We report direct measurement of S-branch Raman coherence lifetimes of CO$_2$ due to CO$_2$-CO$_2$ collisions by employing picosecond time-resolved coherent anti-Stokes Raman scattering (CARS) spectroscopy. A custom-built, high-peak-power, nearly transform-limited ps laser system offers an ideal combination of frequency and temporal resolution for such measurements. The rotational S-branch transitions of CO$_2$ ground state [0,0$^0$,0] with rotational quantum number J = 0 – 52 were simultaneously excited by using a broadband (∼3-nm) laser pulse with a full-width-half-maximum (FWHM) of ∼100 ps. The coherence lifetimes of self-broadened CO$_2$ for a pressure range of 0.05-1.5 bar were directly measured by probing the rotational coherence with a nearly transform-limited, 80-ps-long laser pulse. The measured linewidth of J=6 and J=50 transitions are found to be ∼0.106±0.0002 and ∼0.070±0.0002, respectively. As expected, the energy-transfer from high J levels has a significantly longer coherence lifetime because of the inertia associated with higher angular momentum. These measurements are very significant for performing accurate thermometry or CO$_2$ concentration measurements in gas-phase reacting flows.