

TIME (DO NOT FILL IN)

**Time-resolved spectroscopy of superconductors using synchrotron radiation**X. Xi,<sup>a)</sup> J. Hwang,<sup>a)</sup> H. Zhang,<sup>a)</sup> C.S. Stanton,<sup>a)</sup> D.H. Reitze,<sup>a)</sup> D.B. Tanner,<sup>a)</sup> and G.L. Carr<sup>b)</sup>*a) Physics Department, University of Florida, Gainesville, FL 32611**b) National Synchrotron Light Source, Brookhaven National Laboratory, Upton, NY 11973*

The National Synchrotron Light Source provides several beamlines which deliver high-brightness infrared synchrotron radiation. A combination of beamline design features and spectroscopic instrumentation allows the facility to reach the extremely low frequency limit of  $2\text{ cm}^{-1}$  ( $\sim 60\text{ GHz}$  or  $0.25\text{ meV}$ ). A 10 T magnet is also available. A key capability of the synchrotron is the capability for sub-nanosecond time-resolved (pump-probe) infrared spectroscopy. A mode-locked Ti:sapphire laser produces picosecond near-infrared or visible pump pulses that are synchronized to broadband infrared probe pulses from the synchrotron. A temporal resolution of  $\sim 200\text{ ps}$ , limited by the synchrotron pulse duration, may be achieved. We have used this facility to study quasiparticle recombination in metallic superconductors, including the effects of magnetic field.

We generate quasiparticles in metallic superconductors by breaking Cooper pairs with our Ti:sapphire laser. These excitations quickly relax to the gap edge and then, more slowly, recombine with partners of opposite spin, releasing the pair gap energy mainly as phonons. The effective quasiparticle recombination rate is determined by multiple factors. We observe a bottleneck effect [1] in the relaxation because the recombination to Cooper pairs is controlled by a balance between the densities of broken pairs (quasiparticles) and superconducting-gap-energy phonons (which are pair-breakers). Besides this well-known effect, the quasiparticle excitation spectrum is also expected to play an important role. Evidence for these factors comes from a pump-probe study of  $\text{Nb}_{0.5}\text{Ti}_{0.5}\text{N}$  thin films in magnetic fields up to 10 T. Excess quasiparticles were produced with laser pulses and probed with far-infrared synchrotron pulses. We find that the recombination rate decreases with increasing magnetic field. This effect is most noticeable for the case where the external magnetic field is oriented parallel to the sample surface, minimizing the effect of vortices in the type II superconducting film. To explain this effect, we consider how a magnetic field modifies the quasiparticle excitation spectrum through the Pauli paramagnetism of the quasiparticles. The Zeeman contribution shifts the energies of the spin-up and spin-down populations, making a spin-polarized quasiparticle population. In addition, the field modifies the gap itself through pair lifetime effects. Both of these may affect the recombination rate [2]. The dependence of the effect on temperature, magnetic field, field orientation, and laser fluence will be discussed.

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[2] S.B. Kaplan *et al*, *Phys. Rev. B* **14**, 4854 (1976)