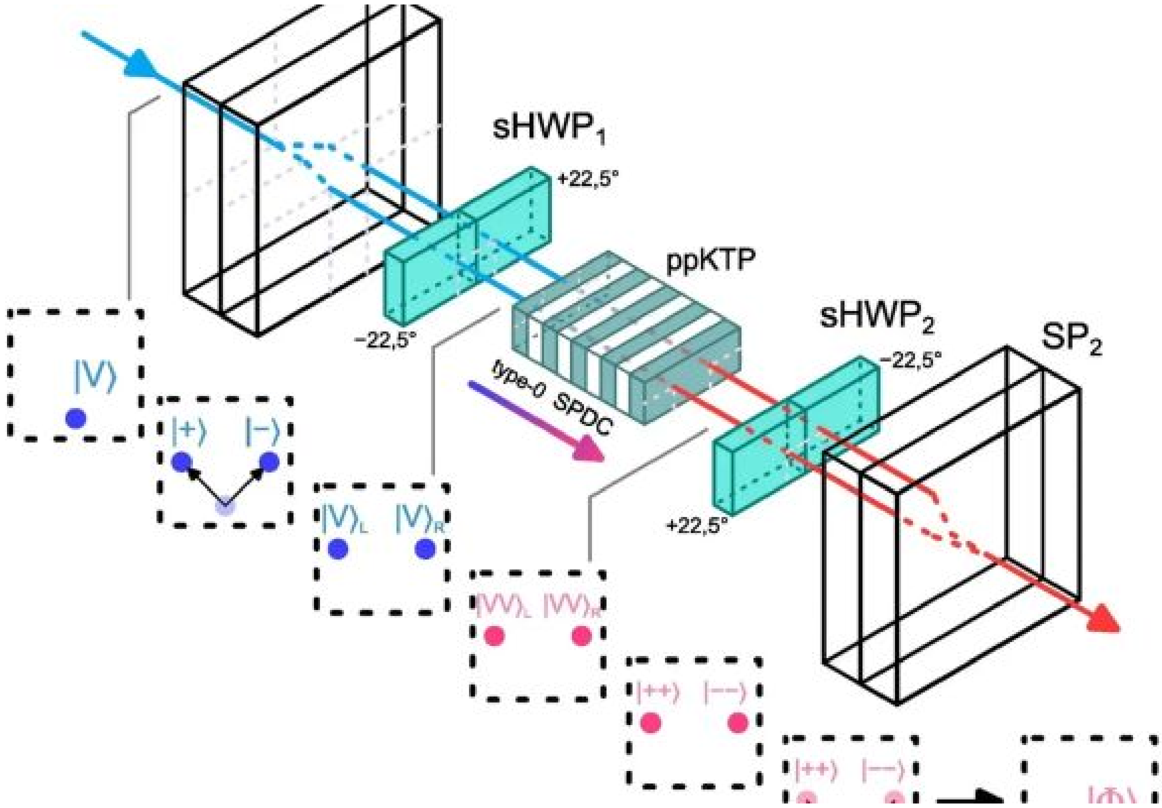

SPaDEs: A look at its advantages and performance

ICFO researchers introduce SPaDEs (Symmetric Parallel Displacement Entanglement Source) as a novel design for a polarization-entangled photon source (EPS) that uses Savart plates, presenting it as a significant advancement over traditional EPS designs, especially those based on single beam displacers.

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What sets SPaDEs apart is its ability to effectively address the issue of longitudinal walk-off, a common problem in EPSs that use beam displacement. This phenomenon, where different polarization modes experience different spatial shifts as they pass through optical elements, can significantly degrade the quality of entanglement. The paper underscores the use of Savart plates as a key factor in mitigating this issue.?

Conventional beam displacers split a beam based on polarization but do not maintain th spatial overlap of the two polarization components after the displacement. This leads to situation where the two beams, after passing through a beam displacer, are no longe perfectly aligned along the propagation direction. This misalignment is referred to a

longitudinal walk-off. This walk-off can be particularly detrimental when using nonline
r crystals for spontaneous parametric down-conversion (SPDC). Ideally, for efficie
t entanglement generation, both polarization modes should experience the same nonline
r interaction within the crystal. However, with longitudinal walk-off, the two modes mi
ht interact with different regions of the crystal, leading to a mismatch in the genera
ed entangled pairs and thus reducing the quality of entangleme
t. SPaDEs tackles this challenge by using Savart plates for both the splitting and recombinat
on of the pump beam. This symmetrical design ensures that any spatial shift introduced to
ne polarization mode is precisely compensated for when the beams are recombined, effectiv
ly eliminating the walk-off effect. ICFO researchers **Giacomo Paganini**, **Dr. Alvaro Cuevas**, **Dr. Robin Camphausen**, **Alexander Demuth**, led by **ICREA Prof. Valerio Pruneri**, provide experimental evidence to support this claim, demonstrating that the longitudinal walk-off in their SPaDEs setup is negligible compared to a setup using a conventional beam displacer. The paper, published in APL Photonics, emphasizes that this elimination of walk-off offers a significant advantage when working with certain types of nonlinear crystals, particularly those with non-uniform poling periods or shorter lengths. In such crystals, even slight misalignments due to walk-off can severely affect the efficiency of entanglement generation. By eliminating walk-off, SPaDEs broadens the range of usable nonlinear crystals, increasing its versatility and suitability for various applications.

ICFO researchers have evaluated the performance of the SPaDEs system using a range of metrics. One of the key parameters assessed is brightness, a measure of how efficiently the source produces entangled photon pairs. The brightness achieved by SPaDEs, (9.50 ± 0.03) ? 104 pairs/(s ? mW), is enough for practical quantum communication applications like free-space or fibre-based QKD. The paper acknowledges that while this brightness is not the highest, it represents a balance between efficiency and other desirable characteristics of the source.

A critical aspect of any EPS is the quality of entanglement produced. In this regard, SPaDEs exhibits exceptional performance, as shown by its high fidelity, which measures how closely the generated state matches the ideal entangled state. The fidelity of 0.992 ± 0.001, derive
from the violation of Bell's inequality (quantified by the CHSH parameter of 2.82 ± 0.04
, highlights the generation of high-quality entangled photon pairs. This near-perfect fideli
y underscores the effectiveness of the Savart plate design in minimizing any unwanted effec
s that could degrade entanglemen
. Researches have also identified potential areas for future enhancement. One is improving t
e heralding efficiency of the source. Heralding efficiency refers to the probability
f successfully detecting one photon of an entangled pair, which signals the presence of t
e other photon. The authors suggest that utilizing higher-quality optical components cou
d lead to an increase in this efficienc
. The development of SPaDEs represents a step forward in the field of entangled phot

n sources. Its unique design effectively addresses the limitations of traditional be
m displacement systems, paving the way for more robust, efficient, and versatile EPSs. Wi
h future refinements, SPaDEs holds significant promise for advancing quantum technologie
, particularly in the realm of quantum communicatio

Reference:

Giacomo Paganini, Alvaro Cuevas, Robin Camphausen, Alexander Demuth and Valerio Pruneri, High-quality entangled photon source by symmetric beam displacement design. APL Photonics 10, 031302 (2025).