4D Magnonics and Beyond: Key Phenomena and a Technology Roadmap

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We analyse the state of the art and sketch a roadmap for further progress in magnonics in terms of the dimensionality of involved spin-wave phenomena. The early studies of spin waves in uniform stationary media were followed by investigations of systems with one-dimensional (1D) variations of their properties. The XXI century renaissance of magnonics can be attributed to studies of spin waves in 2D structures, which are now expected to be superseded by 3D magnonic architectures. While the latter revolution has been hindered for both technological and fundamental reasons, a workaround may be offered by 4D magnonics, which takes advantage of time as the fourth dimension and roots in the pioneering research from 1960ss. Furthermore, magnetic hysteresis and micromagnetics give magnonic architectures a natural reconfigurability, which is widely perceived as the fifth dimension and brings us to 5D magnonics as the klondike of spin-wave phenomena of ultimate complexity and scientific beauty. This nomenclature is mapped straightforwardly onto the perceived applications of spin-wave research in traditional, neuromorphic, and quantum computing devices: 1D magnonics caters readily for the signal processing; 2D magnonics favours technologies benefiting from spatial multiplexing, such as basic logic circuits and reservoir computing, the key performance indicators of which can be enhanced enormously by 3D magnonics; 4D magnonics will underpin schemes exploiting time multiplexing and quantum computing; and 5D magnonics will be the key enabler of in-memory computing and field-programmability, as well as inverse design and training of artificial neuron networks.