APS March Meeting, Boston, MA
Thursday, March 7, 2019
Poster T70.002

A Neoclassical Framework That Reunifies Modern Physics

Alan M. Kadin
Princeton Junction, NJ
amkadin@alumni.princeton.edu

Abstract

The unity of classical physics was broken by quantum uncertainty on the micro level and curved space-time on the cosmic level. In contrast, a novel neoclassical picture incorporates key aspects of quantum and relativistic physics, while maintaining deterministic local reality at all levels. This approach maintains quantum discreteness without Hilbert space, and reproduces curved light without space-time. Key aspects include:

- Real rotating vector fields self-organize into soliton-like wave packets with quantized spin; these represent elementary particles.
- Characteristic frequency and wavelength of these wave packets define time and space, and are modulated by gravity.
- Wave packets maintain constant frequency for both massive and massless "particles", reproducing relativistic trajectories.
- Transitions are due to continuous interactions between wave packets that conserve total frequency, wavevector, and spin.

Quotations

- Richard Feynman
  - I think I can safely say that no one understands quantum mechanics. (The Character of Physical Law, 1965)

- Albert Einstein
  - Everything should be made as simple as possible, but not simpler.

Introduction: What is Time?

- Classical Physics
  - Time is universal and uniform.
  - Time is anchored by the large-scale motions of sun, moon, and earth (the day, month, and year).
  - The Clockwork Universe is the paradigm.
- Relativity
  - Time is relative, non-uniform, and abstract.
  - Time is defined by 4D abstract space-time.
- Modern Operational View
  - Time is what our atomic clocks tell us it is.
- Neoclassical View
  - Taking the modern view one step further, time and space are defined by frequency and wavelength of fundamental quantum waves, including speed and gravity modulations.
  - Time is just a parameter to measure change on the microscopic scale, not a dimension.
  - There is no abstract space-time.

Principles of Classical Physics

- Real particles and waves (fields) follow continuous, deterministic trajectories in 3D space
  - Moving particle maintains constant total energy $E(p,r)$, unless changed by local influence of another particle or field.
  - Wave packet with $\omega(k,r)$ moves with speed $v = \partial\omega/\partial k$ with constant ω and can refract or diffract
- Any classical trajectory possible in principle
  - Any speed possible
  - Any angular momentum possible
- Time and space are distinct, abstract, universal, and uniform
  - Passive background for trajectories
- No physical point particles or divergences

New Phenomena in Early 20th Century

- Universal speed limit c
- Light waves bends in gravitational field
- Universal discreteness in angular momentum given by $\hbar$
  - Also intrinsic quantized spin
- Universal discreteness in energy given by $\hbar\omega$.
  - 1 electron per energy level – exclusion principle
- Waves act as particles and particles as waves (wave-particle duality)
  - Electrons as de Broglie waves with $\hbar k = p$
- Radioactive decay appears random
  - Suggests possible intrinsic uncertainty

The Great Split in 20th Century Physics

- 3 Regimes with completely different physics and math
  - Macro scale – governed by classical physics
  - Micro scale – governed by quantum mechanics
  - Cosmic scale – governed by relativity
- Recall that Newton unified physics in heavens with that on earth with universal gravitation.
- Can one *reunify* modern physics on all scales in simple, consistent framework that incorporates quantum and relativistic phenomena?
  - Believed to be impossible, but new neoclassical synthesis is proposed.
  - Different from anything previously proposed.

Principles of Relativity

- Speed of light c always constant – special relativity
  - Also speed limit for all particles
- 4D space-time -- abstract, non-universal, non-uniform
  - Reference frames related by Lorentz transformations
  - Speed-related time dilation and length contraction
- Gravity distorts 4D space-time in general relativity (GR)
  - Creates curved trajectories for light
  - Gravitational time dilation and length contraction
  - Grav. red shift – not constant ω or E.
- Space-time may have singularities and divergences
  - Black holes and event horizons for very strong gravitational fields.

Principles of Quantum Mechanics

- Complex wave function
  - Abstract field representing statistical amplitude of point particle with phase factor
- Mathematics based on abstract Hilbert space
  - Complex linear superpositions of waves
- Multiple particles create product Hilbert spaces
  - Correlations create non-local entanglement
- Measurement of particle creates sudden change in wave function
- Quantized Spin is intrinsic property of point particle
- Transition to classical physics requires decoherence with loss of uncertainty, entanglement, and phase factors.

Principles of Neoclassical Physics*

- Real particles and waves (fields) follow continuous, deterministic trajectories in 3D space
  - Moving particle maintains constant total energy E, unless changed by local influence of another particle or field.
  - Wave maintains constant frequency ω and can refract or diffract
- All matter is made of fundamental quantum waves
  - Only classical trajectories accessible by quantum waves are possible.
  - Quantum waves have maximum speed c
  - Quantum waves have spin and angular momentum quantized by $\hbar$.
- Time and space are distinct and defined by clocks and rulers made of quantum waves
  - These show time dilation and length contraction.
  - No real Space-time
  - No physical point particles or divergences
  - No Hilbert space

* A.M. Kadin, "Fundamental Waves and the Reunification of Physics", Foundational Questions Inst. Essay Contest, 2017,

Neoclassical Relativity*

- Novel *interpretation* of special and general relativity
  - Derived from fundamental quantum waves, rather than from an independent abstract space-time.
  - Local clocks and rulers same as standard theory.
  - All objects composed of quantum waves obey same relations.
  - Reproduces standard trajectories for massless and massive particles.
  - No experimentally testable differences, at least for weak gravity.
- But this suggests that strong-gravity effects in GR may be improper extrapolation of theory into untested regime.
  - Black Holes and Event Horizons may not exist in nature
  - Alternative model of dense “dim star” with weak escape of light.
- Most physical constants are not universal
  - c, G, e, m_e may vary in space and time, from fixed reference.
  - But $\hbar$ and dimensionless constants (fine-structure and gravitational coupling constants, mass ratios) remain universal.

*A.M. Kadin, “Gravitation and Cosmology without Divergences”, 2018.

Neoclassical Quantum Physics

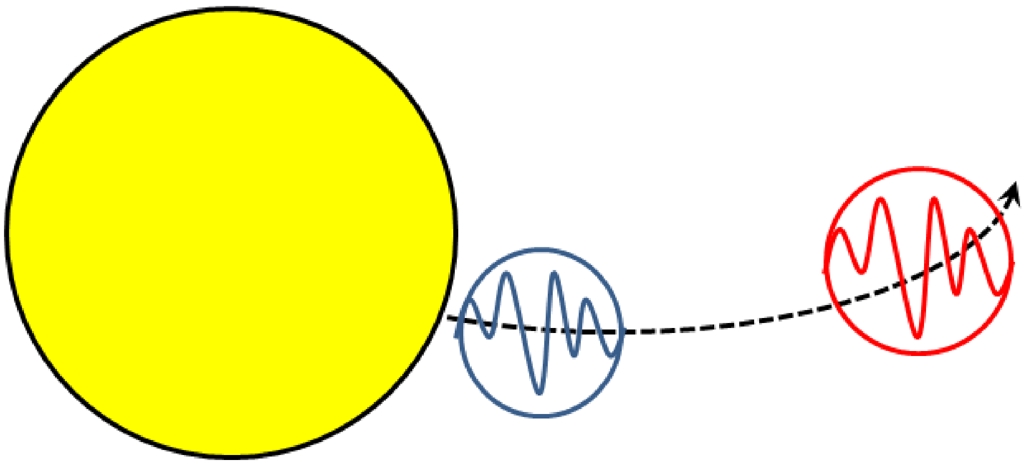
- QM should be viewed as a mechanism for discretizing continuous fields
  - These soliton-like wave packets constitute elementary “particles”; no point particles exist.
- This is NOT an alternative interpretation of orthodox QM
  - Distinct theory with without fundamental uncertainty, superposition, or entanglement.
- Rotating vector fields carry quantized spin
  - Real rotating vector maps onto complex scalar wave function
- Continuous transitions between quantized states mediated by photons at all levels.
- Possible experimental tests
  - No linearly polarized single photon – energy-resolving photodetector
  - No spin superpositions – two-stage Stern-Gerlach measurement
  - Breakdown of scaling anticipated for Quantum Computing

Neoclassical Time and Space

- Dispersion relation for relativistic de Broglie wave
  - $\omega^2 = c^2k^2 + \omega_0^2$, where $\omega_0 = mc^2/\hbar$.
  - Equivalent form: $(\omega\tau)^2 = (k\Lambda)^2 + 1$
  - $\tau = 1/\omega_0 = \hbar/mc^2$; $\Lambda = \hbar/mc$; $\Lambda/\tau = c$
  - Use electron mass m_e, but others would be consistent
- τ and Λ can be used to define time and space
  - Speed-dependent time dilation and length contraction.
  - $\tau = \gamma\tau_0$, $\Lambda = \Lambda_0/\gamma$, where $\gamma = (1-v^2/c^2)^{-1/2}$.
- Gravity also affects quantum clocks and rulers
  - Grav. Potential $\Phi(r)<0$, dimensionless $\phi(r) = \Phi/c^2$
  - Grav. time dilation $\tau = \tau_0\,(1- \phi) > \tau_0$, for weak $\phi \ll 1$
  - Grav. length contraction $\Lambda = \Lambda_0/(1-\phi)$
  - Dependences for large ϕ may be unknown.

Neoclassical Photon Trajectories

- In classical optics, light bends due to changing index $n = c_0/c_m$,
  - $c_m < c_0$ is speed of light in medium and c_0 in vacuum.
- In GR, curvature attributed to bending of space-time, but slowing of light is alternative interpretation of *same trajectory.*
  - $c = c_0/n(r)$, so $\omega = c_0 k/n(r)$, where $n = 1-2\phi > 1$
- Constant-ω photon trajectory, using fixed timebase
  - $d\omega/dt = 0 = (\partial\omega/\partial k)(dk/dt) + (\partial\omega/\partial r)(dr/dt)$.
  - Since $v = \partial\omega/\partial k$ for wave packet, $dk/dt = -\partial\omega/\partial r = -2c_0 k\, d\phi/dr$
  - Trajectory curves toward increasing $|\phi|$
- Also accounts for grav. red shift of photon.
  - Photon rising out of gravitational well increases speed c.
  - f constant, but $\lambda = c/f$ increases, corresponding to red shift.
- Trajectory computed without need for 4D space-time.



Photon moving out of gravitational well.
In neoclassical picture, its frequency remains constant but its wavelength gets longer

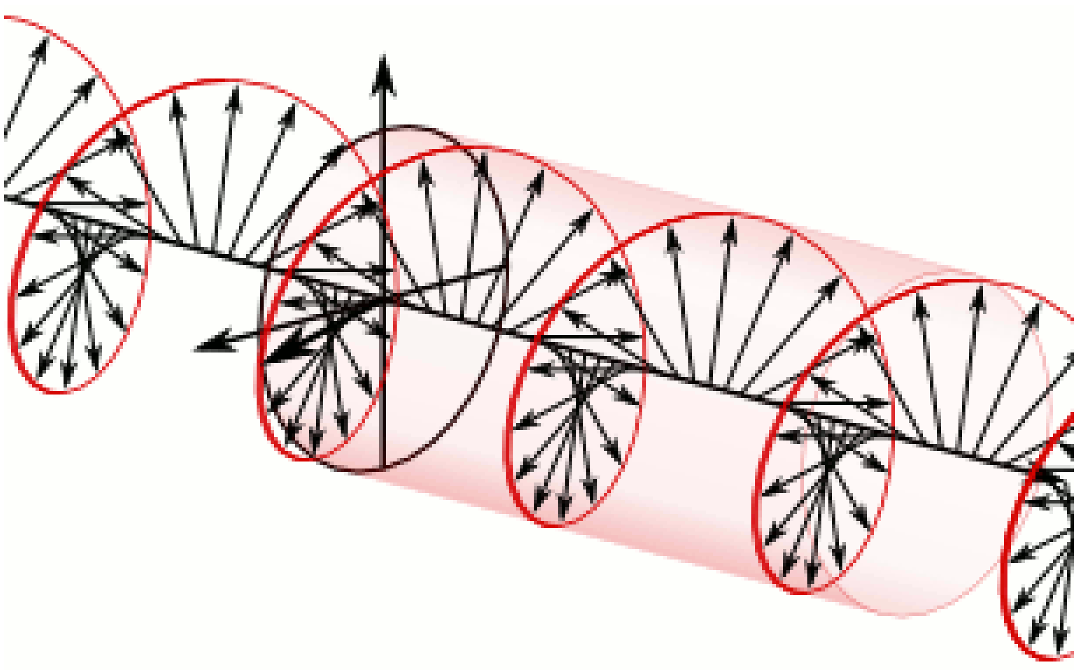
Neoclassical Particle Trajectories

- "Particle" is real wavepacket given by $(\omega\tau)^2 = (k\Lambda)^2 + 1$
  - No separate point particle or probability distribution.
- c is speed limit because all objects made of quantum waves
  - $v = \partial\omega/\partial k = c^2\, k/\omega = c\, k\Lambda/[1+(k\Lambda)^2]^{0.5}$,

    $\approx \hbar k/m$ for small k, $\rightarrow$ c for large k.
- Particles follow trajectories of constant total $E = \hbar\omega$
  - $d\omega/dt = 0 \Rightarrow dk/dt = -\,\partial\omega/\partial r$
  - Equivalent to computation using classical Hamiltonian
  - For v<<c, $\hbar\omega = mc^2 + \hbar^2k^2/2m + \phi mc^2$
  - For $\phi \ll 1$, $\hbar dk/dt = -mc^2\, \partial\phi/\partial r$ for classical limit
- Non-classical trajectories include higher-order effects in ϕ
  - Due to ϕ-dependence of c and m.
  - Reproduces GR effects - rotation of perihelion of Mercury.

Neoclassical Spin of Photon

- From Maxwell's equations, classical circularly polarized (CP) EM wavepacket has rotating vector **E**-field with energy density $\mathcal{E}$ and angular momentum density $\mathcal{S}$
  - $\mathcal{E} = \varepsilon_0 \mathbf{E}^2$; $\mathcal{S} = \varepsilon_0 \mathbf{E}^2/\omega$
  - If total spin S = $\hbar$, then E = $\hbar\omega$ follows automatically.
- Neoclassical single photon is real CP wavepacket with spin $\hbar$ – No point photons!
- N-photon state with spin N$\hbar$ is CP wavepacket with **E** larger by $\sqrt{N}$.
- 2-photon state with opposite CP wavepackets is linearly polarized (LP) with S = 0 and E= $2\hbar\omega$.
- But single LP photon should not exist!
  - Important implications for quantum measurements.
- Note that spin is Lorentz-invariant – photon has same spin $\hbar$ in any reference frame, while energy E changes.



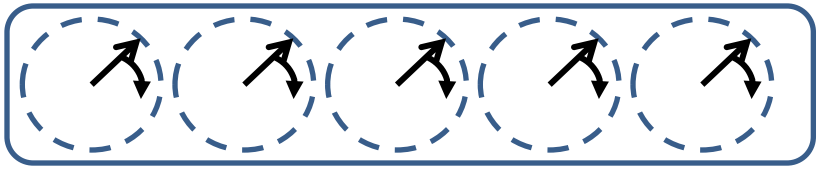
Photon as Circularly Polarized EM Wave Packet

Neoclassical Spin of Electron*

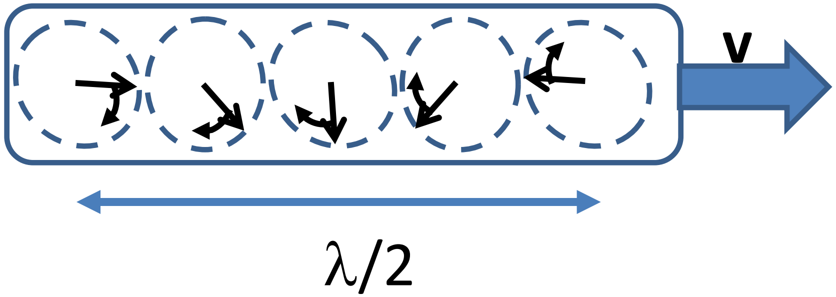
- Electron is wavepacket with rotating vector – no point electron
  - Vector Klein-Gordon eq. $\partial^2\mathbf{F}/\partial t^2 = c^2\nabla^2\mathbf{F} - \omega_0^2\mathbf{F}$, where $\hbar\omega_0 = m_0c^2 + V(r)$
  - If $\mathbf{F}(\mathbf{r},t) = F_0(\mathbf{r})\ \text{ang}[\omega t + \phi(\mathbf{r})]$ with a fixed spin axis,

    the KG equation becomes $E\psi = [m_0c^2 + V(r)]\psi - (\hbar^2/2m)\nabla^2\psi$, where $E = \hbar\omega$ and $\psi = F_0 \exp(i\phi)$.
  - *Real vector rotation about a fixed axis maps onto the Schrödinger equation for complex scalar.*
- <u>Assume</u> that rotating vector carries spin, with $\mathcal{E} = 2\mathcal{S}\omega$
  - Then $S = \hbar/2$ ➔ $E = \hbar\omega$ as required.
- This can be transformed to its rest state with $E = mc^2 = \hbar\omega$.
  - Uniform phase at rest, phase gradient if moving.
- Electron is charged, so it has a magnetic moment μ.
  - Spin axis is || **or** anti-|| to **B** field, with energy difference $2\mu B$.
  - Electron should NOT exist in superposition of up and down states.

*A.M. Kadin and S.B. Kaplan, "Electron Spin and Rotating Vector Fields", 2017



Single Electron at Rest, showing in-phase rotation of vector field



Moving single electron, showing phase-lag of de Broglie wave

Wavepackets and Solitons

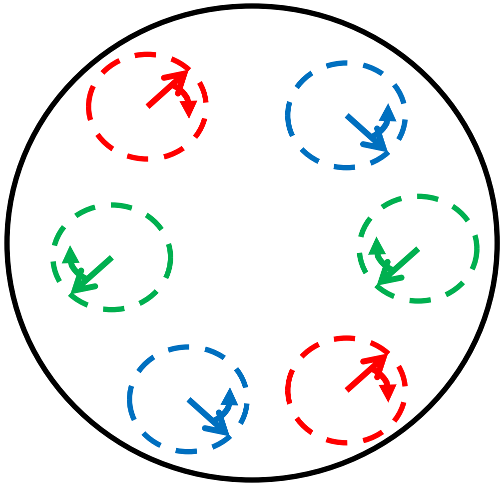
- If a wavepacket can represent a quantum particle, why has a model of this type never been seriously considered?
  - Wavepackets in linear media do not maintain their integrity – they may split or merge, attenuate or disperse.
- But certain classical nonlinear wave equations have special solutions known as **solitons,** which are wavepackets with fixed amplitude that maintain their integrity.
  - Soliton may act like particle, even if it is distributed wavepacket – it cannot split, merge, or attenuate.
  - It may act like a linear medium, since the nonlinear terms may cancel out for this amplitude.
- Suggestion: Quantum "particles" may be solitons
  - Problem – quantum wave equations such as the KG or Schrödinger equation are linear.
  - *Appropriate nonlinear differential equations not yet identified.*

Exclusion Principle and Entanglement

- One of the foundations of atomic theory is the Exclusion Principle, whereby only 1 electron (of each spin) may occupy a given atomic energy level.
  - Pauli proposed (1925) a mathematical construction that enforces the exclusion principle, involving antisymmetric exchange of wavefunctions.
  - Pauli's construction provided the first example of quantum entanglement, which spread throughout orthodox QM before Einstein and Schrödinger (1937) noticed the non-local aspects.
- But the Exclusion Principle is a natural consequence of soliton-like behavior.
  - A classical soliton may also permit only one excitation in a particular location at a particular time.
- Entanglement may be unnecessary, undesired mathematical artifact of Pauli's construction
- Different quantum properties of electron and photon may be due ***not*** to different exchange symmetries, but rather to different nonlinear equations.

Elementary Particles and Composites

- All elementary "particles" of standard model are rotating vector fields with distributed spin
  - Leptons and quarks are fermions with $\hbar/2$
  - Photons, gluons, W & Z are bosons with $\hbar$
  - Described by real distributed relativistic wave packets
  - No point particles
  - Internal degrees of freedom remain deterministic, even though uncontrolled.
- Composites are simply bound bags of wave packets
  - Nucleons, atoms, nuclei, molecules
  - These are not waves at all, but inherit quantization from components
  - Quantum diffraction (of neutrons or atoms) due to quantized momentum transfer, not de Broglie waves.
  - Macroscopic systems may also have quantized states mediated by photons.



Neutron or proton is not a wave;
it is a particle ~ 1 fm
with internal structure of 3 quark vector fields
bound by gluons fields

Speculations on Nonlinear Quantum Field Equations

- *This problem has not yet been solved.*
  - Helpful suggestions or collaboration would be of interest.
- Requirements for candidate equations
  - Two types – fermions with $\hbar/2$; bosons with $N\hbar$
  - Lorentz covariance
  - Simple, locally realistic
  - Reduces to relevant linear equation for quantized spin
- Candidate eqn. for photon – modified EM wave equation
  - Scalar and vector EM potentials φ, $\mathbf{A}$ in natural units.
  - $[(\partial/\partial t - \varphi)^2 - (\nabla - \mathbf{A})^2]\ (\varphi,\mathbf{A}) = 0$
  - φ modulates ω and $\mathbf{A}$ modulates $\mathbf{k}$.
  - The soliton behavior of this or other candidate equations have not yet been evaluated.

Proposed Tests of Neoclassical Quantum Picture

- Neoclassical relativity exactly equivalent to orthodox relativity, at least for weak fields
  - Cannot be distinguished experimentally
- But neoclassical quantum theory is quite different from orthodox quantum theory in absence of superposition and entanglement at all scales.
  - Simple experimental tests using light beams, atomic beams, and interacting qubits
  - These tests have not been done, but could be done quickly.
- See Appendix for further details.

Conclusions

- Orthodox modern physics – classical, quantum, and relativity are each valid in their own distinct domains.
- Alternative reunified neoclassical picture – single paradigm for all physics.
- (ω,k) of real quantum fields define time and space
- Rotating vector fields (which map onto complex scalars) form soliton-like particles with quantized spin, but nonlinear math *not yet identified*.
- c is not a universal constant, but $\hbar$ is.
- Abstract spacetime and Hilbert space obscure fundamental physics.
- This provides an alternative *interpretation* of relativity, but a testably *different* quantum theory which avoids quantum paradoxes.
- Tests do not require high-energy accelerators, but can be done with light beams, or atomic beams, or quantum bits.
- If Quantum Computing does *not* work, it may be time to consider this alternative neoclassical framework.

References

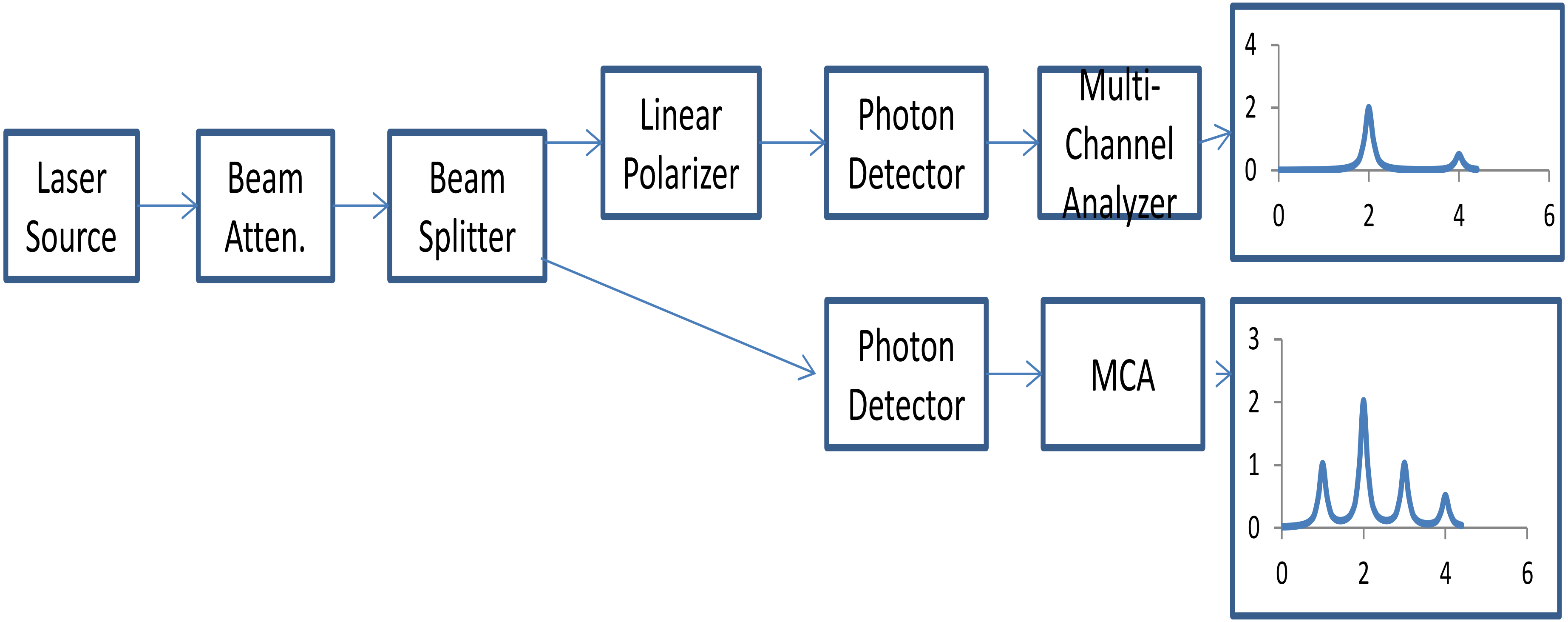
- A.M. Kadin, “Fundamental Waves and the Reunification of Physics”, Foundational Questions Inst. Essay Contest, 2017, https://fqxi.org/community/forum/topic/2972.
- A.M. Kadin and S.B. Kaplan, “Electron Spin and Rotating Vector Fields”, 2017, http://vixra.org/abs/1709.0360
- A.M. Kadin, “Gravitation and Cosmology without Divergences”, 2018, http://vixra.org/abs/1804.0231
- A.M. Kadin, “Waves, Particles, and Quantized Transitions: A New Realistic Model of the Microworld”, 2011, https://arxiv.org/abs/1107.5794
- A.M. Kadin, “Wave-Particle Duality and the Coherent Quantum Domain Picture”, 2006, https://arxiv.org/abs/quant-ph/0603070
- A.M. Kadin, “Circular Polarization and Quantum Spin: A Unified Real-Space Picture of Photons and Electrons, 2005, https://arxiv.org/abs/quant-ph/0508064

Appendix: Experimental Tests of Quantum Foundations

- Neoclassical quantum picture predicts local reality without entanglement or indeterminacy
- Simple experiments should show sharp deviation from orthodox quantum theory.
  - Determine whether single photon must be circularly polarized -- entanglement.
  - Determine whether spin-polarized atomic beam splits in a rotated magnetic field -- superposition.
  - Determine whether coupled qubits form delocalized energy band – scaling for quantum computing.

Proposed Test – LP Single Photon

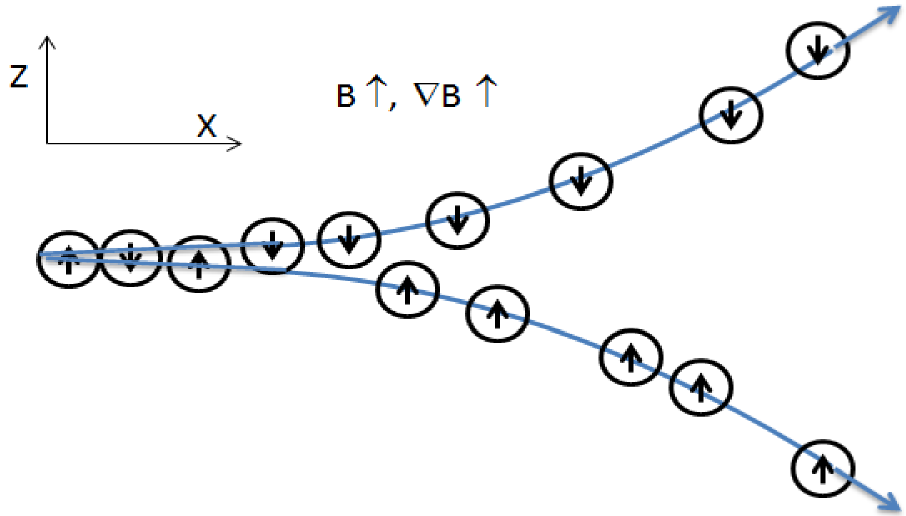
- LP single photons are central to most optical tests of quantum entanglement.
  - But neoclassical single photons are real CP wavepackets; LP fields must be photon pairs.
  - LP single photons have been observed in experiments, but with fast event detectors that cannot distinguish 1 from 2 simultaneous photons.
  - New superconducting energy-sensitive photon detectors can determine number of photons in fast pulse.
- Proposed experiment – measure photon count distribution in weak laser pulses
  - Compare results with and without linear polarizer.
  - In neoclassical picture, LP pulses should have only even number of photons.



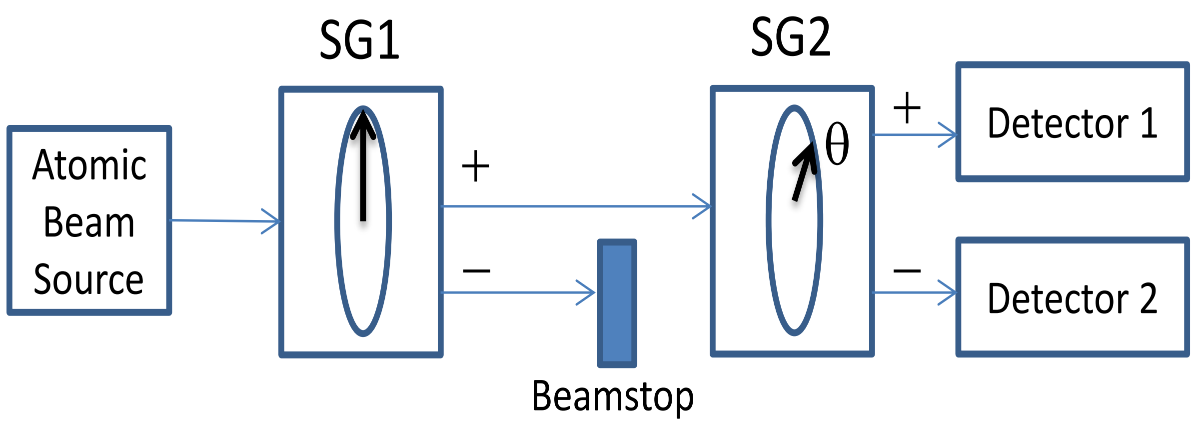
Counting Photons in a Light Pulse using Energy-Resolving Detector with and without Polarizer

Proposed Test – Magnetic Spin Superposition

- Stern-Gerlach experiment (1922) provided first evidence for spin quantization of electrons.
  - Univalent atomic beam placed in magnetic field gradient
  - Assumed to be in superposition of $\downarrow$ and $\uparrow$ spins.
  - Split into two sub-beams, corresponding to $\uparrow$ and $\downarrow$
- Two-stage SG experiment used in many textbooks to illustrate quantum measurement
  - One sub-beam is sent to 2nd SG analyzer, rotated by angle θ.
  - Expected statistical distribution as $\cos^2\theta$ and $\sin^2\theta$.
  - But this experiment was never done – admitted by Feynman, ignored by others.
- Proposed experiment – carry out 2-stage SG experiment
  - In neoclassical picture, no superposition states; spins rotate to new field direction.
  - Expected result – 0 or 100%, with no distribution.



Original Stern-Gerlach Experiment – spin separation

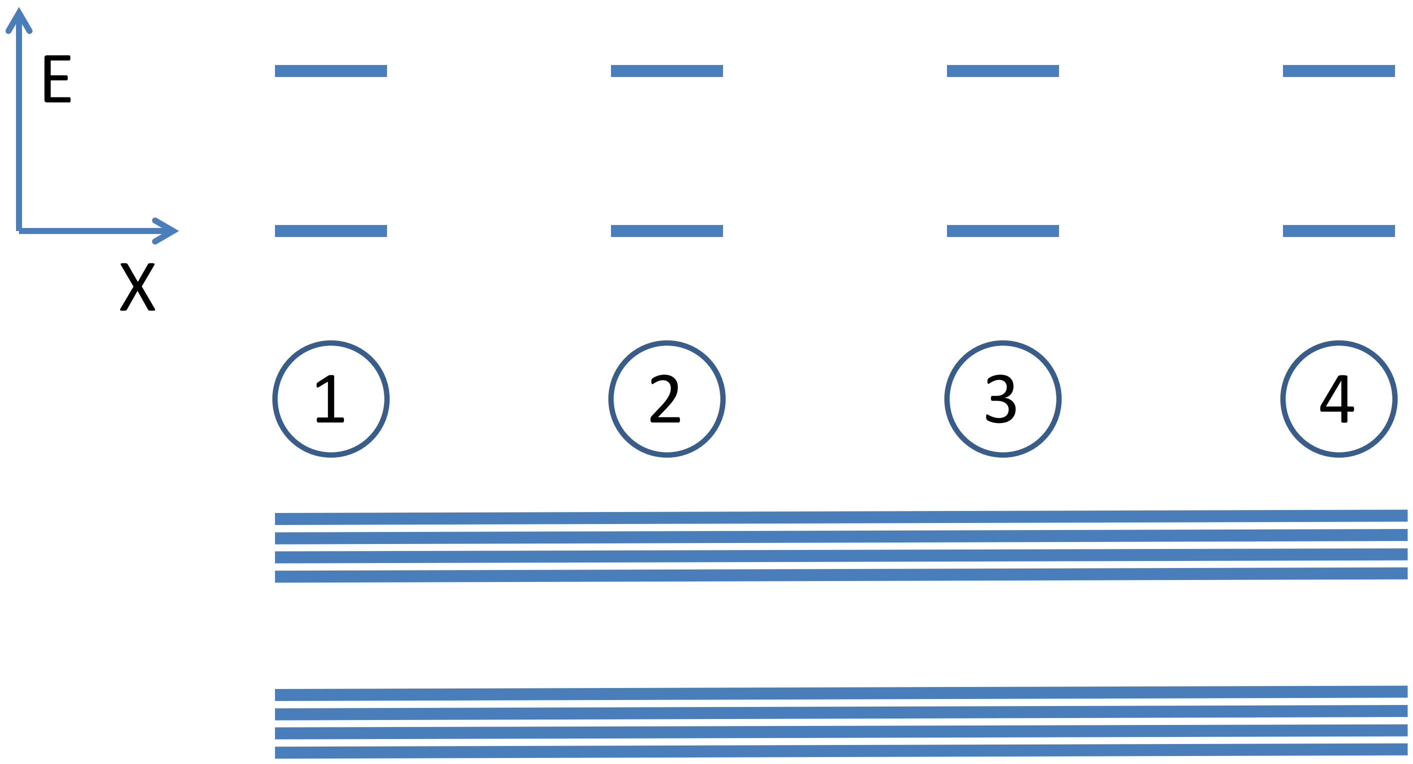


2-stage Stern-Gerlach Experiment

Proposed Test – Interacting Qubits

- Quantum computing is first major application critically dependent on quantum entanglement
  - 2^N effective parallelism for N qubits due to expansion of Hilbert space.
  - Massive parallelism enables QC to solve difficult problems with finite resources.
- But neoclassical model has no entanglement and no Hilbert space.
  - Quantum computing should not work at all!
- Example of N coupled quantum oscillators
  - Orthodox picture predicts 2^N entangled states
  - Neoclassical picture predicts 2N delocalized states (band theory)
- Similar to interacting superconducting qubits (Neill 2018)
  - Delocalized band model should work better than model of entangled localized qubits.

Energy Levels of Coupled and Uncoupled Qubits



- Localized states broaden into extended bands
- No increased degrees of freedom

More References

- A.M. Kadin and S.B. Kaplan, “Proposed Experiments to Test the Foundations of Quantum Computing”, 2016, http://vixra.org/abs/1607.0105
- A.M. Kadin, “Single-spin Devices and the Foundations of Quantum Mechanics”, 2014, http://vixra.org/abs/1409.0004
- A.M. Kadin and S.B. Kaplan, “Is a Single Photon Always Circularly Polarized: A Proposed Experiment Using a Superconducting Microcalorimeter Photon Detector”, 2014, https://arxiv.org/abs/1407.2605
- H. Schmidt-Bocking et al., “The Stern-Gerlach Experiment Revisited,” Euro. Phys. J. H41, pp. 327-364, 2016.
- A. Lita et al., “Counting near-IR single photons with 95% efficiency, Optics Express 16, 3032, 2008.
- C. Neill et al., “Blueprint for demonstrating quantum supremacy with superconducting qubits,” Science 260, 19, 2018.