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

([Article in press](#) ?)Reimer, C.^{a,b}, Sciarra, 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} [✉](#) [👤](#)^aInstitut National de la Recherche Scientifique (INRS-EMT), Varennes, QC, Canada^bJohn A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, United States^cDepartment of Energy, Information Engineering and Mathematical Models, University of Palermo, Palermo, Italy[View additional affiliations](#) [v](#)

Abstract

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Taking advantage of quantum mechanics for executing computational tasks faster than classical computers¹ 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 states⁴ are particularly interesting because they can enable the realization of universal quantum computers by means of a 'one-way' scheme⁵, where processing is performed through measurements⁶. 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 constant⁷, and also enables novel algorithms⁸. Here, we experimentally realize, characterize and test the noise sensitivity of three-level, four-partite cluster states formed by two photons in the time⁹ and frequency¹⁰ 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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