Quantum simulator with hot atomic vapors (SQVAC)

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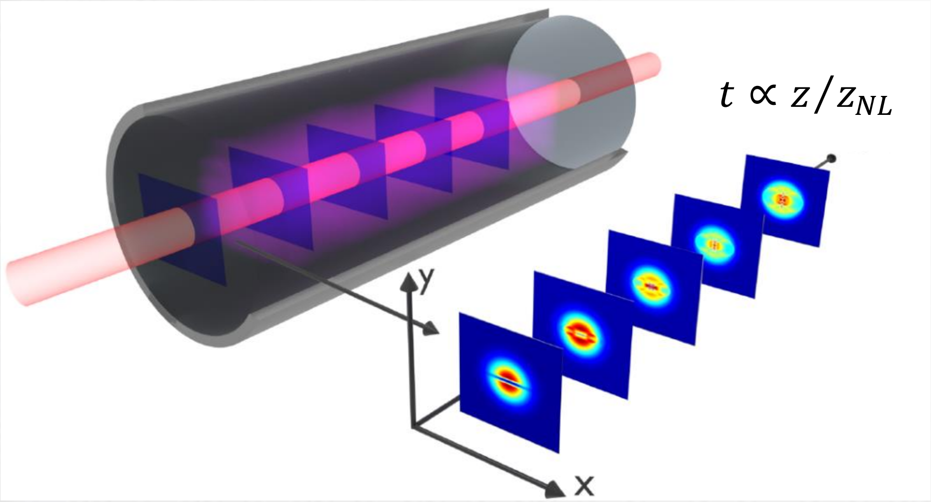
Photons propagation in a non-linear vapor

Non-Linear Schrödinger Equation $$i\frac{\partial\psi}{\partial z} = -\frac{1}{2k_0}\nabla_r^2\psi + k_0\Delta n\,\psi$$



Madelung transformation

$$\psi(\boldsymbol{r},z) = \sqrt{\rho(\boldsymbol{r},z)}\,e^{i\phi(\boldsymbol{r},z)}$$

2D Euler equations

Fluid's density

$$\rho = |\psi|^2 = \mathrm{I}$$

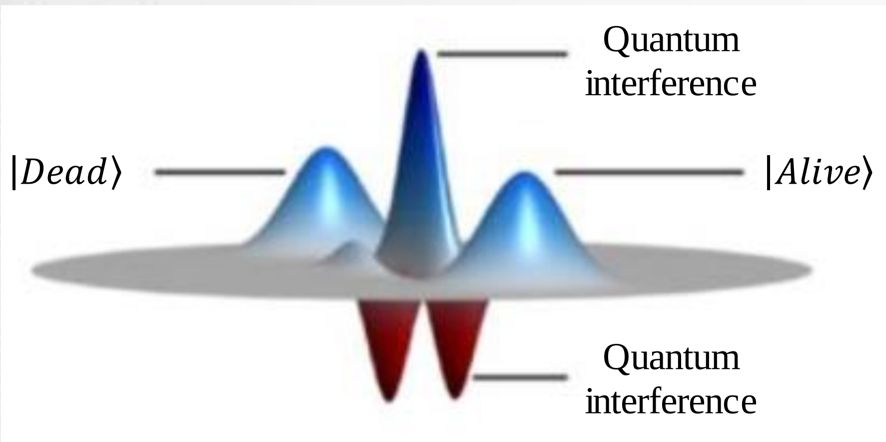
Fluid's velocity

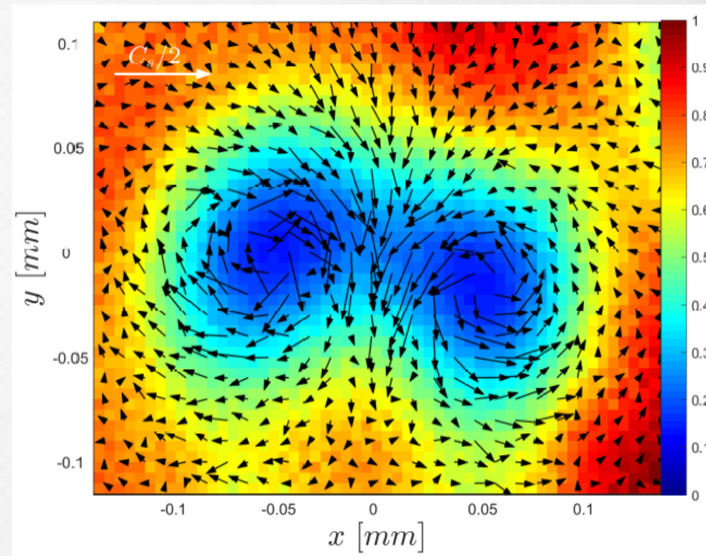
$$\mathrm{u} \propto \nabla\phi$$

Wavefunction & Electric field equivalence

$$\Psi = |\Psi| e^{i\varphi}$$

$$E = \sqrt{I} e^{i\varphi}$$

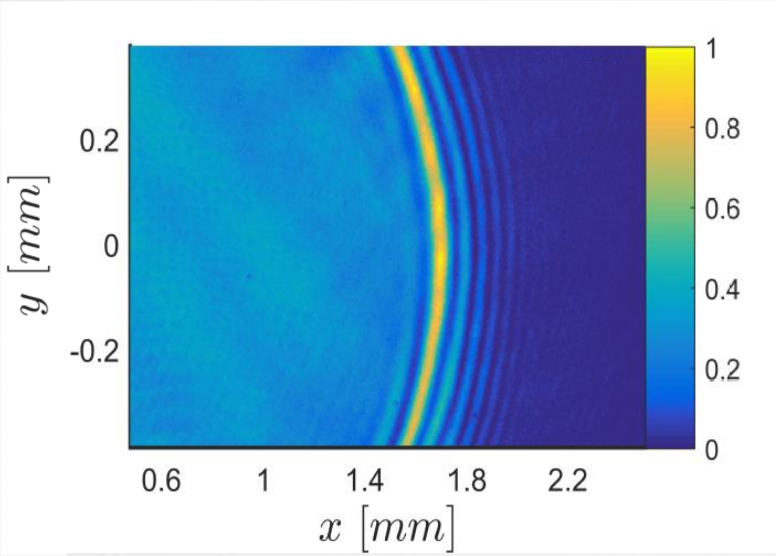


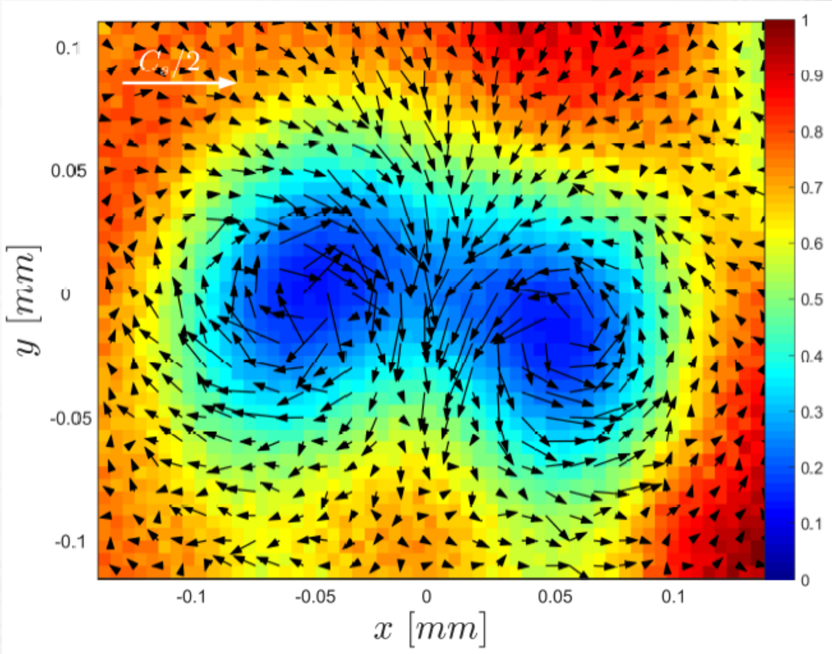


Detection of amplitude and phase of the field (equivalent of measuring the full wavefunction in situ)

This approach leeds to « Quantum fluids of light » and observations of precursor effects of wave condensation

Fluid dynamic studies





Dissipation-enhanced collapse singularity of a nonlocal fluid of light in a hot atomic vapor
P. Azam, A. Fusaro, Q. Fontaine, J. Garnier, A. Bramati, A. Picozzi, R. Kaiser, Q. Glorieux, and T. Bienaimé, Phys. Rev. A 104, 013515 (2021).

Vortex creation, annihilation and dynamics in atomic vapor
P. Azam, A. Griffin, S. Nazarenko, R. Kaiser, Phys. Rev. A 105, 043510 (2022).

Comparison with numerical simulations

	Simulation	Experiment	Ratio
Energy	$E_{simu} = 80$ Wh	$E_{laser} = 70$ Wh $E_{oven} = 140$ Wh $E_{camera} = 30$ Wh $E_{monitoring} = 35$ Wh $E_{exp} = 275$ Wh	
Time	For a 1024×1024 matrix: 15 seconds a step	Measurement at a rate of ≈ 50 Hz (set laser frenquency/intensity + record output beam)	
$L/z_{NL} = 50$	50 steps $\times$ 15s = **12.5 min** $\Rightarrow$ **16.5 W**	$\approx$ **50Hz** $\Rightarrow$ **1.5 mW**	$\times 37500$ $\times 11000$

Limitations of classical digital solutions

Moore's law

Reach physical limitations (size of a transistors) to keep doubling the number of transistors per processors each year

Energy cost

In 2019, it is responsible of 4 to 10% of the total greenhouse gases and it consumes 10 to 15% of the world electricity

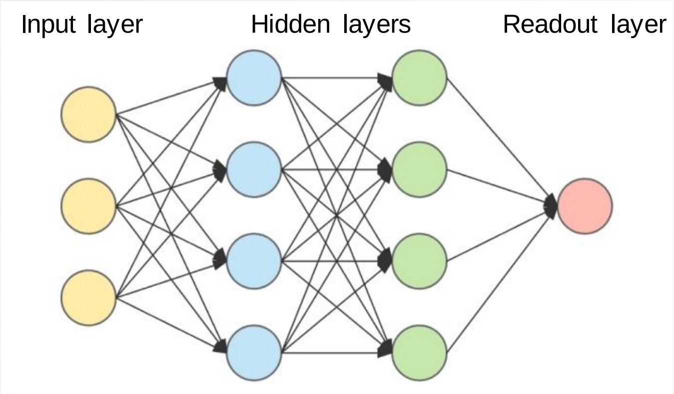
Calculus time

Increase of complex tasks and calculus (as machine learning, thermodynamics simulations,…), time of calculation is non-negligeable

Analog computers: Specific problems / Solve faster / Lower energy cost

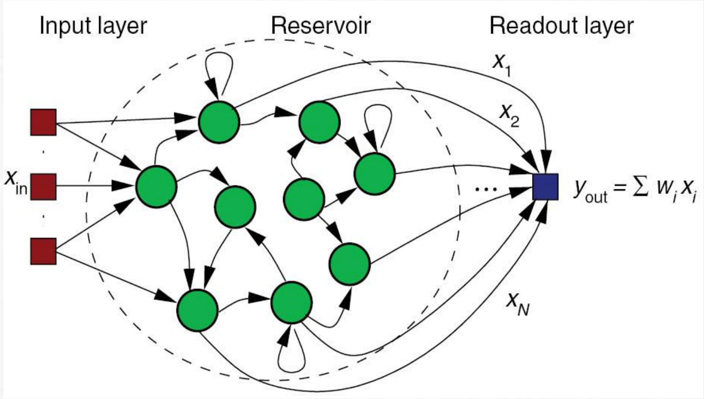
Extreme Learning Machine

Artificial neural network



Back-propagation

Reservoir computing



Feed forward

Pierangeli D., Marcucci G. & Conti C. (2021). **Photonic extreme learning machine by free-space optical propagation**. *Photonics Research*, *9*(8), 1446-1454.

Principal advantage is the training speed

Our hardware is 2D → Image classification

Thank you for your attention