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Self-Correcting Quantum Computers: New Physical Aspects

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Abstract:

I review the notions of bare (unprotected) quantum computers (QC), externally protected QCs [1] and internally protected QCs. Quantum topological states are used as a resource to achieve for the first time a fully-fledged quantum device like a quantum computer, including self-correcting initialization, measurements and quantum gates [2]. This construction is based on Topological Color Codes [3,4] which have very nice and powerful transversality properties which allow them to perform quantum tasks like topological quantum distillation, teleportation, dense coding etc. There are recent proposal to experimentally realize Topological Color Codes using Rydberg atoms in several platforms [5]. The underlying physical phenomena in these new quantum devices is the notion of topological order: a new paradigm in strongly correlated systems. We show how quantum topologically protected states can be constructed not only in 2D space but also in higher dimensional systems [6]. Further implications of self-correction will be explored. REFERENCES: -[1]-"Error Threshold for Color Codes and Random 3-Body Ising Models" H. G. Katzgraber, H. Bombin, M. A. Martin-Delgado Phys. Rev. Lett. 103, 090501 (2009) -[2]-"Self-Correcting Quantum Computers" H. Bombin, R. W. Chhajlany, M. Horodecki, M.A. Martin-Delgado (2009) -[3]-"Topological Quantum Distillation" H. Bombin, M.A. Martin-Delgado Phys.Rev.Lett. 97 (2006) 180501 -[4]-"Topological Computation without Braiding" H. Bombin, M.A. Martin-Delgado Phys.Rev.Lett.98:160502, (2007) -[5]-"Digital Coherent and Dissipative Quantum Simulations with Rydberg Atoms" Hendrik Weimer, Markus Mller, Igor Lesanovsky, Peter Zoller, Hans Peter Buchler Nature Phys. 6, 382-388 (2010) -[6]-"Exact Topological Quantum Order in D=3 and Beyond: Branyons and Brane-Net Condensates" H. Bombin, M.A. Martin-Delgado Phys.Rev.B75:075103, (2007)