# Building a room temperature quantum computer

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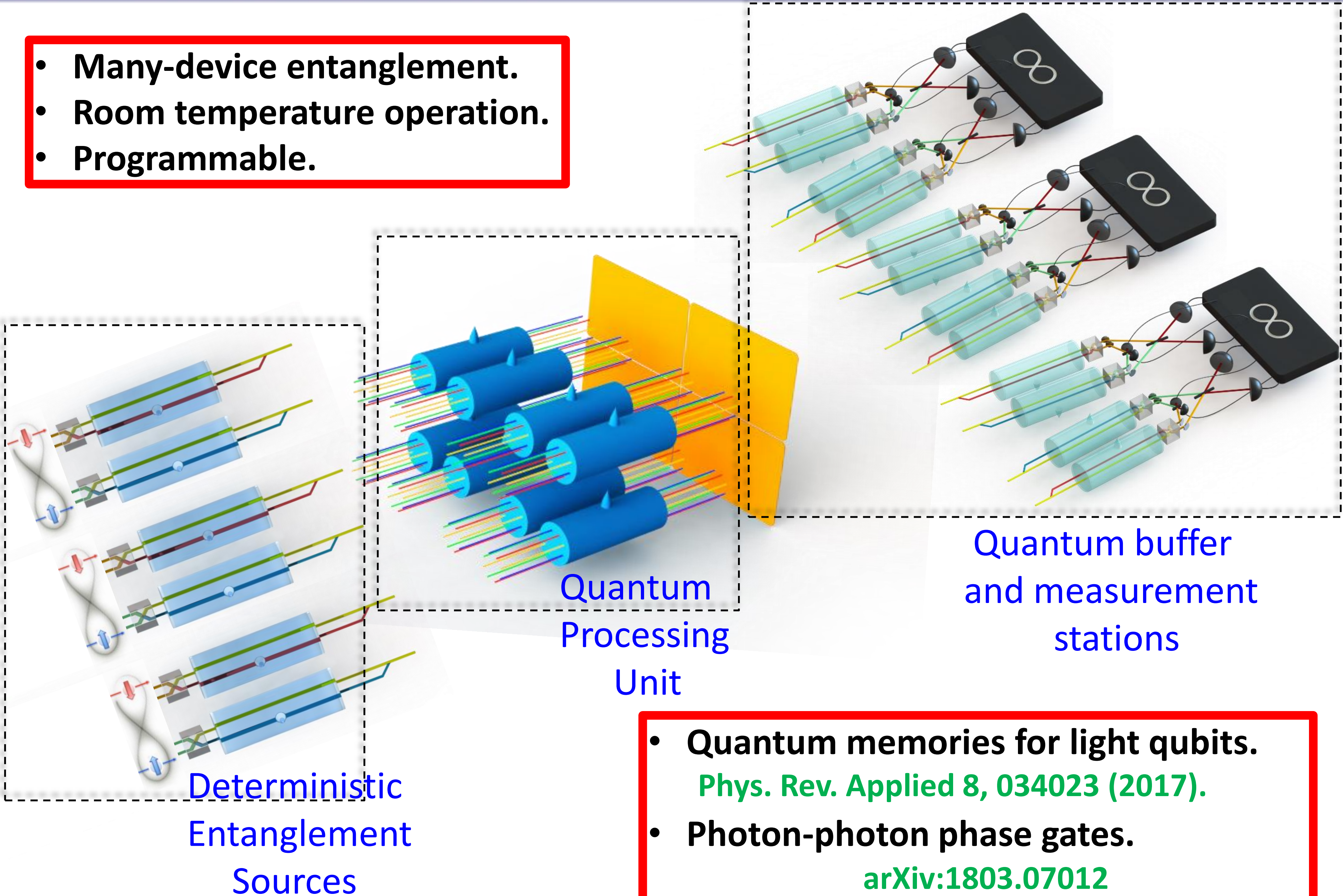
SIMONS FOUNDATION

# Room temperature quantum computer concept

- **Many-device entanglement.**
- **Room temperature operation.**
- **Programmable.**

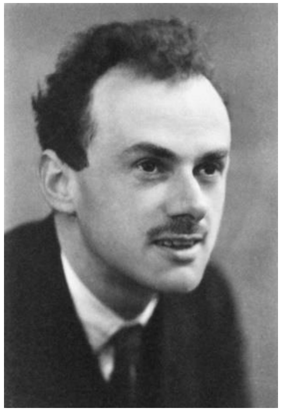



- **Quantum memories for light qubits.**
  **Phys. Rev. Applied 8, 034023 (2017).**
- **Photon-photon phase gates.**
  **arXiv:1803.07012**

# Bridge between AMO and NP: Dirac and Jackiw-Rebbi equations

- The Dirac equation merges quantum mechanics with special relativity.

$$i\hbar \frac{\partial \psi}{\partial t} = H_{\mathrm{D}}\psi = (c\hat{p}\sigma_x + mc^2\sigma_z)\psi$$

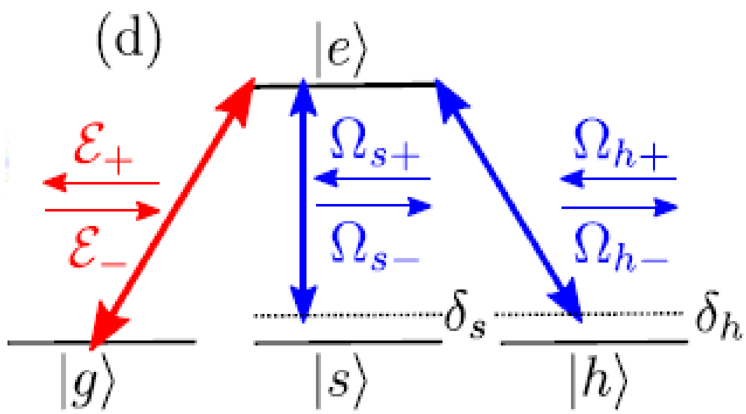


- The Jackiw-Rebbi model describes a Dirac field coupled to a soliton field.

$$i\partial_t \mathbf{\Psi} = \left( \alpha c p_z + \frac{\beta m c^2}{\kappa}\phi(z) \right)\mathbf{\Psi}$$

- A kink in the soliton yields a topologically protected zero-energy mode.

# Dirac dynamics using spinor of light




$$\hat{\Psi}_+ = \cos\theta\hat{\mathcal{E}}_+ - \frac{1}{\sqrt{2}}\sin\theta(\hat{\sigma}_{gs} - i\hat{\sigma}_{gh})$$

$$\hat{\Psi}_- = \cos\theta\hat{\mathcal{E}}_- + \frac{1}{\sqrt{2}}\sin\theta(i\hat{\sigma}_{gs} - \hat{\sigma}_{gh})$$

**Spinor of light:**

$$\hat{\mathbf{\Psi}} = (\hat{\Psi}_+, \hat{\Psi}_-)^T$$

**The spinor obeys a Dirac-like equation:**

$$i\hbar\frac{\partial}{\partial t}\hat{\mathbf{\Psi}} = \left(i\hbar v_g\sigma_z\frac{\partial}{\partial} + \hbar\delta\sin^2\theta\sigma_y\right)\hat{\mathbf{\Psi}}$$
$$- iL_{\text{abs}}v_g\sin^4\theta\left(\sigma_z\frac{\partial}{\partial z} - \frac{\delta}{c}\sigma_y\right)^2\hat{\mathbf{\Psi}}$$

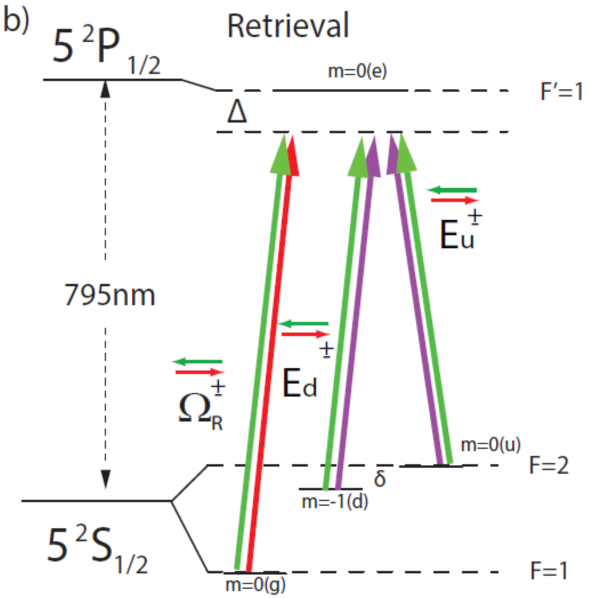
$$c^* = v_g = c\cos^2\theta$$

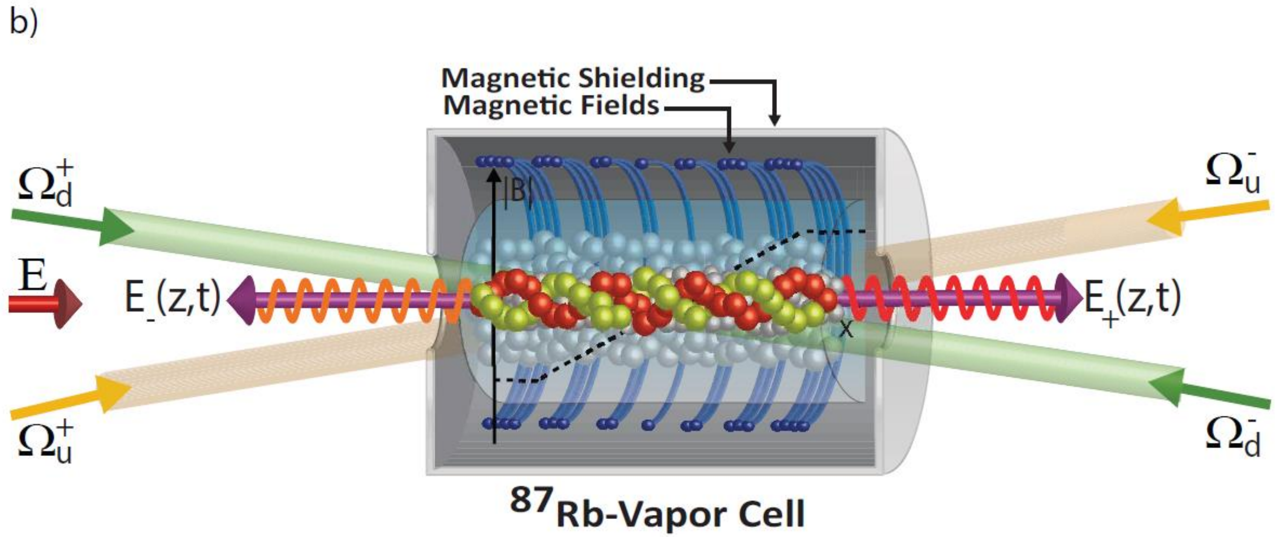
$$m^* = \hbar\delta\sin^2\theta / v_g^2$$

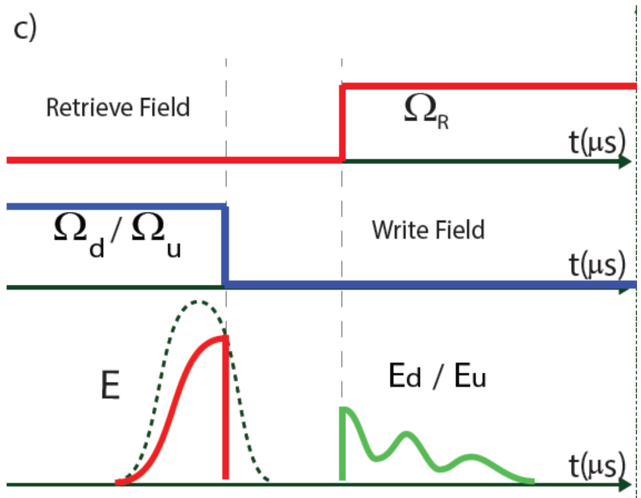
PRL 105, 173603 (2010).

Scientific Reports 4, 6110 (2014).

# Creating spinors of light experimentally




## Realizing topological relativistic dynamics with slow light polaritons at room temperature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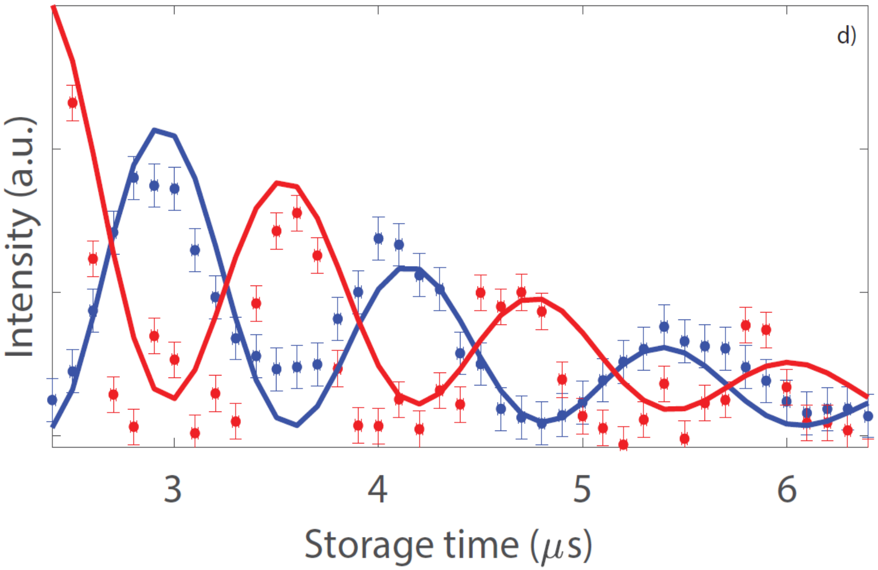
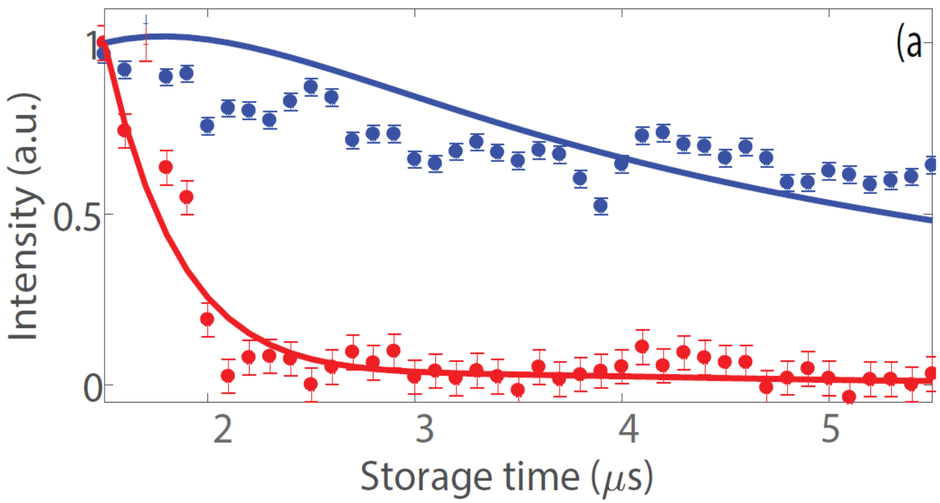
**arXiv:1711.09346**

# Quantum simulation of Dirac and Jackiw-Rebbi spinor dynamics

$$i\partial_t\psi = \left(iv_g\sigma_z\partial_z + m_{eff}v_g^2\sigma_y - \gamma\right)\psi$$




$$i\partial_t\psi = \left(iv_g\sigma_z\partial_z + m_{eff}(z)v_g^2\sigma_y - \gamma\right)\psi$$



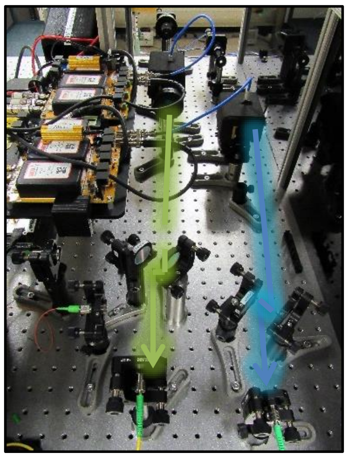

"Realizing JR would require **beams of relativistic particles interacting with Fermi quantum fields**. This realization of the **same physics** requires **only diode lasers and a cell of Rb atoms**."

# Quantum processing network in Stony Brook (in collaboration with BNL)

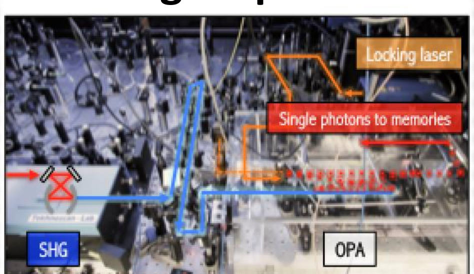
**~15 interconnectable quantum devices**

## Photon Sources

**Ancilla qubits**

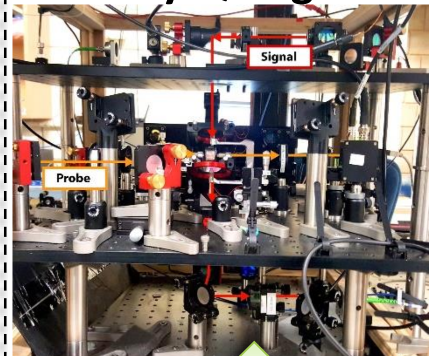


**Entangled photons**

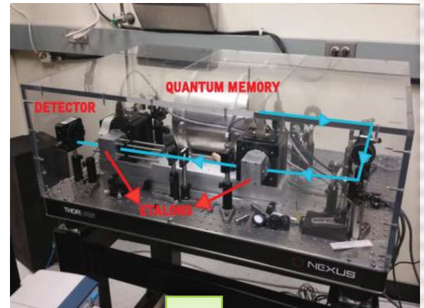


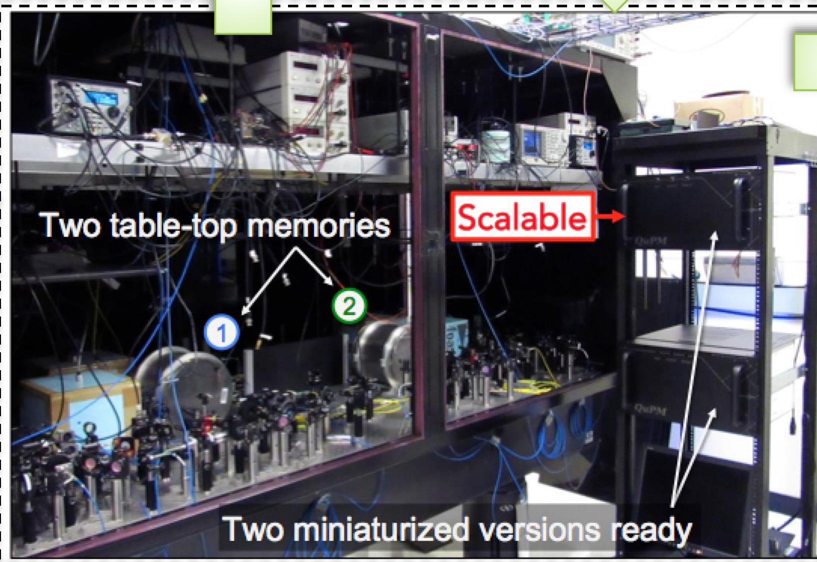

## Quantum processing units

**Cavity QED gate**

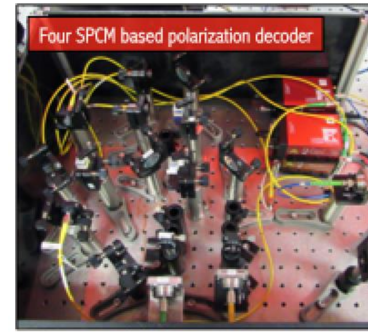



**RT phase gate**

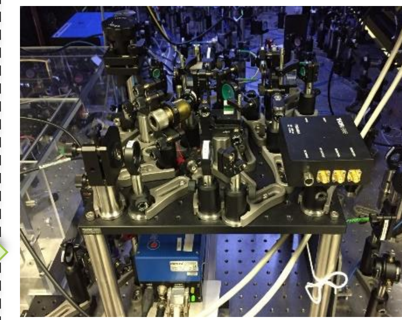



## Network of quantum memories




**Bell measurements**



**Homodyne detectors**

## Measurement stations

**- Largest quantum processing network of its kind.**