Quantum sensing for deep tissue magnetic resonance imaging

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The development of quantum technologies is an area expected to revolutionize medical diagnosis by taking advantage of quantum information processing to improve devices, such as sensors. Quantum sensors will serve applications ranging from thermometry to diagnostic imaging with sub-micrometer resolutions [1-4]. The current spatial resolution of non-invasive in-vivo magnetic resonance imaging (MRI) is limited to a scale of millimeters in conventional imaging modalities. However, relevant tissue microstructure details and processes linked to disease occur at molecular and microstructural scales governed by the laws of quantum physics. We use nuclear spins of molecules intrinsic to biological systems (e.g. water protons) as quantum sensors of their environment and control them with magnetic resonance techniques to characterize quantitatively the underlying microstructure efficiently in time and precision (Figure 1) [1,4-7]. We exploit fundamental concepts of quantum mechanics developed within the area of quantum information sciences, as quantum-control and -information theory tools to non-invasively quantify deep tissue-microstructure parameters such as cell-sizes or axon diameters [4-5]. This allows us to resolve structures with length scales that are about 100 times smaller than the actual imaging resolution.

References

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Figures

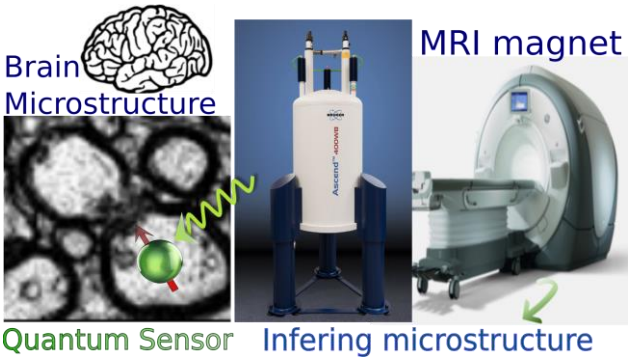

Figure 1: Schematic quantum sensing for improving tissue microstructure resolution by Magnetic Resonance Imaging