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High-dimensional one-way quantum processing implemented on d-level cluster states

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Reimer, C.[a,b], Sciara, S.[a,c], Roztocki, P.[a], Islam, M.[a], Romero Cortés, L.[a], Zhang, Y.[a], Fischer, B.[a], Loranger, S.[d], Kashyap, R.[d,e], Cino, A.[c], Chu, S.T.[f], Little, B.E.[g], Moss, D.J.[h], Caspani, L.[i], Munro, W.J.[j,k], Azaña, J.[a], Kues, M.[a,l], Morandotti, R.[a,m,n]

[a]Institut National de la Recherche Scientifique (INRS-EMT), Varennes, QC, Canada
[b]John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, United States
[c]Department of Energy, Information Engineering and Mathematical Models, University of Palermo, Palermo, Italy

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Abstract

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Taking advantage of quantum mechanics for executing computational tasks faster than classical computers[1] or performing measurements with precision exceeding the classical limit[2,3] requires the generation of specific large and complex quantum states. In this context, cluster states[4] are particularly interesting because they can enable the realization of universal quantum computers by means of a 'one-way' scheme[5], where processing is performed through measurements[6]. The generation of cluster states based on sub-systems that have more than two dimensions, d-level cluster states, provides increased quantum resources while keeping the number of parties constant[7], and also enables novel algorithms[8]. Here, we experimentally realize, characterize and test the noise sensitivity of three-level, four-partite cluster states formed by two photons in the time[9] and frequency[10] domain, confirming genuine multi-partite entanglement with higher noise robustness compared to conventional two-level cluster states[6,11–13]. We perform proof-of-concept high-dimensional one-way quantum operations, where the cluster states are transformed into orthogonal, maximally entangled d-level two-partite states by means of projection measurements. Our scalable approach is based on integrated photonic chips[9,10] and optical fibre communication components, thus achieving new and deterministic functionalities. © 2018, The Author(s), under exclusive licence to Springer Nature Limited.

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