of the bias beam at 25 Hz but increases with it at 500 Hz. The same phenomena were seen repeatedly in the other YBCO films used. The experimental result for the frequencies of 25–1000 Hz show that the continuous wave laser beams enhance the sensitivity of the film as a weak radiation detector at higher chopping frequency range (more than 80 Hz) but reduce it a $\nu < 80$ Hz near the critical temperature of the YBCO film. This means that $a\alpha_{ch}(\nu, \tau_t) + b\beta_{ch}(\nu, \tau_c) = 0$ near 80 Hz, $\langle\Delta R\rangle < \langle\Delta R\rangle_0$ at $\nu < 80$ Hz and $\langle\Delta R\rangle > \langle\Delta R\rangle_0$ in the range 80–1000 Hz (even more). For example, $\langle\Delta R\rangle \simeq 2\langle\Delta R\rangle_0$ with a continuous wave beam of 30 mW at 500 Hz, that is, the enhancement factor is two. The enhancement shows the non-bolometer response. The mechanism remains to be investigated.

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