Laser-cooled atoms, Heisenberg's Uncertainty Principle, and A Proposal of New Deterministic Quantum-Mechanical Experiments

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Abstract:

According to Heisenberg's uncertainty principle, both, position and momentum of a particle, cannot be known with ultimate accuracy; the product: $\Delta x \,.\, \Delta p > \mathrm{h}$. Whereas in the case of Laser-cooled atoms, we know that velocity of the particle is close to zero; and its position x is so perfectly known, that an atom is said to be held in Laser forceps. These experiments show that both position and momentum of atoms are accurately knowable! Similarly, when momentum of an atom is zero, the wavelength of its de Broglie wave is very very long; and according to quantum-mechanical interpretation, the atom is likely to be detected anywhere within its de Broglie wavelength, with higher probability at the peaks of the wave. Whereas the experiments with Laser-cooled atoms show that the atom is confined precisely within the Laser forceps. To avoid this anomaly, new experiment is proposed here in which, instead of quantum mechanical waves, which have wavelength $h / m\, v$, corresponding to phase velocity of the wave, we can let the waves corresponding to group-velocity, of the wavelength $h\, v / m\, c^2$, interfere in double-slit interference experiment. And we can expect that a particle may deterministically tunnel from one peak of the group-wave to next peak of the group wave; and can be detected at predictable points.

Key Words: Quantum mechanics, Heisenberg's uncertainty principle, Laser-cooled-atoms, de Broglie wavelength, Group wavelength.

Introduction:

According to Heisenberg's uncertainty principle, both, position x and momentum p of a particle cannot be simultaneously known with ultimate accuracy. The uncertainty in position Δx , and uncertainty in momentum Δp are related by Heisenberg's uncertainty relation: $\Delta x \,.\, \Delta p > h$.

Whereas in the case of Laser-cooled atoms when their velocity tends to zero, the atom gets trapped in Laser forceps, and its position too is perfectly known like a fruit in one's hand. This situation arises a question, whether the mass of an atom becomes uncertain, to satisfy the 'uncertainty principle'? Or is it possible to predict and measure position of particles more accurately, than currently predicted by quantum mechanics?

Quantum mechanical wave, with its wavelength equal to a particle's de Broglie wavelength, are currently interpreted in terms of probability of detecting a particle. The square of quantum mechanical wave predicts the 'probability-density' of finding a particle in a given volume-element. Einstein's opinion on this probabilistic interpretation, proposed by Born, was that: "GOD does not play dice." The experiments with Laser-cooled atoms show that both: position and momentum of atoms is possible to be known, with great accuracy. So these experiments generated a hope in this author's mind that it may be possible to predict position of detection of all particles. This paper proposes an experiment with low-intensity-beam of the lightest-available particle, electron, accelerated at suitable velocity such that their 'group-wavelength' becomes measurable. These group-waves, with group wavelength, $h\ v\ /\ m_e\ c^2$, are expected to show tunneling of particles from one peak of the group-wave to next peak of the group-wave.

Calculation of group wavelength, and its experimental measurement:

Group wavelength of a particle is defined as (velocity of a particle) / (frequency of that particle).

Group wavelength of an electron, $\lambda_g = v_e / (m_e c^2 / h) = h v_g / (m_e c^2)$

Where: m_e relativistic-mass of the electron = $(9.109\ 382\ 91(40) \times 10^{-31}) / (1 - v^2 / c^2)^{1/2}$ kg; Planck's constant, $h = 6.626\ 069\ 57(29) \times 10^{-34}$ J·s; and Speed of light $c = 2.99\ 792\ 458 \text{ x } 10^8$ $\text{m}\cdot\text{s}^{-1}$.

For the velocity v_g = (o.8) c , the group-wavelength $\lambda_g \sim (1.9410481897/ 2) \text{ x } 10^{-12}$ m.

Classical radius of an electron is = $2.8179403267 \text{ x } 10^{-15}$ m.

Experts of experimental physics should be able to see regular distances of the order 10^{-12} meters between the successive bubbles in the tracks produced in bubble chambers, or in the latest detectors.