Quantum fields in accelerated cavities: from relativistic velocities to a desktop experiment

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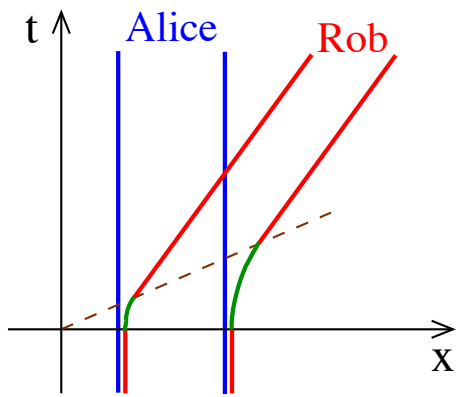
With D. E. Bruschi, D. Faccio and I. Fuentes, arXiv:1210.6772



Plan

1. Particle creation by spacetime kinematics
2. **Relativistic** field in a **relativistic** **rigid** cavity
   - **Resonances** in periodic motion
3. Experimental mode mixing scenario
   - **At threshold of current technology!**
4. Summary

Particle creation by spacetime kinematics

Kinematics in/of spacetime mixes and creates particles!

Moore (1970) (Dynamical Casimir Effect)

Hawking (1974); Unruh (1976)

- **Relativity viewpoint: focus on local quantities**

  $\langle \phi^2 \rangle$, $\langle T_{\mu\nu} \rangle$, ...

- **Quantum information viewpoint: nonlocal entanglement**

  Alsing and Milburn (2003); Fuentes-Schuller and Mann (2005); ...

  $\rightarrow$ Quantum information protocols; quantum gates

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Caveat: no relativistic quantum measurement theory!

Sorkin (1993); Benincasa et al (2012)

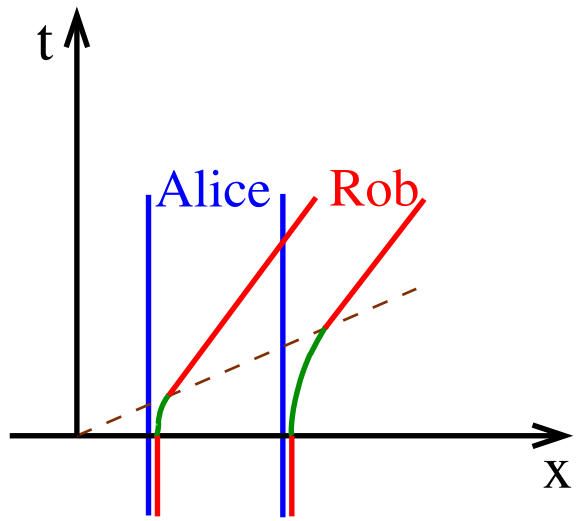
Field in a moving rigid cavity

Con (The Bad)

- Field shielded from Unruh thermality

Pros (The Good)

- **Spatial** localisation explicit
- Choose inertial at $t \to \pm\infty$
  - Usual notion of 'particle' at early and late times
- Spectrum discrete
  - Entanglement quantifiers available



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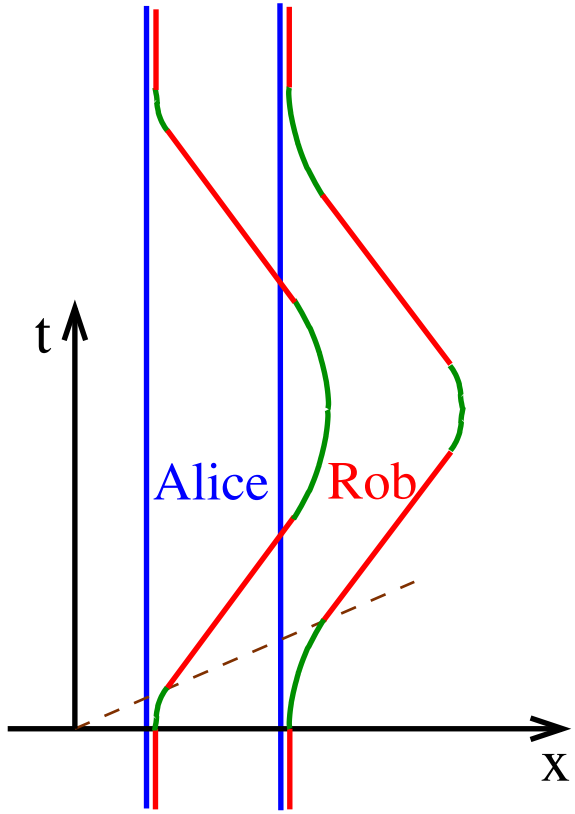

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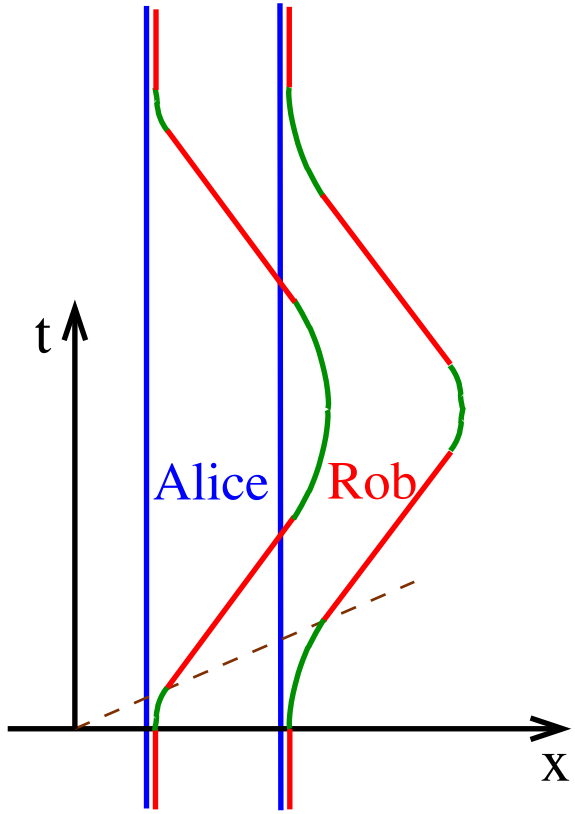

Analysable! (The Ugly)

- Systematic perturbative treatment in La/c^2

  L: cavity proper length (rigid)

  $a(\tau)$: proper acceleration (time-dependent)
- Adjustable travel scenarios
- **Relativistic:** velocities and travel times unrestricted
- $(3+1)$: cavities rigid to first order in (vector) acceleration

Linear order in acceleration

Effects come from changes in acceleration, not from acceleration!

cf. moving mirror $\langle T_{\mu\nu} \rangle$ Davies and Fulling (1976)

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Periodic motion

- Particle **creation** resonance at $\omega_{\text{cr}} = \omega_k + \omega_{k'}$
- Mode **mixing** resonance at $\omega_{\text{mix}} = |\omega_k - \omega_{k'}|$

$(3+1)$ cavity

- Can arrange $\omega_{\text{mix}} \ll \omega_{\text{cr}}$
- ω_{mix} at threshold of current technology!

Experimental scenario

Cavity

- Rectangular, scale $\sim 1\,\mathrm{cm}$

Quanta

- Massless, $\lambda = 600\,\mathrm{nm}$
- **highly vertical**: $|k_x|, |k_y| \ll |k_z|$

Motion

- **Horizontal** shake (linear or circular)

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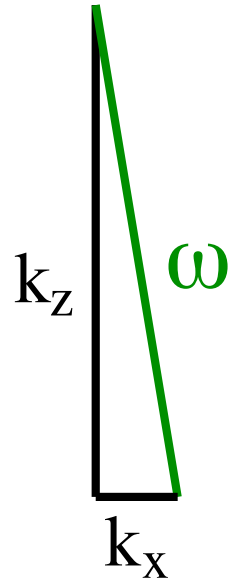

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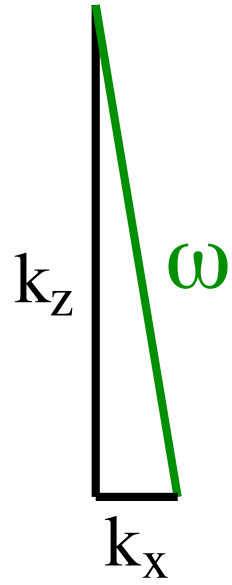

Pythagoras!

- Mode mixing threshold $0.7\,\mathrm{MHz}$ (circular: $4 \times 10^7\,\mathrm{rpm}$)
- Amplitude $1\,\mu\mathrm{m} \Rightarrow$ mixing timescale $1\,\mathrm{ms}$

  - Horizontal **momentum mixing**: observable?
  - Interference between the mixed modes $\Rightarrow$ **beamsplitter gate!**

Summary

- **Relativistic** quantum field in a **relativistic** rigid cavity
  - Systematic perturbative treatment at small acceleration
- $(3+1)$ cavity: new mode mixing resonance identified
  - **At threshold of current technology!**
- **Laboratory experiment?**
  - Mechanical?
  - SQUID simulation? Friis et al, PRL (2013)