

# Generation of n-qubit W states using Spin Torque

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**Short Abstract.** W-states are symmetric-multipartite states where the constituent parties share a single excitation in the form of uniform superposition of all one-hot basis states. Due to its entanglement and robustness properties, it is an important resource for various quantum information as well as communication tasks, and hence, its efficient preparation is of immense interest to the community. We have worked out a deterministic scheme to prepare arbitrary W states in an n-qubit system with all-to-all connectivity in  $O(\log n)$  stages. This is a significant improvement over existing linear step preparation algorithms. We have also discussed how such an all-to-all connectivity can be engineered indirectly in the one-hot subspace (of the full Hilbert space) of a system of spin-impurities interacting successively with itinerant electrons.

**Keywords:** Quantum State Preparation, W state, Spin Torque Quantum Computing (QC) Architecture

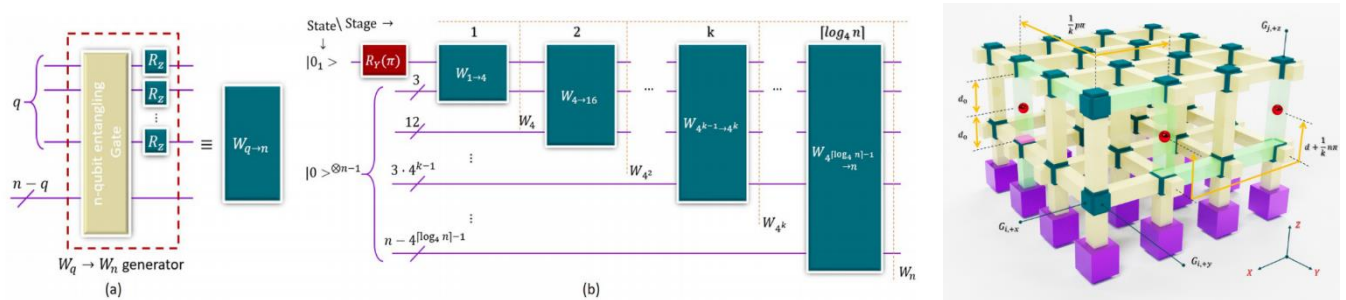
## Extended Abstract:

**1 Introduction/Motivation.** Preparing arbitrary quantum states is by itself an important research problem. Among the vast variety, certain states exhibiting high degree of entanglement, like W states, are extremely useful. While there exist schemes for W state preparation and their demonstrations in several potential NISQ devices, the cost of many deterministic schemes scales at best linearly with the number of qubits. It is understood that error accumulates with circuit-depth in noisy devices and therefore finding lower-depth preparation algorithms is warranted. It is also known that architecture-aware compilation can improve the fidelity of an algorithm implementation, therefore tailoring algorithms according to architectures under consideration is also immensely useful.

**2 State Preparation Algorithm.** We approach this task studying unitary time evolutions in a system of  $n$  spin-

$1/2$  particles coupled pairwise via direct exchange interaction. We show analytically that it is possible to expand a W state of  $q$  qubits to a W state of  $n$  qubits, by appending ground states to the initial state and evolving the combined system for appropriate time. The relative phase factors in the evolved state are corrected via single qubit rotations. It turns this expansion is feasible as long as  $q < n \leq 4q$ . Relying on this expansion, we formalize a scheme to generate an  $n$  qubit W state in  $\lceil \log_4 n \rceil$  stages.

**3 Potential Implementation.** In Ref. [1], we extend a quantum computing architecture, first considered by Ref. [2] to illustrate a CNOT gate, but with more number of qubits. It is modelled via scattering of spin-current from a spin-coherent channel containing spin-impurities. With proper design we show that it is possible to emulate an all-coupled interaction among the spin-impurities in a one-hot subspace (spanned by computational basis states with a single 1 in the literal).



**Figure.** (1) Quantum Circuit representation of state preparation algorithm. (2) Proposed arrangement of spin qubits (red) and reservoirs (purple) adapted from the spin-torque based QC architecture proposed in Ref.[2].

## References:

- [1] Sharma, Amritesh, and Ashwin A. Tulapurkar. "Generation of n-qubit W states using spin torque." Physical Review A 101.6 (2020): 062330.
- [2] B. Sutton and S. Datta, Manipulating quantum information with spin torque, Scientific reports 5, 17912 (2015).