Measuring the relaxation time of the photo-induced perturbation of the superconducting state (often referred to as a “hotspot”) in current-biased superconducting nanowires may shed new light on the photodetection mechanism of superconducting single photon detectors and on the quasiparticle thermalization in superconductors. Here we report on the measurement of the relaxation time of optically excited hotspots in current-carrying WSi superconducting nanowires as a function of bias current ($I_B$), temperature ($T$) and excitation wavelength ($\lambda$). Our investigation yielded the discovery of an unexpected effect, that the hotspot relaxation time ($t_{HS}$) depends on the bias current ($I_B$) carried by the superconducting nanowires.

We measured $t_{HS}$ by operating a fiber-coupled WSi SNSPD [1] at lower bias currents than that used for single-photon detection. In this bias range the detector delivered an output pulse only if two (or more) photons created hot spots that overlapped spatially and temporally. We illuminated the detector with a pulse-pair source and measured the photoresponse count rate ($PCR$) as a function of the time delay ($t_D$) between the pulses. We measured $PCR$ vs $t_D$ curves as a function of $I_B$ at several temperatures and wavelengths. Figure 1a shows $PCR$ vs $t_D$ curves measured at different bias currents. Surprisingly, $PCR$ vs $t_D$ curves became broader as the bias current increased. We defined $t_{HS}$ as the full width at half maximum of each $PCR$ vs $t_D$ curve. Figure 1b shows the $t_{HS}$ vs $I_B$ curve extracted from the data shown in Figure 1a. When $I_B$ was increased from $I_B = 1.9 \mu A$ to $I_B = 3.5 \mu A$, $t_{HS}$ increased by one order of magnitude from $t_{HS} \approx 80$ ps to $t_{HS} \approx 800$ ps. To our knowledge, this effect had not been observed before.

The shortest hotspot relaxation time measured in our WSi SNSPD is a factor of $\sim 4$ longer than that measured with NbN (15-30 ps [2,3]), which may limit the maximum count rate of WSi SNSPDs to a lower value than NbN SNSPDs, due to latching [4,5] or afterpulsing [6].

Figure 1. a. Normalized $PCR$ vs $t_D$ curves measured with the detector operating in two-photon detection regime at $I_B = 1.9 \mu A$ (red); 2.3 $\mu A$ (orange); 2.7 $\mu A$ (green); 3.1 $\mu A$ (cyan); 3.5 $\mu A$ (blue). The black arrow indicates the direction of increasing $I_B$. Each of the $PCR$ vs $t_D$ curves was normalized so that the maximum value of the corresponding Lorentzian fit curve was 2. b. $t_{HS}$ vs $I_B$ curve extracted from fits to the data in panel a. These measurements were performed at $\lambda = 1550$ nm, and $T_B = 0.25$ K.

The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

References