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位相空間で量子干渉の実験検証

Demonstration of quantum interference in phase space

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The concept of interference in phase space depends on the semi-classical interpretation of the quantum mechanical scalar product between two quantum states. It has been used to interpret the oscillation distribution in photon number for a highly squeezing state [1, 2]. What will happen when the squeezed parameter becomes too small to be measured using a macroscopic method? In this report, we experimentally demonstrated oscillation distribution of four-photon state, which cannot be characterized with a squeezed state, generated from a single-pass degenerated optical parametric amplifier (OPA). We applied interference of two waves in the phase space to the oscillatory photon statistics of four photons. It can be considered as an amplitude probability distribution of quantum wave-function due to the phase modulation in the phase space areas of the quantum system of the OPA.

Fig. 1 shows the schematic setup of our experiment. A continuous-wave mode-locked laser and its second harmonic generated (SHG) light are injected into the OPA using a Type-I BBO crystal. The distribution of photon number was measured and evaluated by measuring the coincidence counts of single-photon detectors (D1~4). The results of our experiment showed that the distribution of photons exists oscillation for fourfold coincidence counts from the OPA when the coherent laser increased, while the coherent laser has a Poisson distribution, as shown in Fig. 2. Here, the oscillator distribution of four-photon state can be qualitatively explained by using the formalism of interference in phase space. We consider the quantum state generated from the OPA, $|\varphi\rangle$, as a highly elongated ellipse, and the four-photon state, $|4\rangle$, as a circle band in phase space. The two parts combined to create two symmetrically located areas of overlap A_4. Each area A_4 corresponds to one probability amplitude, so we get $\langle 4|\varphi\rangle = \sqrt{A_4}e^{i\phi_4} + \sqrt{A_4}e^{i\phi_4}$ according to the concept of interference in phase space. We thus arrive at, $P_4 = |\langle 4|\varphi\rangle|^2 = \left|\sqrt{A_4}e^{i\phi_4} + \sqrt{A_4}e^{i\phi_4}\right|^2 = 4A_4\cos^2\phi_4$. Both the amplitude factor A_4 and the interference determining phase, ϕ_4, depend on the photon number of coherent laser. There are two phase-periods of ϕ_4 to induce two waves of distribution of four photons as increasing the coherent laser, as shown in Fig. 2. We will quantitatively describe this result in in the future work. References: [1] W. Schleich and J. A. Wheeler, Nature, 326, 574, (1987). [2] A. Segundo and J. L.Bonilla, Chin. J. Phys. 47, 633 (2009).

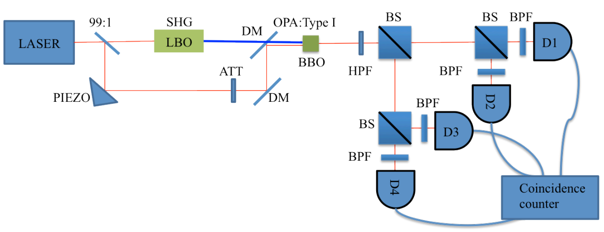

Fig. 1 Schematic setup of multi-photon interference in phase space (LASAR: Ti:sapphire pulse laser @ 800 nm, 99:1: Beam-splitter with 99:1 ratio, ATT: Attenuator, DM: Dichroic mirror HT@400nm HR@800nm, SHG: Second harmonic generation, LBO: 15-mm Type-I LBO crystal, HPF: High-pass fitter, BS: Beam splitter, BPF: Band-pass fitter, D1~4: Single-photon detector)

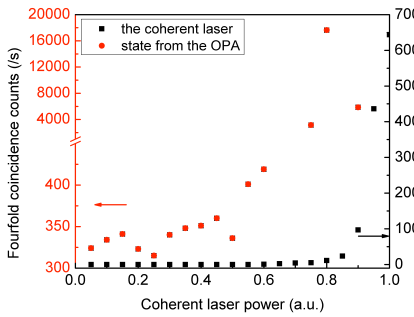

Fig. 2 Fourfold coincidence counts vs. coherent laser power