Abstract

Contextuality, as a distinguishing feature of quantum mechanics, can be revealed by state-independent contextual (SI-C) sets and corresponding inequalities. Optimal SI-C inequalities have been studied in [Phys. Rev. Lett. 109, 250402 (2012)] for the ideal scenario. By taking the SI-C set with 13 rays as an example, we investigate the optimal SI-C inequalities under experimental imperfections, characterized by detection inefficiency and detection error of outcome flip. We first discovered all the extremal symmetric optimal inequalities. Then our results identify the thresholds of detection efficiency and rate of detection error for those optimal symmetric inequalities in the heralded and unheralded scenarios. By incorporating measurement disturbance terms, we extend noncontextuality inequalities to capture the disturbance caused by imperfect detection efficiency in sequential measurements. As it turns out, the detection efficiency should be no less than 0.94741 in the heralded scenario and 0.98244 in the unheralded scenario. Our findings provide valuable insights for designing robust experimental tests of quantum contextuality in realistic settings.