Experimental Distinction Between a Maxwell Universe and Quantum Mechanics

A proposal based on 1S–2S hydrogen spectroscopy Anes Palma · August 2025

Abstract

Source-free Maxwell dynamics for a single scalar energy field ϕ leads to the Schrödinger equation in the narrow-band (envelope) limit. Higher-order terms appear at order $\epsilon^2 = (\Delta\omega/\omega_0)^2$. If that term vanishes, Maxwell alone reproduces every quantitative success of quantum mechanics while retaining a deterministic field picture—no probabilistic ontology required. If it survives, a relative frequency shift of order 10^{-8} is predicted for the 1S–2S interval in atomic hydrogen, four orders above present experimental uncertainty. Either outcome decisively discriminates a Maxwell universe from standard quantum mechanics (QM).

Introduction

The wave equation

$$\partial_t^2 \phi = c^2 \nabla^2 \phi$$

supports a narrow-band ansatz

$$\phi(\mathbf{r}, t) = \Re\big[\psi(\mathbf{r}, t)\, e^{-i\omega_0 t}\big], \qquad \epsilon = \frac{|\partial_t \psi|}{\omega_0} \ll 1,$$

which yields the Schrödinger equation at leading order. The next term in the expansion alters the effective Hamiltonian and provides a clear experimental handle.

Derivation of the ϵ^2 correction

Keeping terms through $O(\epsilon^2)$ gives

$$i\partial_t \psi = -\frac{c^2}{2\omega_0}\nabla^2 \psi - \frac{c^4}{8\omega_0^3}\nabla^4 \psi + \frac{1}{2\omega_0}\partial_t^2 \psi + O(\epsilon^4).$$

With the identifications $\hbar = E_{11}/\omega_{11}$ and $m = E_{11}/c^2$, the effective Hamiltonian reads

$$H_{\text{eff}} = H_0 + \epsilon^2 H_2, \qquad H_0 = -\frac{\hbar^2}{2m}\nabla^2,$$

$$H_2 = -\frac{\hbar^2}{2m}\Big[\frac{\hbar^2}{4m^2c^2}\nabla^4 - \frac{1}{\omega_0^2}\partial_t^2\Big].$$

Magnitude for hydrogen

For the hydrogen ground state $\Delta k \simeq a_0^{-1}$ gives

$$\epsilon \sim \alpha^2 \approx 10^{-4} \implies \epsilon^2 \approx 10^{-8}.$$

The relative shift in the 1S–2S frequency is

$$\frac{\Delta f}{f_0} = \kappa \, \epsilon^2 \sim \kappa \times 10^{-8},$$

i.e. $\Delta f \approx 25$ kHz for $f_0 = 2.466\,061\,413\,187\,035$ Hz. Current Doppler-free two-photon measurements quote uncertainties below 10 Hz, well inside the required range.

Experimental protocol

Step	Action	Target value
Ultracold hydrogen beam	Temperature < 50 mK	Doppler width < 1 kHz
Two-photon excitation	243 nm cavity-enhanced counter-propagating	Linewidth < 500 Hz
Frequency reference	Optical clock traceable to the SI second	Stability $< 10^{-15}$
Systematic shifts	Stark, Zeeman, AC Stark	Controlled below 1 Hz
Data model	Fit line centre vs. carrier bandwidth	Sensitivity to $\kappa\epsilon^2$
Statistical goal	$\sigma_{\Delta f} \leq 5$ Hz	$5\times$ margin on 25 kHz prediction

Interpretation

- If $\epsilon^2 = 0$: Maxwell reproduces all QM predictions; the experiment yields the CODATA value and supports a deterministic field ontology without probabilistic collapse.
- If $\epsilon^2 > 0$: a measurable upward shift appears; QM is incomplete and new physics emerges at order 10^{-8}. Either result is scientifically valuable.

Conclusion

Hydrogen 1S–2S spectroscopy at present technical levels can decide whether quantum mechanics is the exact description of matter or only the leading approximation to a deeper Maxwell-scalar field theory. A null result confirms the sufficiency of Maxwell; a positive result opens the door to physics beyond QM.

References

[1] A. Palma, "Deriving the Schrödinger Equation from Source-Free Maxwell Dynamics", v2 (2025). [2] A. Palma, "Finite-Bandwidth Corrections in a Maxwell Universe" (2025). [3] T. Udem *et al.*, "Absolute Frequency Measurement of the Hydrogen 1S–2S Transition", Phys. Rev. Lett. 125, 053001 (2020). [4] CODATA Recommended Values of the Fundamental Constants, 2022.