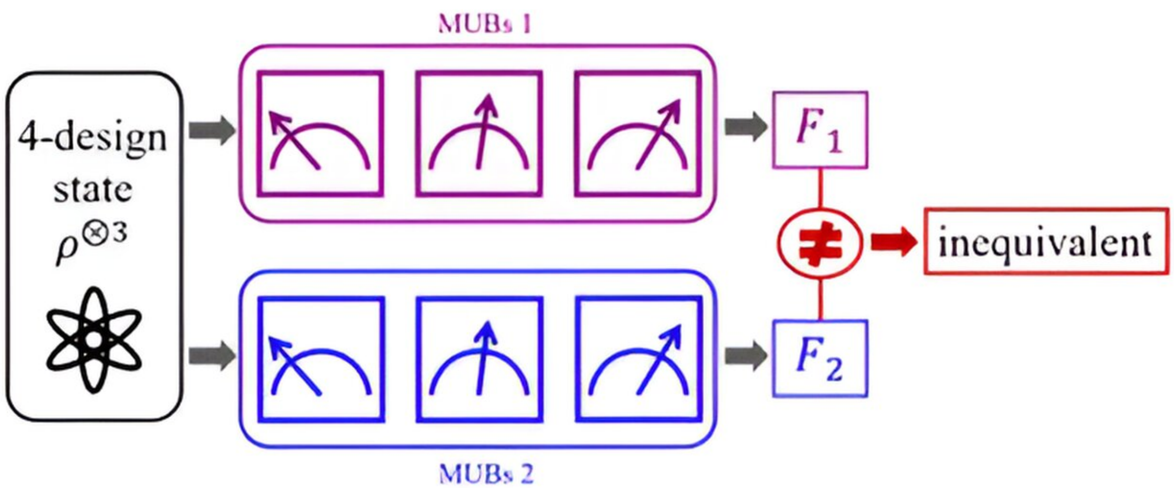
Experimental demonstration of inequivalent mutually unbiased bases for quantum information processing

May 15 2024



Basic idea for distinguishing inequivalent triples of MUBs. Credit: USTC

Research groups demonstrated for the first time that inequivalent mutually unbiased bases (MUBs) have different information extraction capabilities for quantum information processing. The research results were published in *Physical Review Letters*.

Complementary observables, such as coordinates and momentum, are core concepts in quantum mechanics. The corresponding measurements are called mutually unbiased measurements, which are inextricably linked to MUBs.

MUBs are deeply related to both the complementarity principle and the uncertainty relation, playing an important role in the fundamental study of quantum mechanics. It is shown that not all unbiased bases are equivalent. Inequivalent MUBs can be constructed when the dimension of the Hilbert space is equal to or more than 4.

Most of the related studies have been confined to the mathematical differences of inequivalent MUBs, and seldom deal with the endowment differences of inequivalent MUBs in quantum information processing. Therefore, the researchers were interested in whether inequivalent MUBs would show significant differences in quantum information processing.

Starting from a simple quantum estimation problem, the researchers proposed a new method to distinguish the operational distinctions between inequivalent MUBs. In particular, the three-copy estimation fidelity can distinguish between inequivalent MUBs in a dimension 4 Hilbert space.

In order to facilitate the experimental demonstration of this method, researchers constructed two 4-designs with smaller cardinalities in dimension 4, one of which was generated with the Clifford group, and the other which was generated by a numerical optimization procedure.

The 4-designs-based ensemble of pure states ensures that the estimation fidelity does not depend on the unitary transformations, thus reflecting the intrinsic properties of unbiased bases.

The research team, by employing the high-precision multi-copy optical quantum precision measurement platform, experimentally verified that inequivalent MUBs in 4-dimensional space had different information extraction capabilities in the actual measurement of three-copy quantum states

With mutually unbiased measurements used in the experiment for quantum state information extraction, it was revealed that the estimation fidelity was related to the intrinsic properties of the MUBs.

With the different selection of the MUBs, the experimentally obtained maximum fidelity differs from the minimum fidelity by about 4%, and it responded well to the theoretical prediction with only 0.16% average deviation.

This study marks a big step forward in the study of inequivalent MUBs, and it has potential applications in many quantum information processing tasks such as quantum state estimation, entanglement detection and quantum communication.

The research groups include Prof. Li Chuanfeng, Prof. Xiang Guoyong and Prof. Hou Zhibo, led by Academician Guo Guangchan from University of Science and Technology of China (USTC) of Chinese Academy of Science (CAS), in collaboration with Professor Zhu Huangjun from Fudan University,

More information: Wen-Zhe Yan et al, Experimental Demonstration of Inequivalent Mutually Unbiased Bases, *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.132.080202

Provided by University of Science and Technology of China