Perfect vortex and 4 wave mixing to create photon pairs

Chemistry-Physics inter-departmental day

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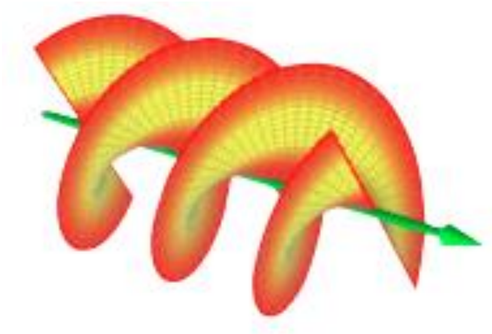
Laboratoire : LCPMR-Laboratoire de Chimie Physique - Matière et Rayonnement

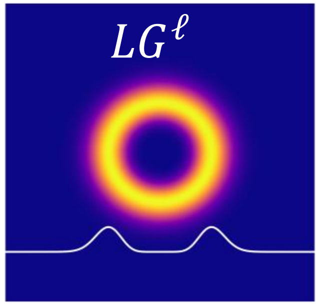
OAM-pairs generation as Quantum Source

QTech needs entanglement states that can be easy controll/encoding information→ New **QSource**

Variable : OAM

- OAM: Orbital Angular Momentum
- Discrete photon qubit (ℓ phase state)
- Opitical Vortex carry OAM



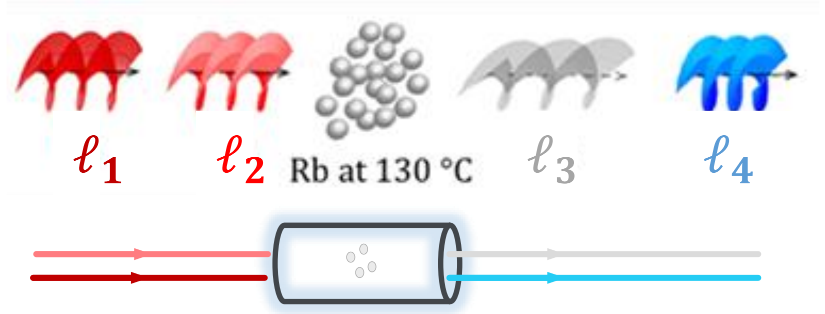


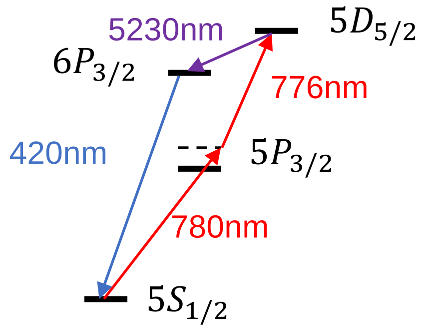
$\ell = 2$

propagative beam carrying an helical wavefront phase.

- phase : $\ell\theta$ with $\ell \in \mathbb{Z}$
- quantization $\hbar\boldsymbol{\ell}/\mathrm{photon}$ → **qudit**

Medium: Hot Rb vapor Spontaneaous Four Wave Mixing





Condition:
Energy conservation
→ Many phase matching

$$k_3 + k_4 = k_1 + k_2$$
$$\ell_3 + \ell_4 = \ell_1 + \ell_2$$

Expectations
∞ OAM-pairs (ℓ_3, ℓ_4)

Limitations:

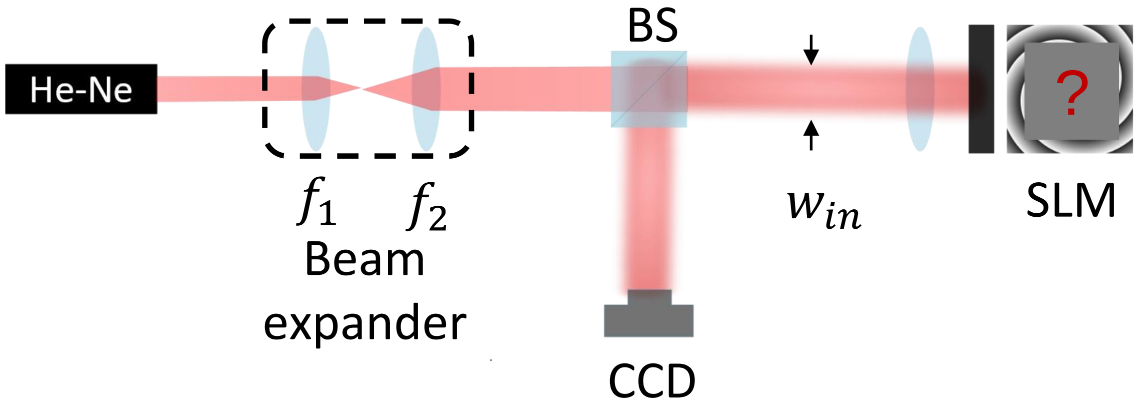
- Other phase matching (curvature phase, Gouy phase in case of LG mode)
- Inputs overlap decreasing with $|\ell_1 - \ell_2|$

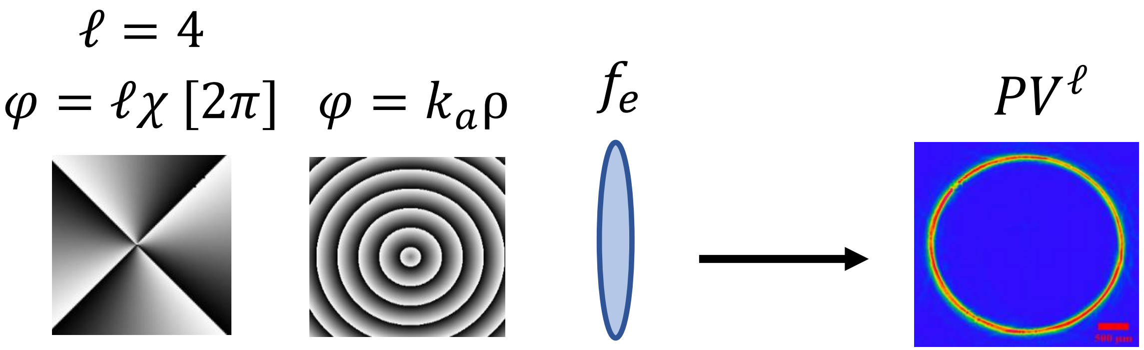
Unfortunately : Radius of LG modes depends of OAM

PV : An ideal PV has ring radius and thickness independent of the OAM

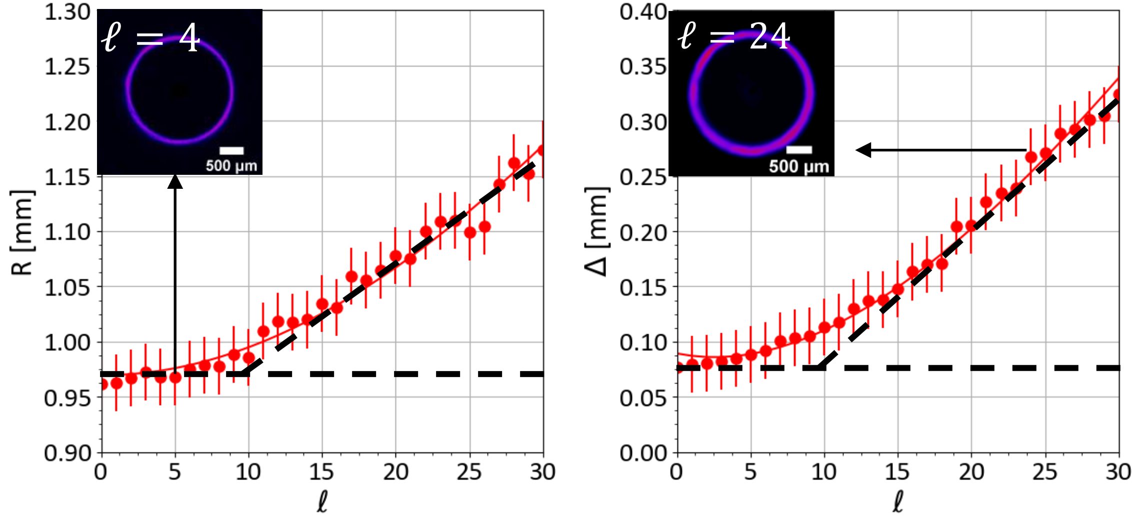
$$PV^{\ell} = e^{ikz} e^{i\ell\theta} \delta(r - R)$$

Set-up: Fabrication of PV





Independent of the OAM ?



Observations

Radius (R) , thickness (Δ)

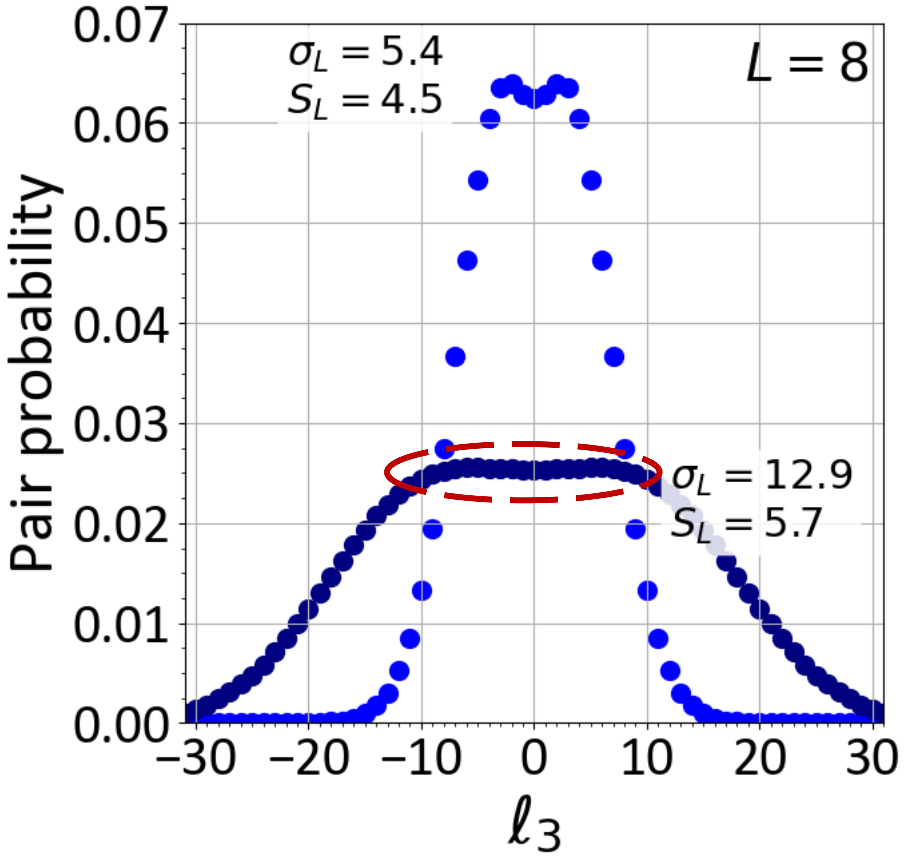
- Constant up to $\ell \sim 10$
- Linear for $\ell \geq 10$

→ Finesse $F = \frac{R}{\Delta} \sim 12$

Prediction : OAM-pairs and probability with PV

$$P_{1234} = \iint A_1 A_2 A_3 A_4 2\pi r dr\, dz \simeq L_{cell} \int A_1 A_2 A_3 A_4 2\pi r dr$$

Assumptions : (i) the input is optimized ($\ell_1 = \ell_2$); (ii) the vortex beams have the same Rayleigh range (Boyd's criterion); (iii) SFWM generates PV; (iv) the output light exists at the ring of the inputs.



Observations

- PV has no Gouy phase so ℓ_3 <0 is allowed and many (ℓ_3, ℓ_4) are permitted.
- The plateau depends on input finesse (Blue F=5; Dark Blue F=10)

Results

PV provide many OAM-pairs with the same probability: High entanglment
The number depends only on the finesse of the input PVBs
PV would provide an large output space for OAM-entanglement

Thank you for your attention

Team: L.Pruvost (DR of CNRS)