Institut de Ciències Fotòniques

Orbital Angular Momentum Correlations in Spontaneous Parametric Down Conversion

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What are the correlations in Orbital Angular Momentum?

Polarization

OAM

Advantages of the Orbital Angular Momentum

OAM degree of freedom is infinite dimensional

OAM eigenstates provide an infinite dimensional basis

Generation of photon pairs correlated in Orbital Angular Momentum

Spontaneous Parametric Down Conversion is a reliable source of photon pairs correlated in OAM

Conservation of Energy $\longrightarrow \omega_p = \omega_s + \omega_i$

Conservation of Momentum $\longrightarrow \vec{k}_p = \vec{k}_s + \vec{k}_i$

Photons generated in SPDC propagate all over a cone

Photons generated in SPDC can be entangled in OAM

$$|\Psi\rangle = \int d\mathbf{P} d\mathbf{Q} \underbrace{\Phi(\mathbf{P}, \mathbf{Q})}_{\text{Spatial Mode Function}} \underbrace{a_s^\dagger a_i^\dagger}_{\text{Creation Operators}} \underbrace{|0, 0\rangle}_{\text{Vacuum State}}$$

Transverse Coordinates

Spatial Mode Function

$$= \Phi_1(\mathbf{P}) \otimes \Phi_2(\mathbf{Q})$$
$$\neq \Phi_1(\mathbf{P}) \otimes \Phi_2(\mathbf{Q}) \rightarrow \text{Entangled}$$

What are the correlations of the generated pair of photons in Orbital Angular Momentum?

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A. Mair et al., Nature **412**, 313 (2001).

S. P. Walborn et al., Phys. Rev. A **69**, 023811 (2004).

G. Molina-Terriza et al., Phys. Rev. Lett. **92**, 167903 (2004).

N. K. Langford et al., Phys. Rev. Lett. **93**, 053601 (2004).

S. Franke-Arnold et al., Phys. Rev. A **65**, 033823 (2002).

J. P. Torres et al., Phys. Rev. A **68**, 050301 (2003).

$$m_p = m_1 + m_2$$

A. R. Altman et al., Phys. Rev. Lett. **94**, 123601 (2005).

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$$m_p \neq m_1 + m_2$$

Effect of the geometrical configuration

Noncollinear emission changes the OAM correlations

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$$\frac{w_p}{\sin \varphi} \gg L$$

$$m_p = m_1 + m_2$$

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Noncollinear emission changes the OAM correlations

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$$\frac{20\mu m}{\sin 0^\circ} \gg 1mm$$

$$m_p = m_1 + m_2$$

Noncollinear emission changes the OAM correlations

$$\frac{w_p}{\sin \varphi} < L$$

$$m_p \neq m_1 + m_2$$

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$$\frac{500\mu m}{\sin 17.1^\circ} = 1.7mm < 5mm$$

$$m_p \neq m_1 + m_2$$

Effect of the Poynting vector walk-off

The walk-off is a effect of the crystal birefringence

The walk-off changes the OAM content of the pump beam

Walk-off effect
is non-negligible if

$$\frac{w_0}{\tan \rho} < L$$

$$\frac{100\mu m}{\tan 4.9^\circ} = 1.1mm < 5mm$$

The walk-off changes the OAM content of the pump beam

The walk-off breaks the azimuthal symmetry

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$$m_p = 0 \quad m_1 = 0 \quad m_2 = ?$$

The walk-off breaks the azimuthal symmetry

Experimental Set Up

Experimental Setup

CW diode laser
 $\lambda_p = 405nm$
 $w_0 \approx 136\mu m$

Experimental Setup: Counting coincidences

Bidimensional Coincidences Scan

Experimental Setup: Measuring for different values of α

walk-off direction

walk-off direction

Experimental Results: Walk-off breaks the azimuthal symmetry

Experimental Results: Walk-off breaks the azimuthal symmetry

- Bidimensional Coincidences Scan
- 0.3mm pinhole

Advantages of the Orbital Angular Momentum

Generation of photon pairs
correlated in Orbital Angular Momentum

What are the correlations
in Orbital Angular Momentum?

Effect of the geometrical configuration

Effect of the Poynting vector walk-off

Experimental set up

We have shown theoretically and experimentally, that the presence of Poynting vector walk-off breaks the azimuthal symmetry of the SPDC process affecting the OAM correlations of the generated photons and the degree of entanglement.

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