Simultaneous Coherence Enhancement of Optical and Microwave Transitions in Solid-State Electronic Spins

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Solid-state electronic spins are extensively studied in quantum information science, both for quantum computation, sensing and communication. Electronic spins are highly interesting due to their large magnetic moments, which offer fast operations for computing and communication, and high sensitivity for sensing. However, the large moment also implies higher sensitivity to a noisy magnetic environment, which often reduces coherence times. Yet, engineering of the spectroscopic properties of electronic spins, e.g. using clock transitions and isotopic engineering, can yield remarkable spin coherence times, as for electronic spins in GaAs, donors in silicon and vacancy centres in diamond. For no material it has been demonstrated, however, that such coherence enhancement techniques can be obtained at the same time for spin and optical transitions. Here we demonstrate simultaneously induced clock transitions for both microwave and optical domains in an isotopically purified $^{171}$Yb$^{3+}$:Y$_2$SiO$_5$ crystal, reaching coherence times of above 100 µs and 1 ms in the optical and microwave domain, respectively. This effect is due to the highly anisotropic hyperfine interaction, which makes each electronic-nuclear state an entangled Bell state. In particular, our results shows the great potential of $^{171}$Yb$^{3+}$:Y$_2$SiO$_5$ for quantum processing applications relying on both optical and spin manipulation, such as optical quantum memories, microwave-to-optical quantum transducers, and single spin detection. In general, similar effects should also be observable in a range of different materials with anisotropic hyperfine interaction.