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The spatial resolution and fluorescence signal amplitude in stimulated emission depletion (STED) microscopy is limited by the photostability of available fluorophores. Here, we show that negatively-charged silicon vacancy (SiV) centers in diamond are promising fluorophores for STED microscopy, owing to their photostable, near-infrared emission and favorable photophysical properties. A home-built pulsed STED microscope was used to image shallow implanted SiV centers in bulk diamond at room temperature. The SiV stimulated emission cross section for 765-800 nm light is found to be $(4.0 \pm 0.3)\times10^{-17}$ cm^2, which is approximately 2-4 times larger than that of the negatively-charged diamond nitrogen vacancy center and approaches that of commonly used organic dye molecules. We performed STED microscopy on isolated SiV centers and observed a lateral full-width-at-half- maximum spot size of 89 ± 2 nm, limited by the low available STED laser pulse energy (0.4 nJ). For a pulse energy of 5 nJ, the resolution is expected to be $\sim$20 nm. We show that the present microscope can resolve SiV centers separated by $\lesssim$ 150 nm that cannot be resolved by confocal microscopy.