Process Theology as a Lens for Bringing Quantum Physics into Focus

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Lecture 4: Quantization: Building the Quantum State Machine → Ordered Indeterminacy (Creativity under constraint)

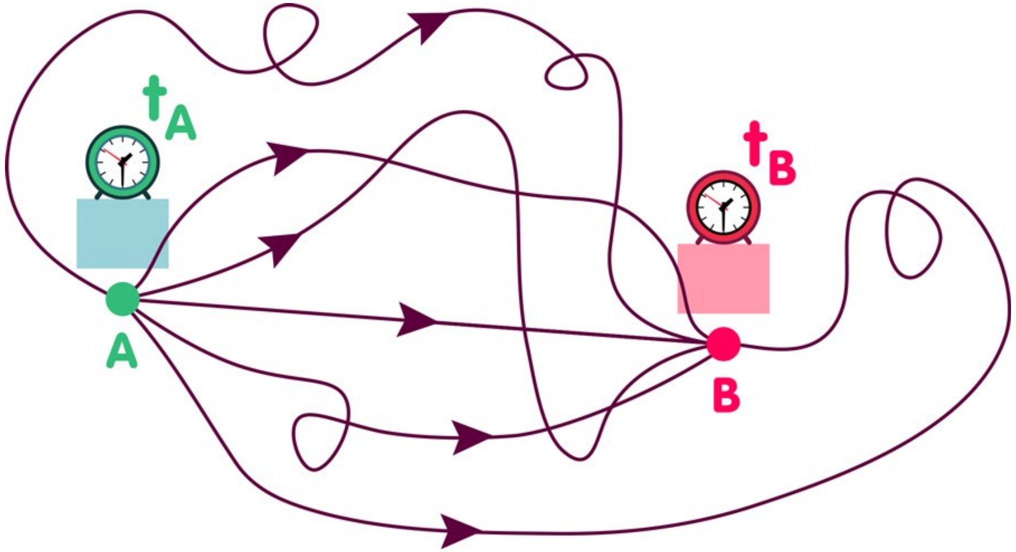
Every Possible Path?

One of the most common statements in popular quantum physics is that a particle literally travels every possible path simultaneously from the source to the detector.

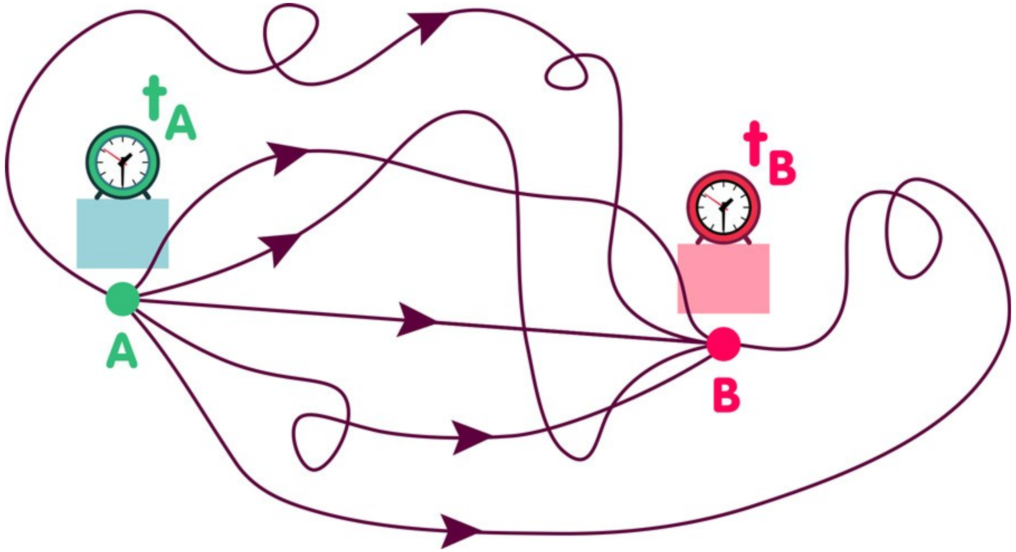
- What if I told you that is a lie?
- Well… maybe not exactly a lie, but certainly an oversimplification not justified by the mathematics.

Tonight I want to explain:

- Why physicists say this,
- What the mathematics actually does, and
- Why we need to be very careful about what it really means.



Why Physicists Say This



Physicists often describe a particle as "Exploring every possible path simultaneously"

- Because the mathematics assigns a probability amplitude to every possible path connecting the source and detector.
- Because this statement is provocative, intuitive, and fits naturally with realist interpretations in which quantum fields or amplitudes are treated as physically real.

What the Model Actually Does:

- The quantum state machine model is designed to accurately predict the probabilities associated with particle-like detections.
- The model is not designed to tell us what path a particle "really" takes between detections — or even whether the particle takes a path at all.

A Simple Example for Clarification

The Experiment

- Imagine a laser emitting photons one at a time toward a detector.
- There are no slits, barriers, or obstacles between the laser and detector.

If photons behaved like perfectly classical particles and every photon left the laser with exactly the same position and momentum:

- We would expect every detection to occur at exactly the same point.
- But that is not what experiments show.

A Simple Example for Clarification

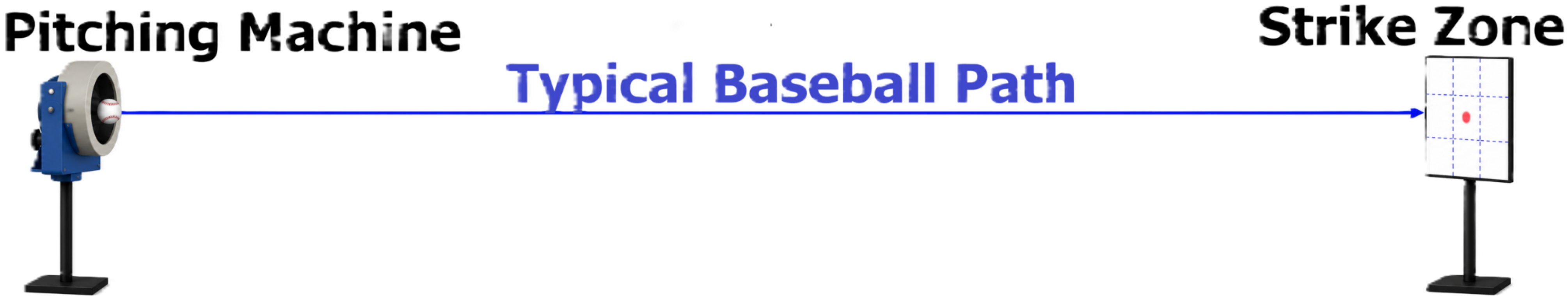
Why Classical Particles Fail

- Real photons do not leave the laser with perfectly defined position and momentum.
- The more precisely we localize the photon at emission, the less precisely its momentum can be defined.

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

- For large objects, this uncertainty is insignificant compared to the total momentum of the object.
- For elementary particles such as photons, the uncertainty becomes significant.

As a result, photon detections no longer occur at exactly the same point on the detector.



Baseballs vs Photons

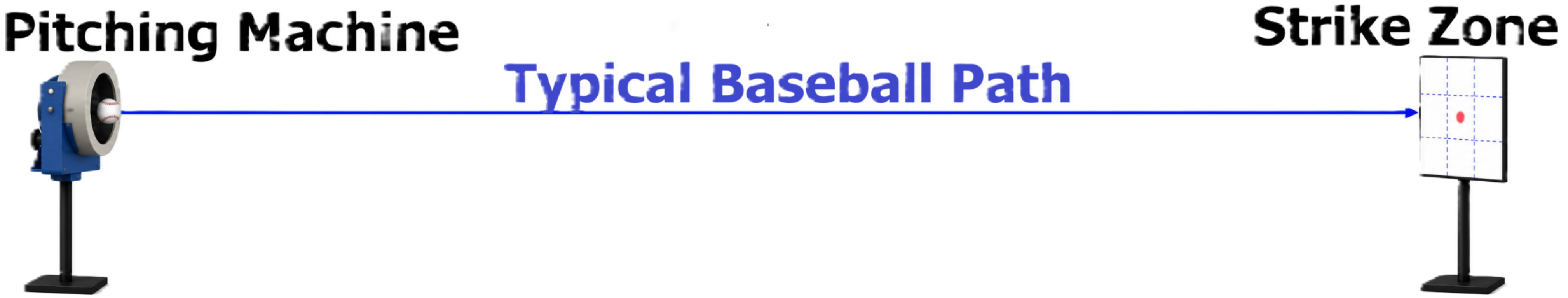
Imagine replacing the photons with baseballs launched from a pitching machine.

- No pitching machine can launch every baseball with exactly the same position and momentum.
- Mechanical imperfections produce a spread of trajectories and impact locations.
- Baseballs are also subject to the uncertainty principle.

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

- But for macroscopic objects such as baseballs, the quantum uncertainty is insignificant compared to the total momentum of the baseball.

The spread in baseball trajectories is therefore dominated by mechanical error rather than quantum uncertainty.



Why Alternative Baseball Paths Are Irrelevant

In principle, the mathematical model can assign probability amplitudes to many possible baseball trajectories.

- But for macroscopic objects, amplitudes associated with alternative paths almost completely cancel.
- Only amplitudes very close to the classical trajectory contribute measurably to the final probability.

In practice, the classical path is the only significant trajectory for the baseball.

This is why baseballs appear to follow a single well-defined path.

Why Photons Are Different

Lasers also contain small mechanical and optical imperfections.

- **But for photons, the uncertainty principle becomes significant.**

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

- **Because photons carry extremely small momentum, the uncertainty in momentum becomes experimentally important.**

As a result, photon detections no longer occur at exactly the same point on the detector.

- **Individual detections initially appear random.**
- **But over time, a stable probability distribution emerges.**

Why Physicists Talk About "All Possible Paths"

For photons, many possible paths contribute measurably to the final probability amplitudes.

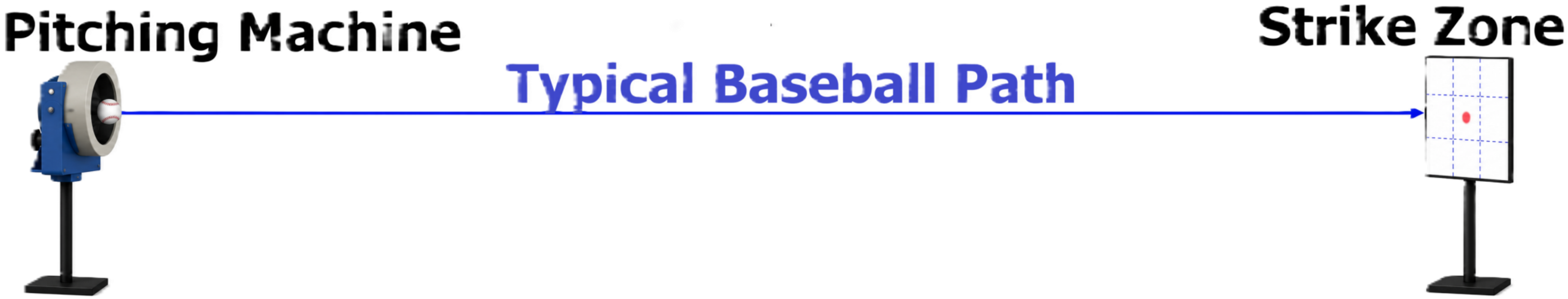
- Physicists therefore often describe the photon as "exploring all possible paths simultaneously."

But this statement can be misleading in two important ways:

- It is the mathematical model — not necessarily the photon itself — that encodes multiple paths.
- In practice, paths whose amplitudes contribute negligibly to the final probability are ignored.

The experiments confirm the detection probabilities predicted by the model.

Whether the photon literally travels those paths is a separate interpretive question.



Why Begin with Classical Mechanics?

To build our quantum state machine model, we first need a classical model.

Our Example: A Baseball Pitching Machine

- Classical physics provides two equivalent ways to describe the path the baseball takes:
  - Newtonian Mechanics

    Based on forces and accelerations.
  - Lagrangian Mechanics

    Based on the principle of stationary action and trajectories.
- Both describe the same classical behavior and make the same predictions.

Roadmap:

From Baseballs to the Quantum State Machine

Our example: a baseball pitching machine.

1. Classical System
Baseball pitching machine

A real system that can be understood using classical physics.

2. Newtonian Mechanics — $\sum F = ma$
Forces and accelerations

One classical description of the motion.

3. Lagrangian Mechanics — $S = \int L\, dt$
Action and trajectories

An equivalent classical description chosen because it is best suited for quantization.

4. Quantization — $\hbar$
Promote classical quantities to operators

Replace classical quantities with operators and construct the quantum model. The bridge from classical to quantum.

5. Hamiltonian Mechanics — H
Energy function (Hamiltonian) and phase space

The classical theory recast into the framework used by quantum theory.

6. Quantum Mechanics — ψ
Quantum states and a Hamiltonian predict detection probabilities

The quantum state machine that makes experimentally testable predictions.

Why Start with the Lagrangian Rather than Newtonian Mechanics?

- Newtonian and Lagrangian mechanics make the same classical predictions.
- The Lagrangian works naturally with systems containing many interacting parts.
- The Lagrangian can be written in a form that respects fundamental symmetries.
- The Lagrangian extends naturally to elementary particles and their associated fields and therefore provides the preferred starting point for modern quantization.

Next: The video walks us through the classical Lagrangian using trajectories like those of our baseball pitcher.

Lagrangian Mechanics: How powerful is it?

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Introduction >

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Lessons from the Video

1. Particles do not take all paths simultaneously
   - The Lagrangian Model accurately predicts classical trajectories by exploring every possible path.
   - But that does not mean that in reality particles explore every possible path.
2. Newtonian Mechanics and Lagrangian Mechanics are two classical models that predict the same results
   - Both are predictive models but neither necessarily represents reality.
3. Configuration Space, Hamiltonian Mechanics and Quantum Mechanics
   - In modeling we often find it useful to plot things in hypothetical spaces
   - Physics experiments occur in ordinary spacetime. Later we will represent those observations using the position basis of Hilbert Space.
   - Hamiltonian Mechanics and Quantum Mechanics use abstract mathematical spaces, including Hilbert Space, that are part of the predictive model we will develop next.

Three Levels of Description

The laser-to-detector experiment can be described at three different levels.

- Each level works well within a particular domain.
- But each level also has important limitations.

Level 1:

Classical Particle Mechanics

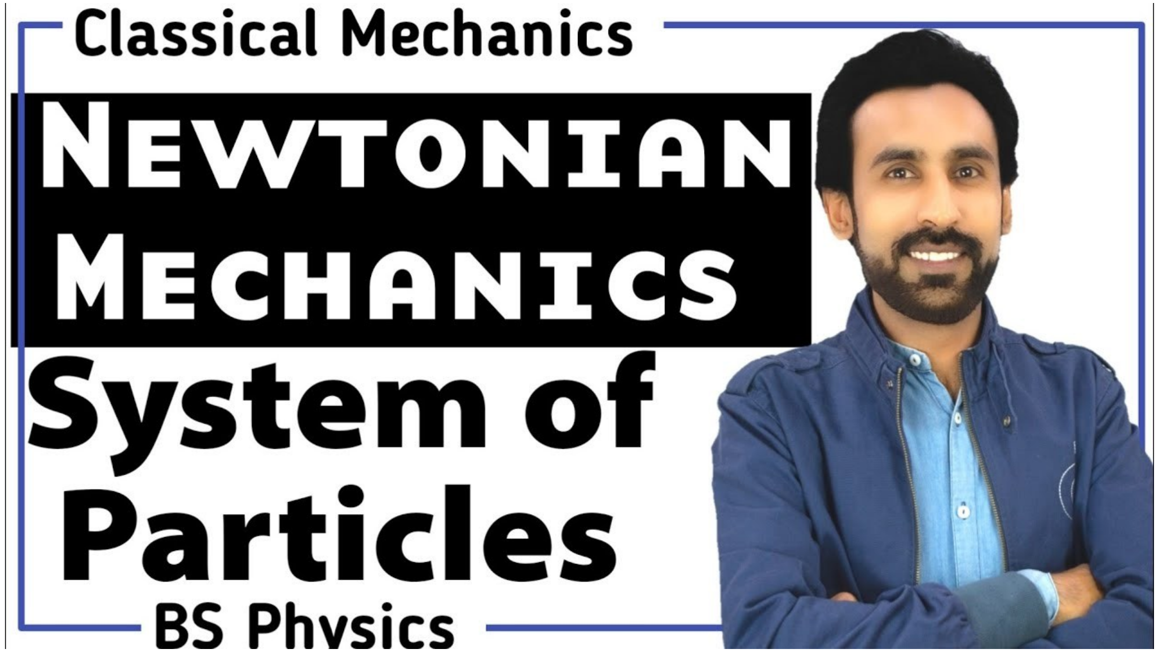
Level 2:

Classical electromagnetic fields

Level 3:

Quantized fields and the Quantum State Machine Model

Level 1: Classical Particle Mechanics



In classical mechanics, particles are modeled as objects with:

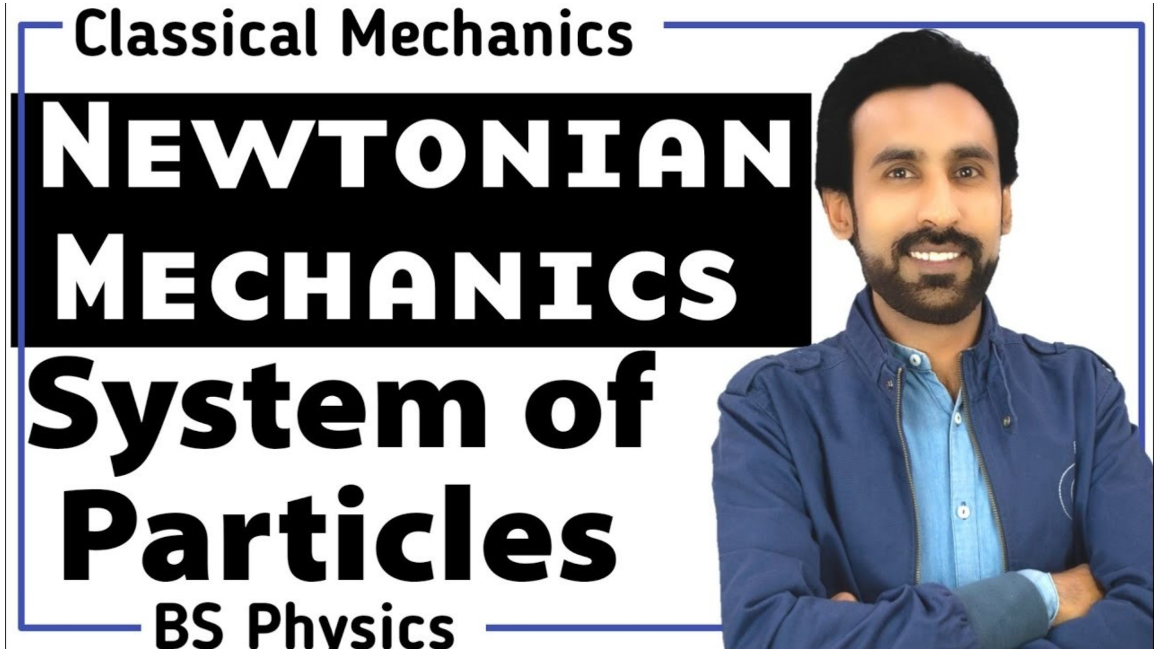
- position,
- momentum,
- and trajectories.

The classical Lagrangian provides a mathematical framework for predicting how these trajectories evolve through time.

- For macroscopic objects, the model predicts the familiar classical trajectories we observe experimentally.
- This approach works extremely well when uncertainty effects are negligible.

Level 1: Classical Particle Mechanics

The Classical Lagrangian



The classical Lagrangian is constructed from classical quantities such as:

- kinetic energy,
- potential energy,
- and classical fields.

The Lagrangian encodes the physical rules governing the system.

- In classical mechanics, these rules determine how particles and fields evolve through time.
- For macroscopic systems, the predictions agree extraordinarily well with experiment.

Why Classical Particle Trajectories Fail for Photons

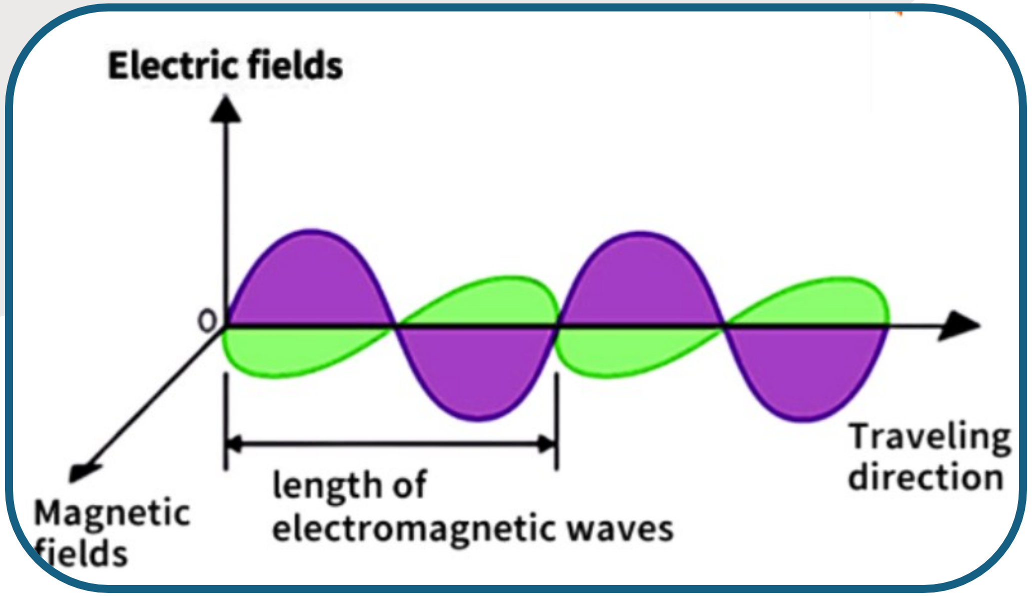
Photons do not behave like classical particles following single well-defined trajectories.

- **The uncertainty principle becomes experimentally important.**

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

- **Many possible paths contribute measurably to the final probability amplitudes.**
- **Classical particle trajectories alone cannot explain the experimentally observed probability distributions of photon detections.**

Level 2: Classical Electromagnetic Fields



Instead of treating light as a particle trajectory, classical electromagnetism models light as a wave in an EM field.

- **A classical field assigns values or vectors to every point in spacetime.**
- **The field version of the Lagrangian produces Maxwell's equations, allowing us to predict how electromagnetic waves propagate and how light intensity is distributed through space.**
- **Energy introduced into the electromagnetic field by the laser propagates continuously through space and time according to Maxwell's equations.**

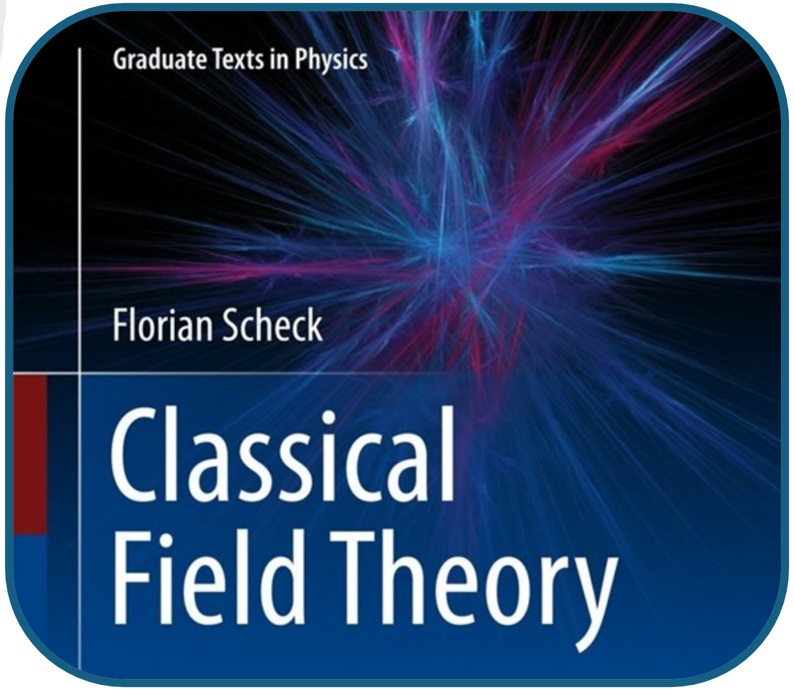
What Classical Fields Successfully Predict

Classical electromagnetic fields successfully predict many observed properties of light.

- **Interference patterns produced by overlapping light waves.**
- **Diffraction patterns produced when light passes through openings or around obstacles.**
- **The propagation of electromagnetic waves through space.**
- **The distribution of light intensity across a detector.**

In our laser-to-detector experiment:

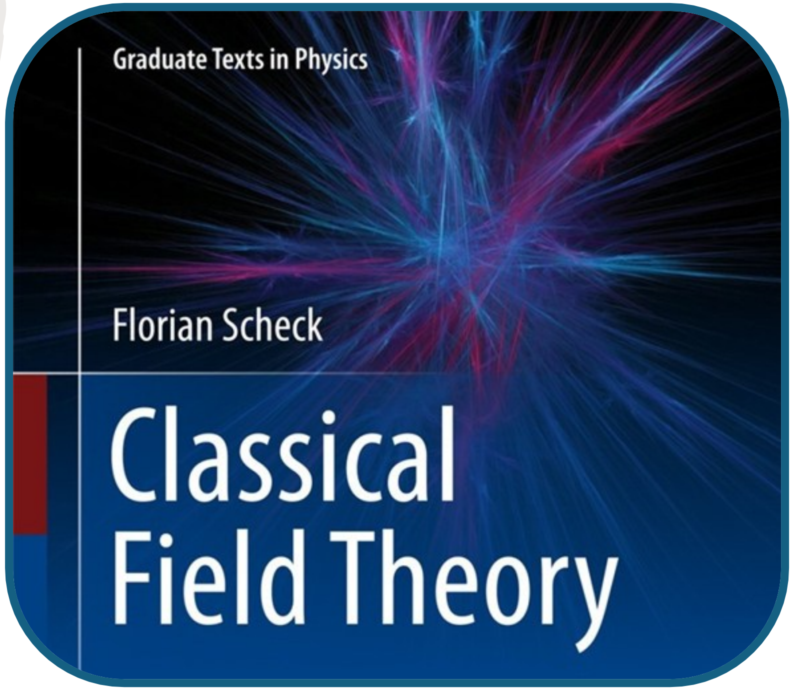
- **Maxwell's equations correctly predict where light intensity will be greatest and where it will be weakest.**
- **The resulting intensity distribution closely matches the pattern that emerges after many photon detections.**



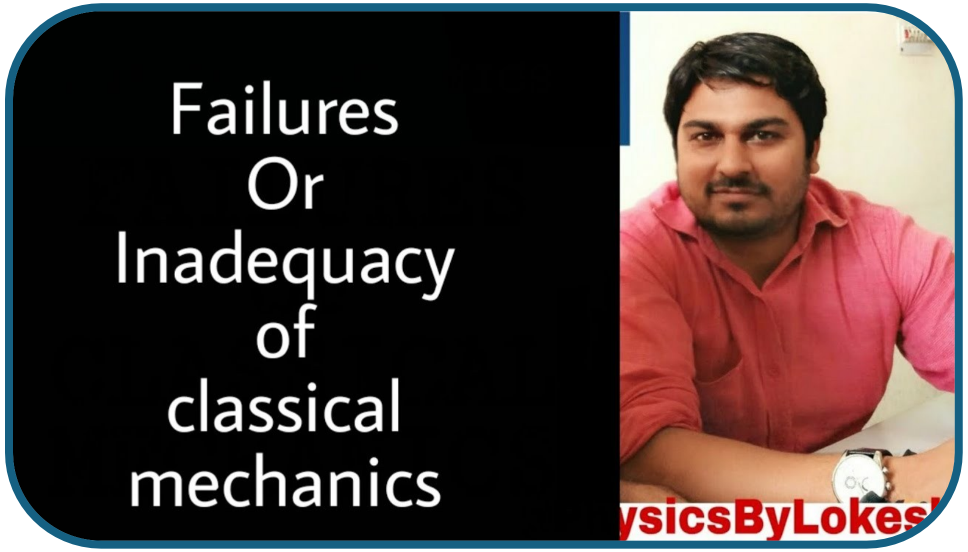
The Crisis of Classical Physics

Despite the success of predictions made using classical physics, there were serious problems:

- Classical electromagnetism was extraordinarily successful.
- Yet several experiments produced results that classical physics could not explain.
- These were not small discrepancies.
- In several cases, classical theory predicted results that were catastrophically wrong.



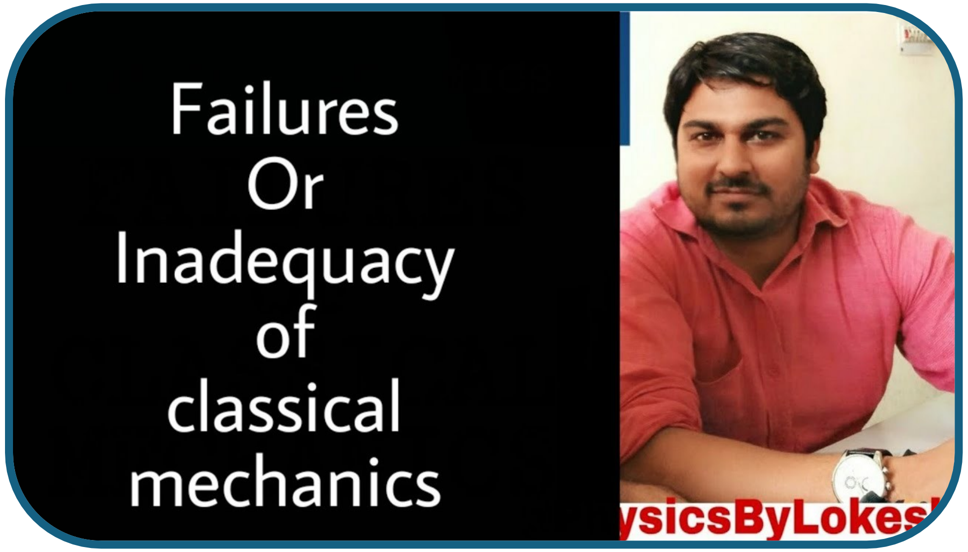
Catastrophic Failures of Classical Physics



Classical physics was extraordinarily successful, but several important predictions were disastrously wrong.

- **Blackbody Radiation**
  - Classical physics predicted that the energy emitted at short wavelengths should become infinite.
  - This became known as the ultraviolet catastrophe.
- **Atomic Stability**
  - Classical electromagnetism predicted that orbiting electrons should continuously radiate energy.
  - Atoms should rapidly collapse into their nuclei.
  - Stable atoms should not exist.
- **Atomic Spectra**
  - Classical theory predicted that atoms should emit a continuous spectrum of light.
  - Experiments instead revealed sharply defined spectral lines.
  - Atomic energy appeared to be quantized.

Catastrophic Failures of Classical Physics



More Experimental Failures

- **The Photoelectric Effect**
  - Light below a threshold frequency could not eject electrons, regardless of intensity.
  - Electron energy depended on light frequency rather than total light energy.
- **Electron Diffraction**
  - Electrons produced interference and diffraction patterns similar to waves.
  - Classical particle trajectories could not explain this behavior.
- **Discrete Photon Detections**
  - Classical electromagnetic fields spread energy continuously through space.
  - Experiments detected light as localized, discrete events rather than continuous arrivals.

Bottom Summary

Classical physics could not simultaneously explain the wave-like and particle-like behavior observed in matter and light.

Classical physics was failing.

- Classical particle trajectories could not explain quantum phenomena.
- Classical electromagnetic fields successfully predicted many wave-like effects.
- Yet classical physics could not explain:
  - atomic stability,
  - atomic spectra,
  - the photoelectric effect,
  - electron diffraction,
  - or discrete photon detections.

The Critical Insight

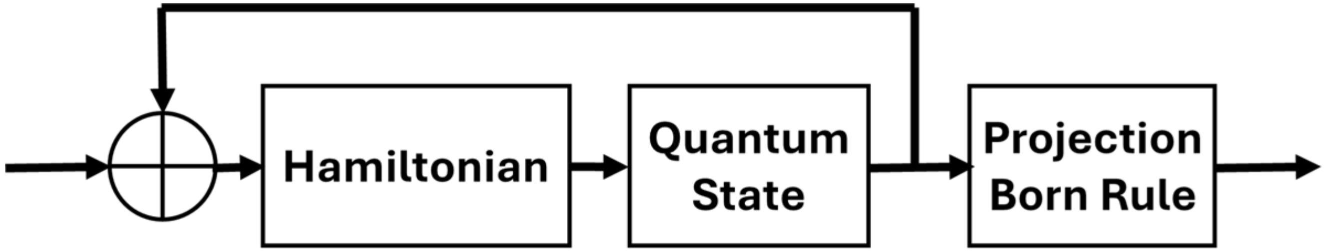
- Physicists did not abandon the classical Lagrangian.
- The Lagrangian already encoded the physical structure and dynamics of the system.
- Instead, they developed a new procedure called quantization.

Quantization would transform a successful classical model into a quantum one.

From Blueprint to Quantum State Machine

The starting point is the classical Lagrangian.

- Quantization of the Lagrangian is a process in which the classical fields are replaced by operators and used to construct the Hamiltonian and define the quantum states.



The result is a quantum model built from:

- **A Hamiltonian**
  Encodes the allowed energy structure and governs state evolution.
- **Quantum States**
  Represent the possible configurations of the system.
- **Hilbert Space**
  The mathematical space containing all possible quantum states.

The Result

Classical Lagrangian → Quantization → Hamiltonian + Quantum States → Quantum State Machine

Our Example: A Single Photon Experiment

To demonstrate how the Quantum State Machine is constructed, we will use a very simple experiment:

- A laser sends a single photon to a detector.

Why this example?

- It is simple enough to understand step-by-step.
- It contains all of the essential elements of quantization.
- The same modeling procedure is used for virtually all quantum systems.

Key Concept:

We are now leaving the roadmap and beginning the actual construction of the model. Although our example is simple, the procedure we develop i essentially the same procedure used throughout modern quantum physics.

Our Example: A Single Photon Experiment

What We Actually Observe:

- A source event
- A detector click
- A statistical pattern after many repetitions

We do not directly observe:

- A photon in flight
- A wave packet in flight
- A field in flight
- A wavefunction in flight

Key insight:

The purpose of the model is to predict the probability of detector clicks. The mathematical objects we introduce along the way are part of the predictive framework.

The Experimental Setup

Our experiment contains:

- Source → Empty Space → Detector

Unlike a light bulb:

- The laser produces a highly focused beam.
- The beam directs energy toward the detector.

For modeling purposes:

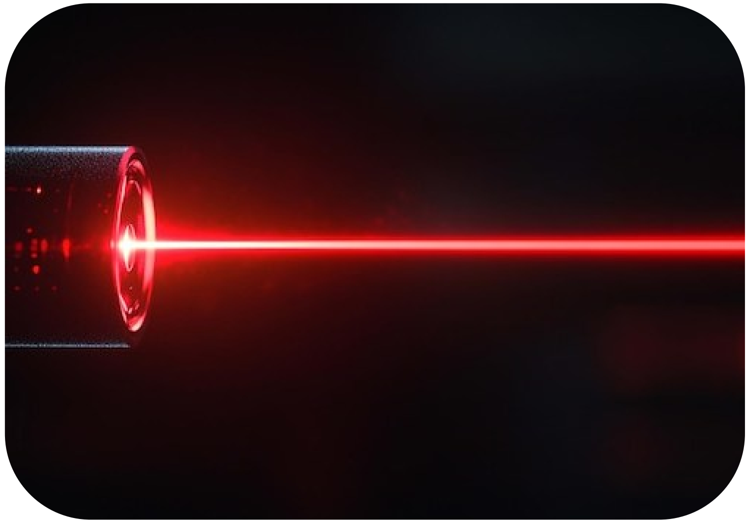
- We represent the beam as an electromagnetic field traveling from source to detector.

Key Concept:

- At this stage we are still doing classical physics.
- We have not yet introduced photons, quantum states, or quantization.

The Experimental Setup

How Do We Model the Beam?



A focused electromagnetic beam can be represented mathematically as:

- A combination of many pure sine waves

This decomposition is called:

- Fourier Series or Fourier Transform

Why do this?

- Because the sine-wave components behave like harmonic oscillators.

Key Concept:

- The purpose of the Fourier decomposition is not to discover what the beam 'really is.
- The purpose is to expose the harmonic oscillators hidden within the electromagnetic field.

Why Are Harmonic Oscillators Important?

Quantization in quantum physics does not mean:

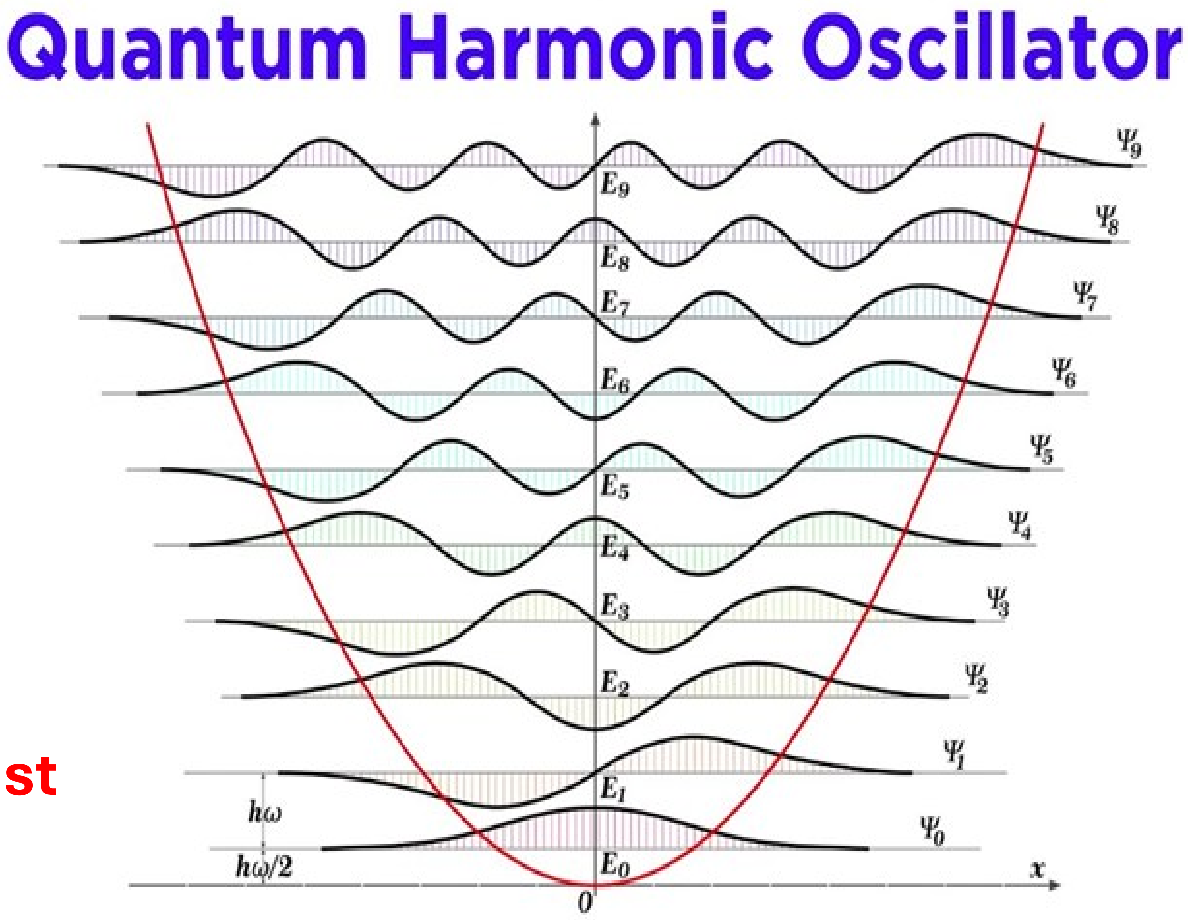
- Chopping a wave into little pieces.

Quantization begins with:

- Classical Harmonic Oscillators
- These oscillators will become the building blocks of the Quantum State Machine.

Key Concept:

Before we can quantize anything, we must first identify the classical harmonic oscillators that are present in the electromagnetic field.



Where We Are Going?

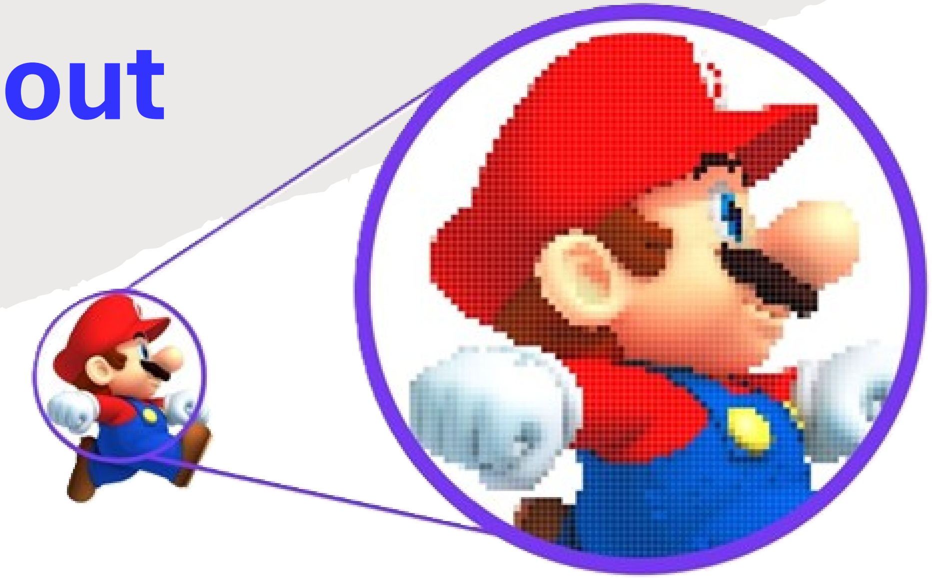
Goal: Build a Quantum State Model for a Single Photon

- We begin with a classical electromagnetic field.
- We identify the harmonic oscillators hidden within that field.
- We quantize those oscillators.
- The resulting quantum model predicts detector probabilities.

Key Concept:

- Notice that we still do not have a photon.
- The photon will emerge later from the quantization procedure.

A Common Misconception About Quantization

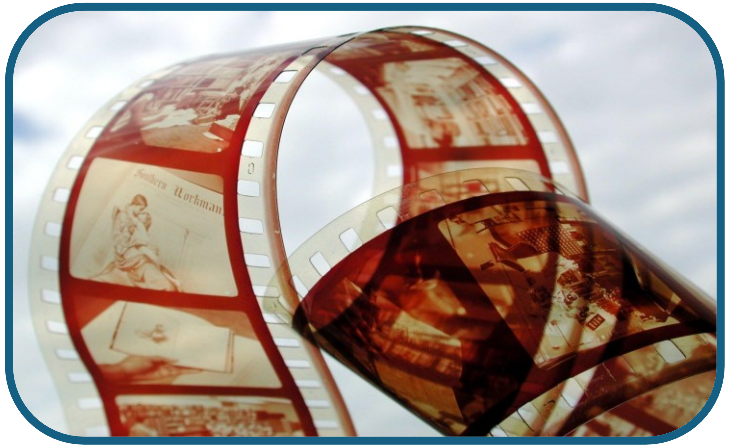


Popular Description

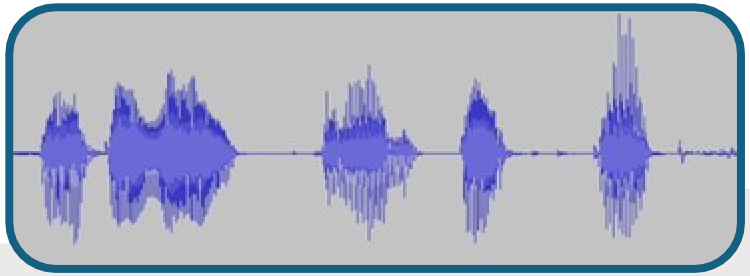
- Quantization means chopping a continuous thing into little pieces.

Examples:

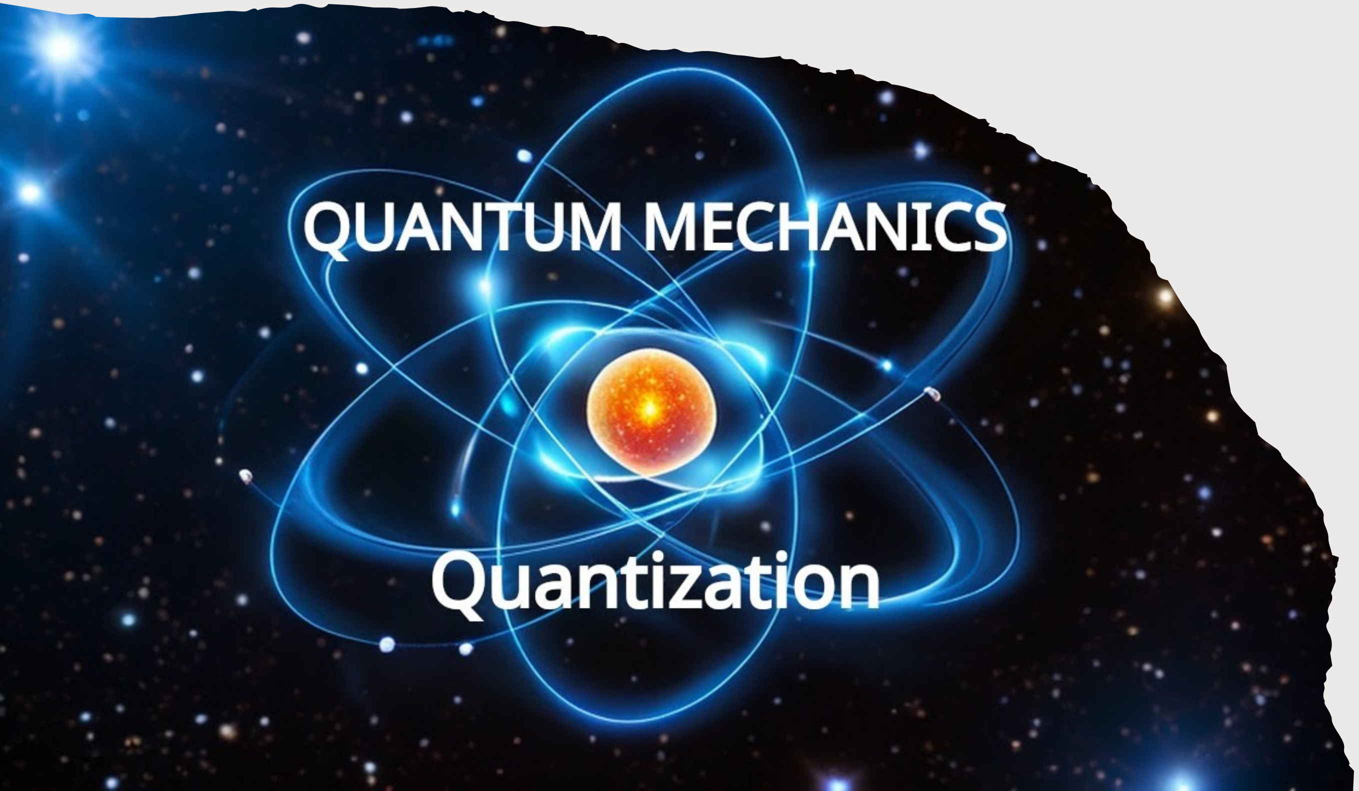
- Pixels in a digital image
- Frames in a movie
- Samples in a digital recording



But that is NOT what happens in quantum field theory.



What Quantization Actually Requires



Before quantization we must first identify:

- Classical Harmonic Oscillators

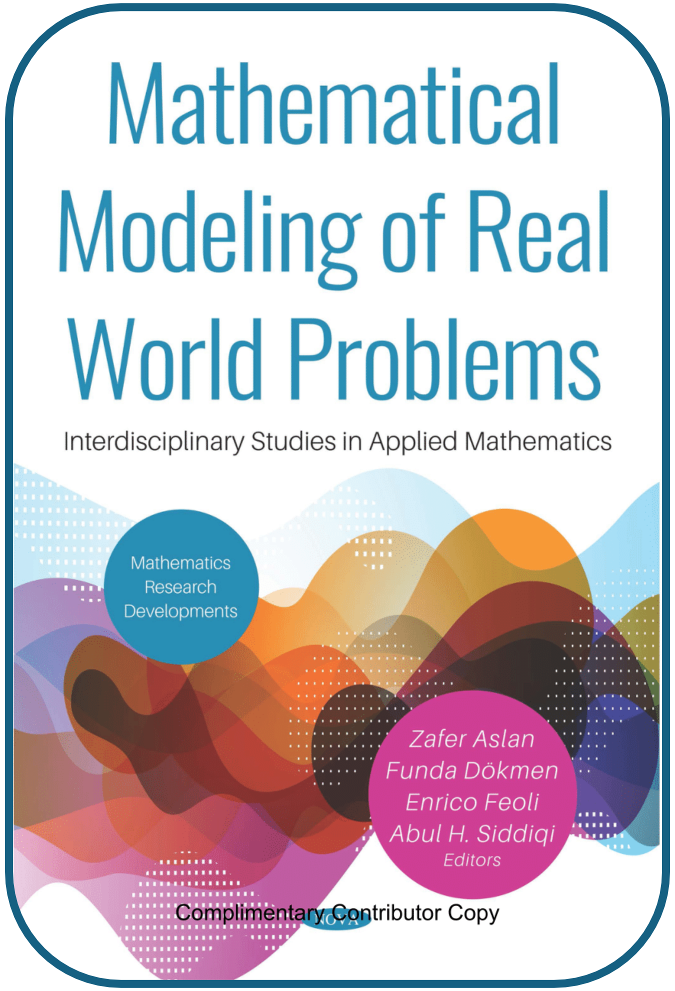
Why?

- Because harmonic oscillators are the objects that will eventually be quantized.

Basic Procedure:

- First we find the oscillators.
- Then we quantize them.
- We do not quantize the electromagnetic field directly.

The Modeling Problem



We wish to model:

- **A laser**
- **Sending a single photon**
- **To a detector**

The electromagnetic field can be represented in more than one way.

- **Modeling Requires Choices**
- **There is not a single mandatory starting point. We have options.**

Modeling Choice #1

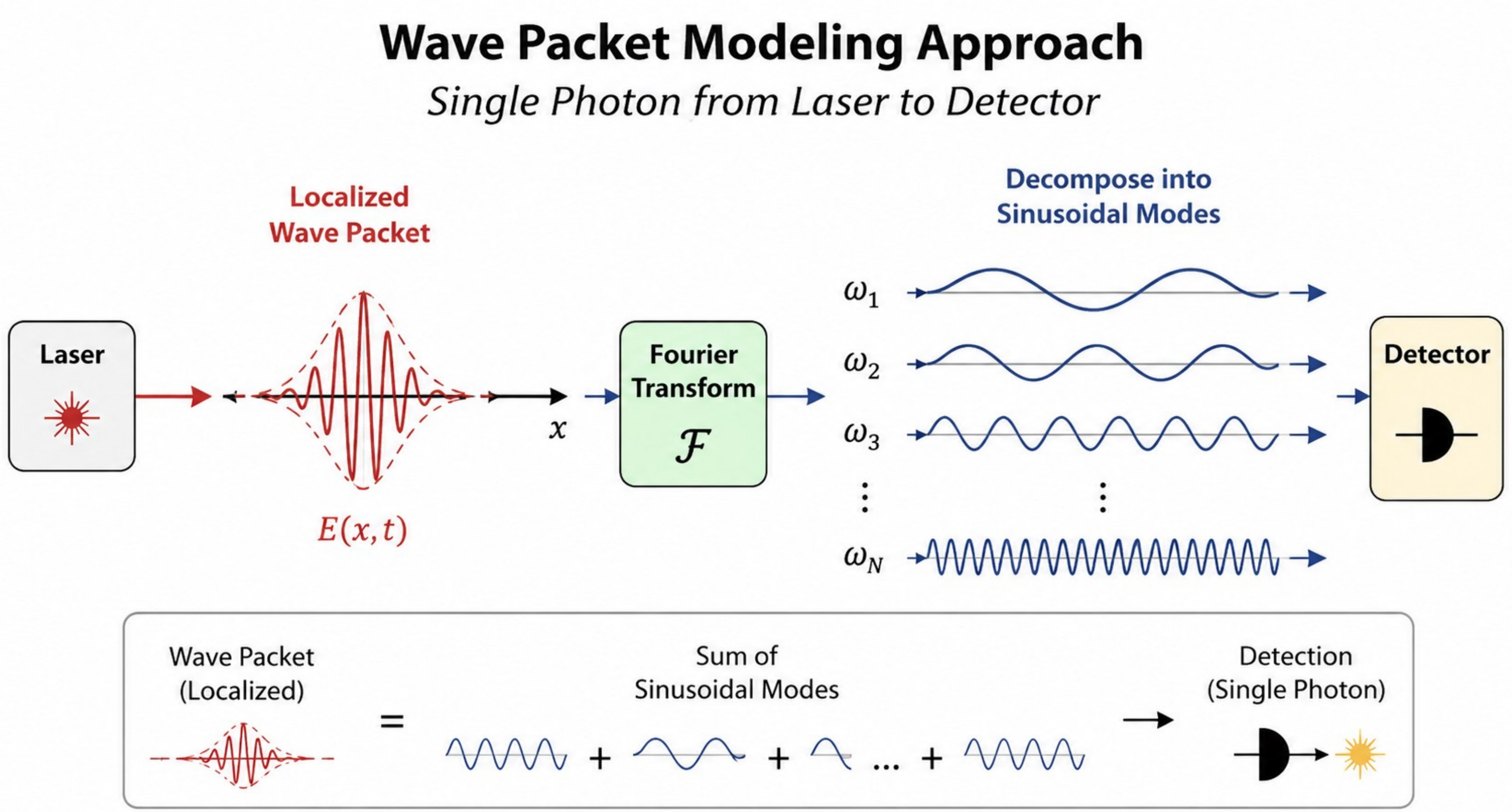
Wave Packet Approach

Represent the electromagnetic field as:

- **A Localized Wave Packet**

Then use:

- **Fourier Transform to decompose the wave packet into sinusoidal modes.**



Result

- **The harmonic oscillators appear directly.**
- **This approach resembles the physical experiment most closely.**

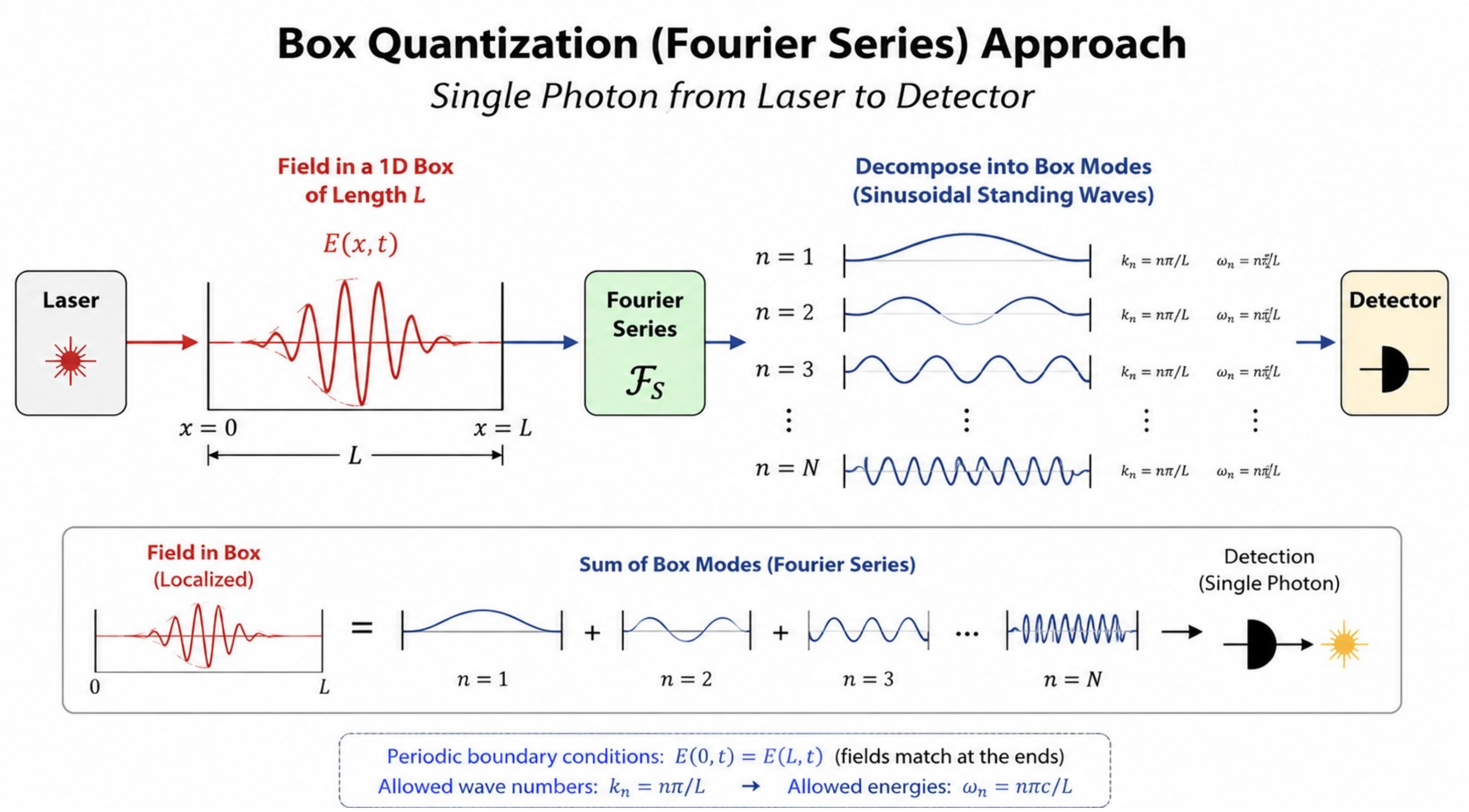
Modeling Choice #2

Box Quantization

- **Place the electromagnetic field inside a large box.**

Then use:

- **Fourier Series to decompose the field into standing-wave modes.**



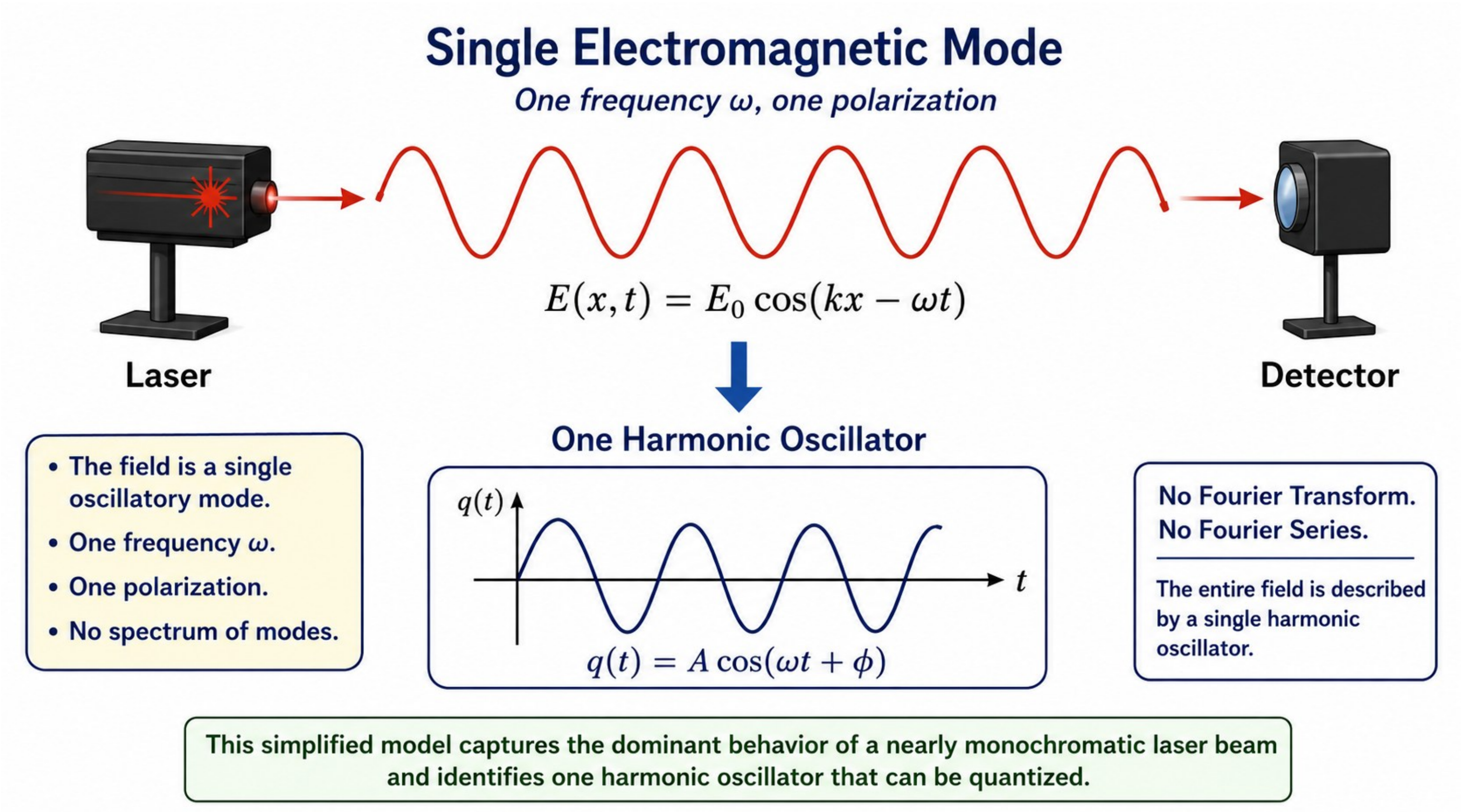
Result

- **The harmonic oscillators appear directly.**
- **The box is a mathematical device, not part of the experiment.**

Modeling Choice #3

Single Electromagnetic Mode

- **For a highly stabilized laser, we may idealize the laser-to-detector experiment as a single-frequency electromagnetic wave.**
- **The field is represented by a single oscillatory mode with one frequency and one polarization.**



Result

- **This simplified model captures the dominant behavior of a nearly monochromatic laser beam and provides the most direct path to quantization.**
- **The resulting harmonic oscillator will become the fundamental building block of the Quantum State Machine Model.**

Three Classical Descriptions of the Same Experiment

The laser-to-detector experiment can be modeled in several different ways:

Model 1: Wave Packet

- Electromagnetic pulse
- Fourier Transform
- Many frequency components
- Harmonic oscillators identified from the spectrum

Model 2: Standing Waves

- Electromagnetic field represented by standing-wave modes
- Fourier Series
- Many standing-wave modes
- Harmonic oscillators identified from the modes

Model 3: Single Electromagnetic Mode

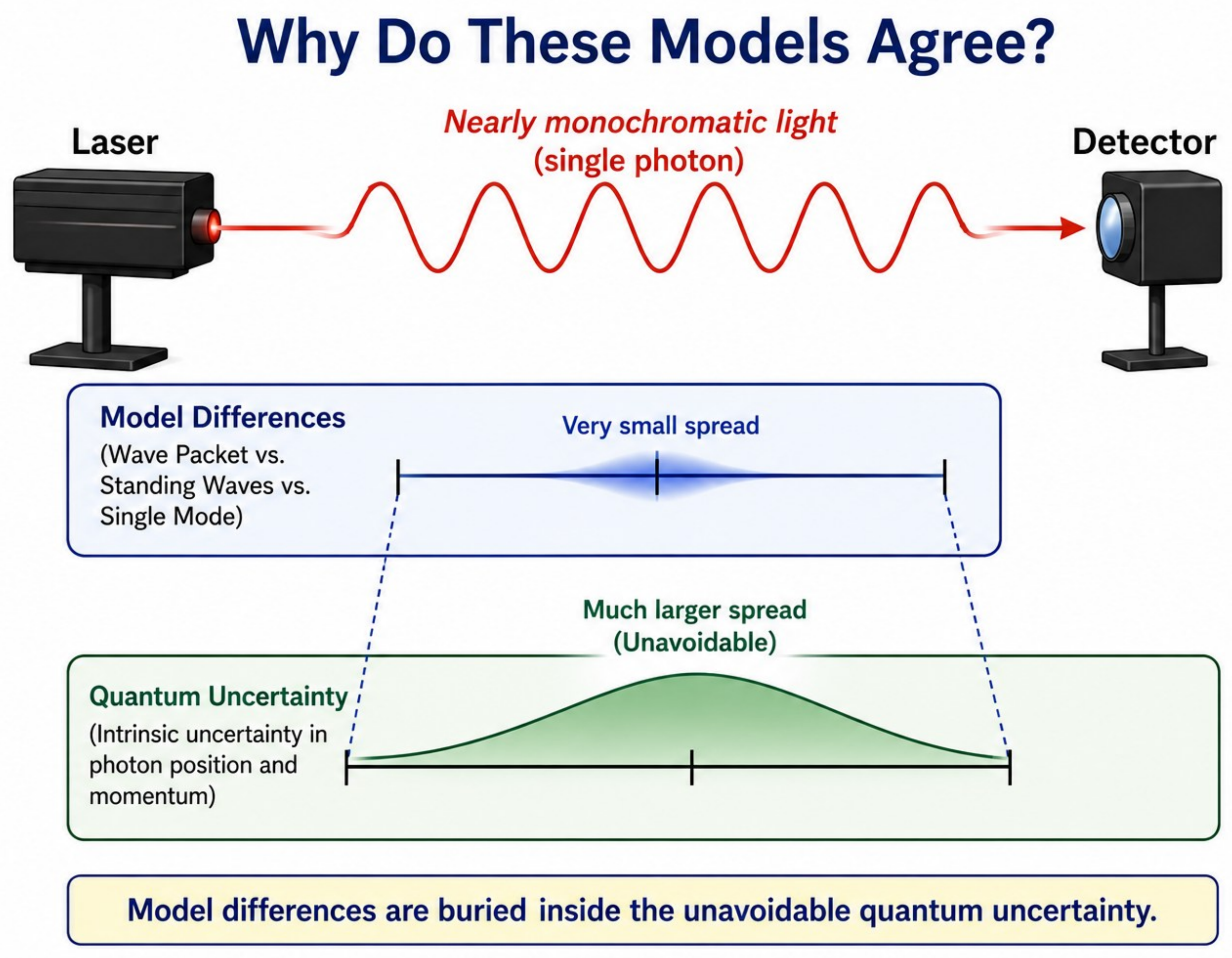
- Nearly monochromatic laser beam
- One frequency
- One mode
- One harmonic oscillator

Key Point:

All three models describe the same physical experiment from different mathematical perspectives.

For a highly stabilized laser emitting nearly monochromatic photons:

- The laser frequency is extremely well defined.
- Differences among the three classical descriptions become very small.
- Those differences become negligible compared with the intrinsic quantum uncertainty that every photon possesses in its position and momentum.
- As a result, all three models predict essentially the same experimentally observable photon detection probabilities.



The Power of Quantization

Although the classical descriptions are different:

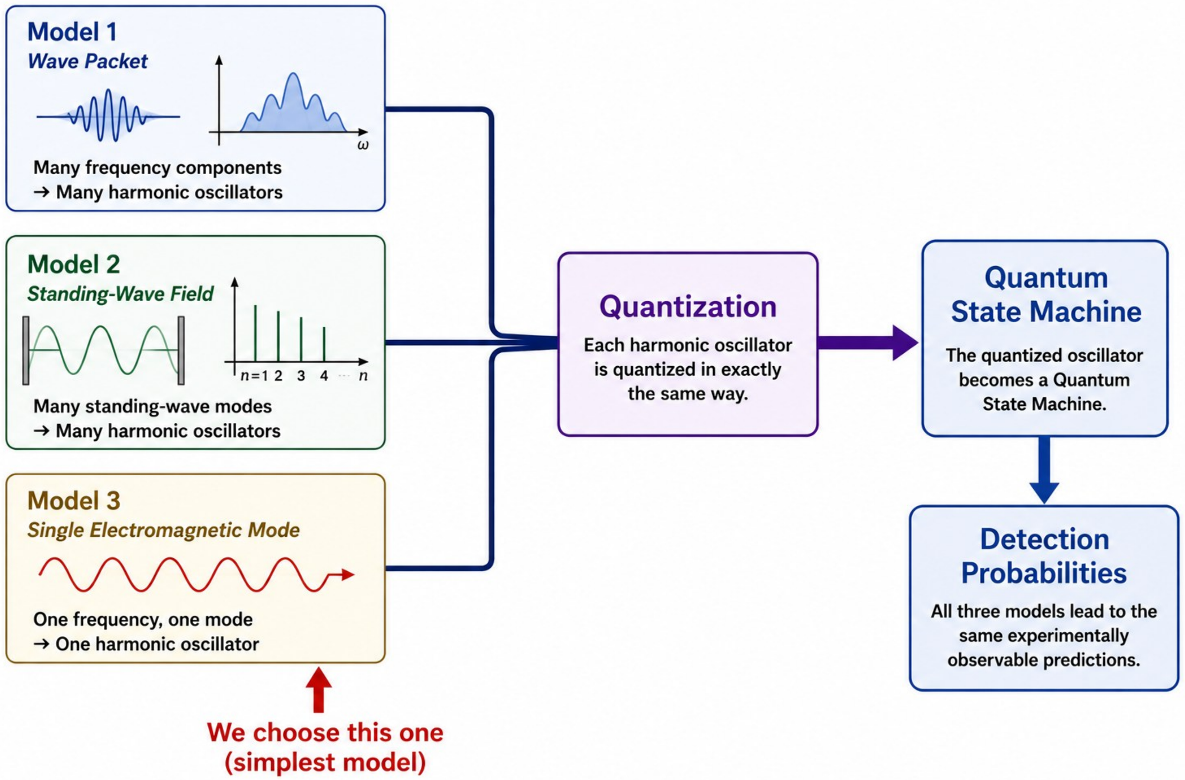
- Each model identifies harmonic oscillators.
- Every harmonic oscillator is quantized in exactly the same way.
- Quantization converts each harmonic oscillator into a Quantum State Machine.

Because all three models lead to essentially the same observable predictions:

- We are free to choose the classical model that is easiest to quantize.

For this lecture we will use: Model 3: Single Electromagnetic Mode

Because it contains only one harmonic oscillator and clearly illustrates the quantization procedure.



An Important Modeling Lesson

The three approaches:

- Start differently
- Use different mathematics
- Look very different
- Yet they produce the same harmonic oscillators and ultimately the same quantum model.

Note:

- This should remind us of Newtonian Mechanics and Lagrangian Mechanics.
- Different models can lead to the same predictions.
- Models are NOT reality

What Has Been Quantized So Far?

Nothing Has Been Quantized at All!

We have only identified:

- Classical electromagnetic fields
- Classical Fourier modes
- Classical harmonic oscillators
- The energies are still continuous.
- The oscillators are still classical.

Next Step

- How do we convert a classical harmonic oscillator into a quantized harmonic oscillator?

Time for a Deep Dive Into Harmonic Oscillators

So far we have identified:

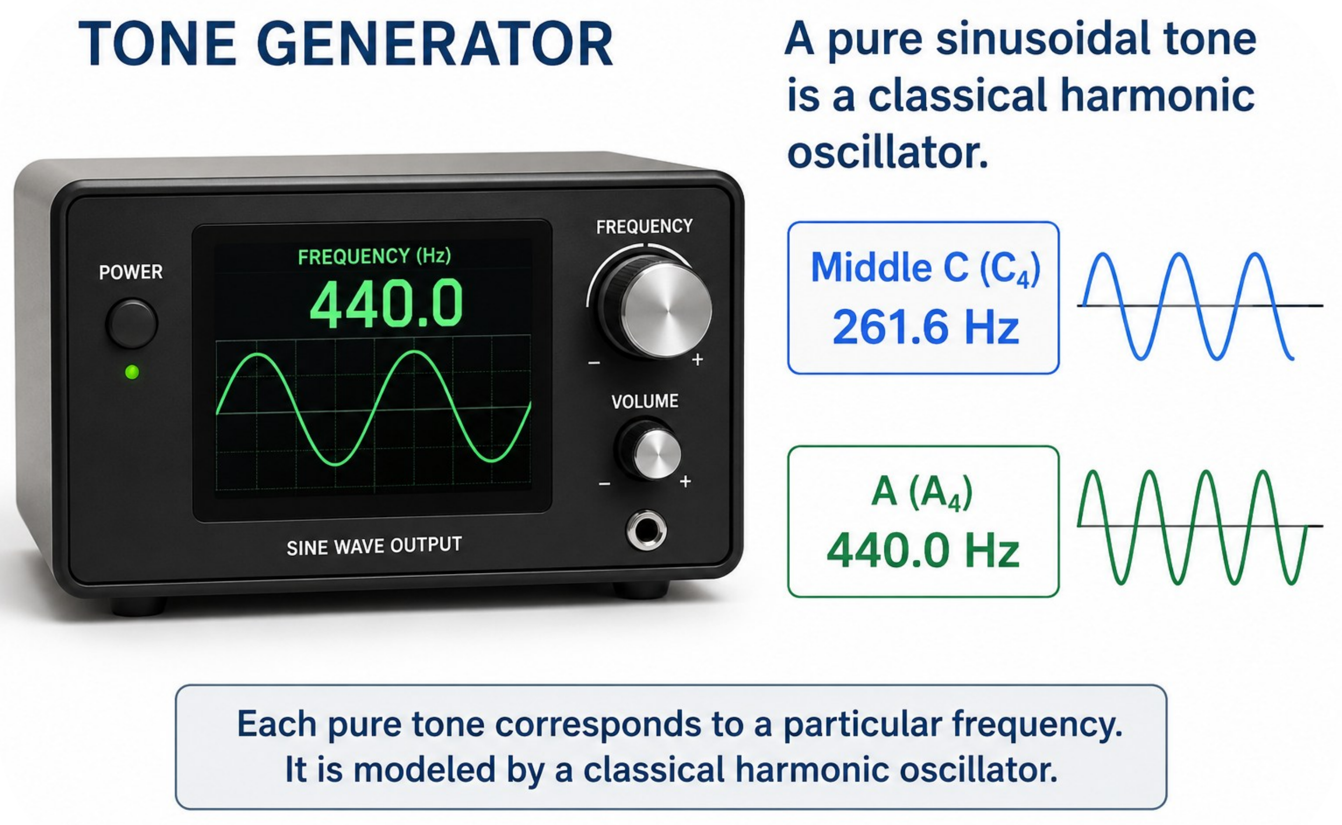
- Classical electromagnetic fields
- Classical Fourier modes
- Classical harmonic oscillators

But we have not yet examined a harmonic oscillator in detail.

Before we quantize anything, let's look closely at a single harmonic oscillator.

Bottom takeaway

- **A pure sinusoidal tone is a classical harmonic oscillator.**



Light Has Frequencies Too

A laser can also generate a nearly pure frequency.

For our experiment:

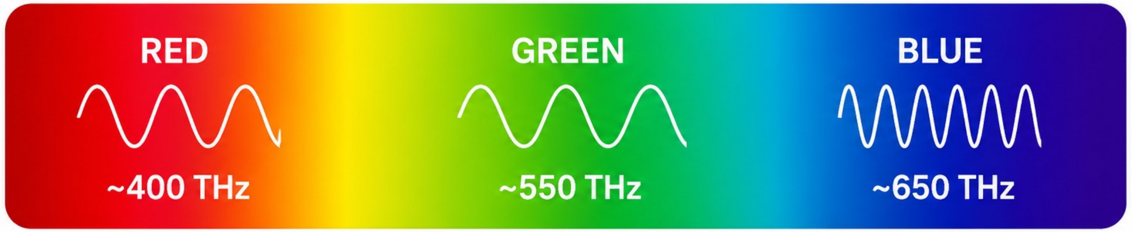
- **Red Laser Mode = 400 THz**

This single Fourier mode behaves like a classical harmonic oscillator.

- **The tone generator provides sounds we can hear**
- **The laser generator provides light we can see**

Light Has Frequencies Too

A laser can also generate a nearly pure frequency.
Different frequencies correspond to different colors of light.



Color	Frequency
Red	~400 THz
Green	~550 THz
Blue	~650 THz

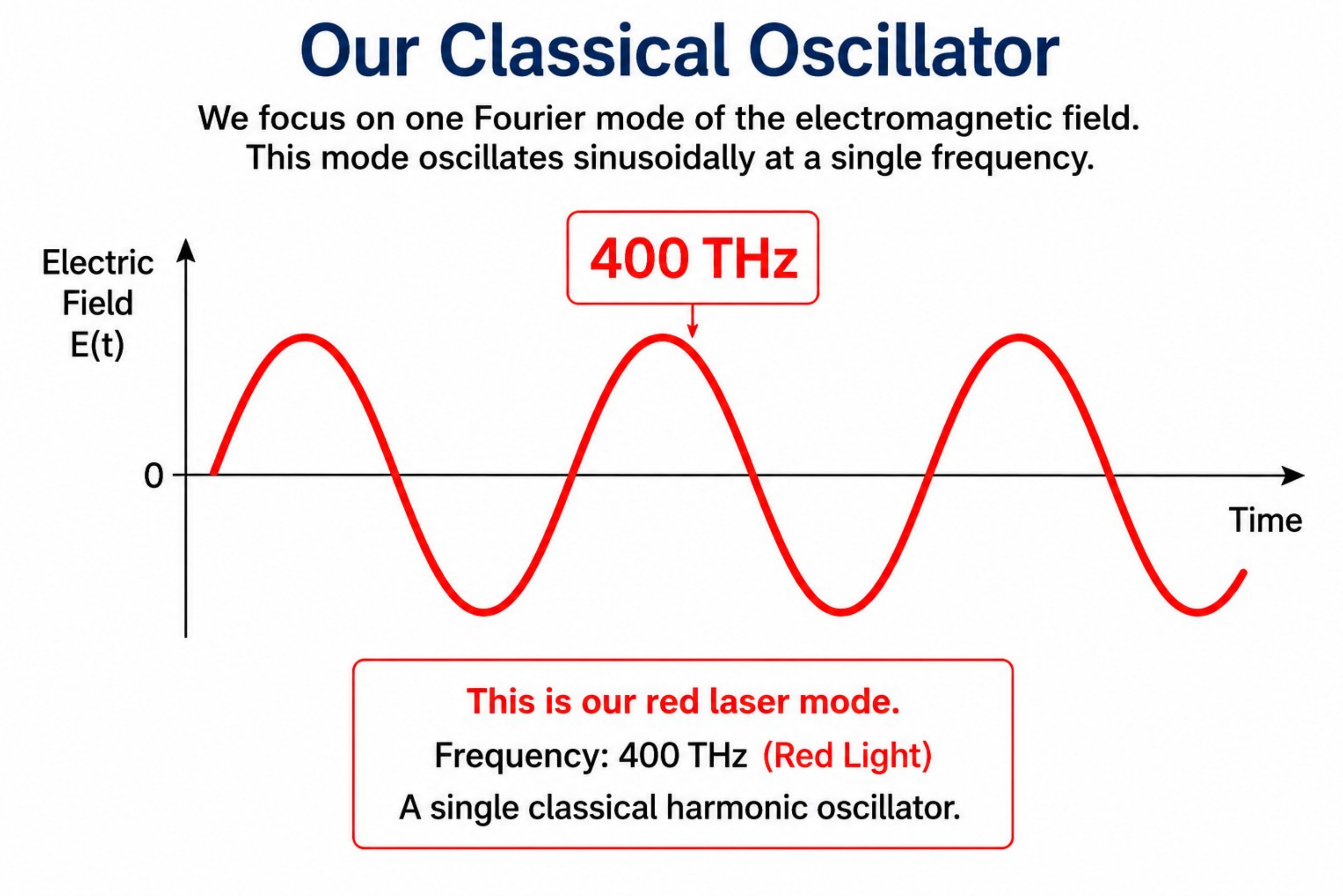
Our Classical Oscillator

We now focus on one Fourier mode only.

- Frequency: 400 THz
- Color: Red

At this stage:

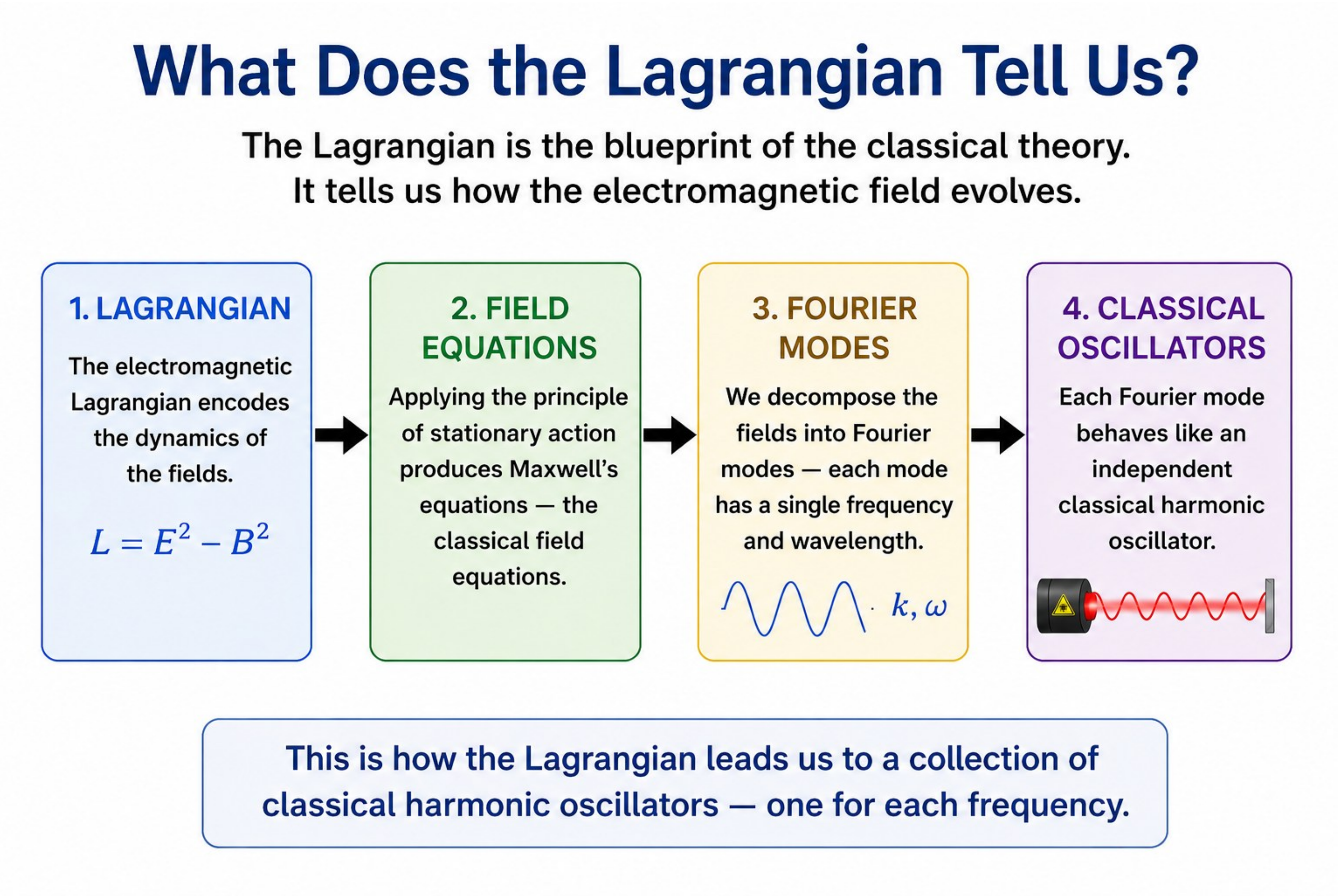
- Classical field
- Classical Fourier mode
- Classical harmonic oscillator
- Nothing has been quantized.



What Does the Lagrangian Tell Us?

Earlier we used the electromagnetic Lagrangian:

- to describe the classical field
- to determine how the field evolves
- The Fourier decomposition revealed a collection of classical harmonic oscillators.
- Our red 400 THz mode is one of them.



Lagrangian versus Hamiltonian

Lagrangian Mechanics focuses on:

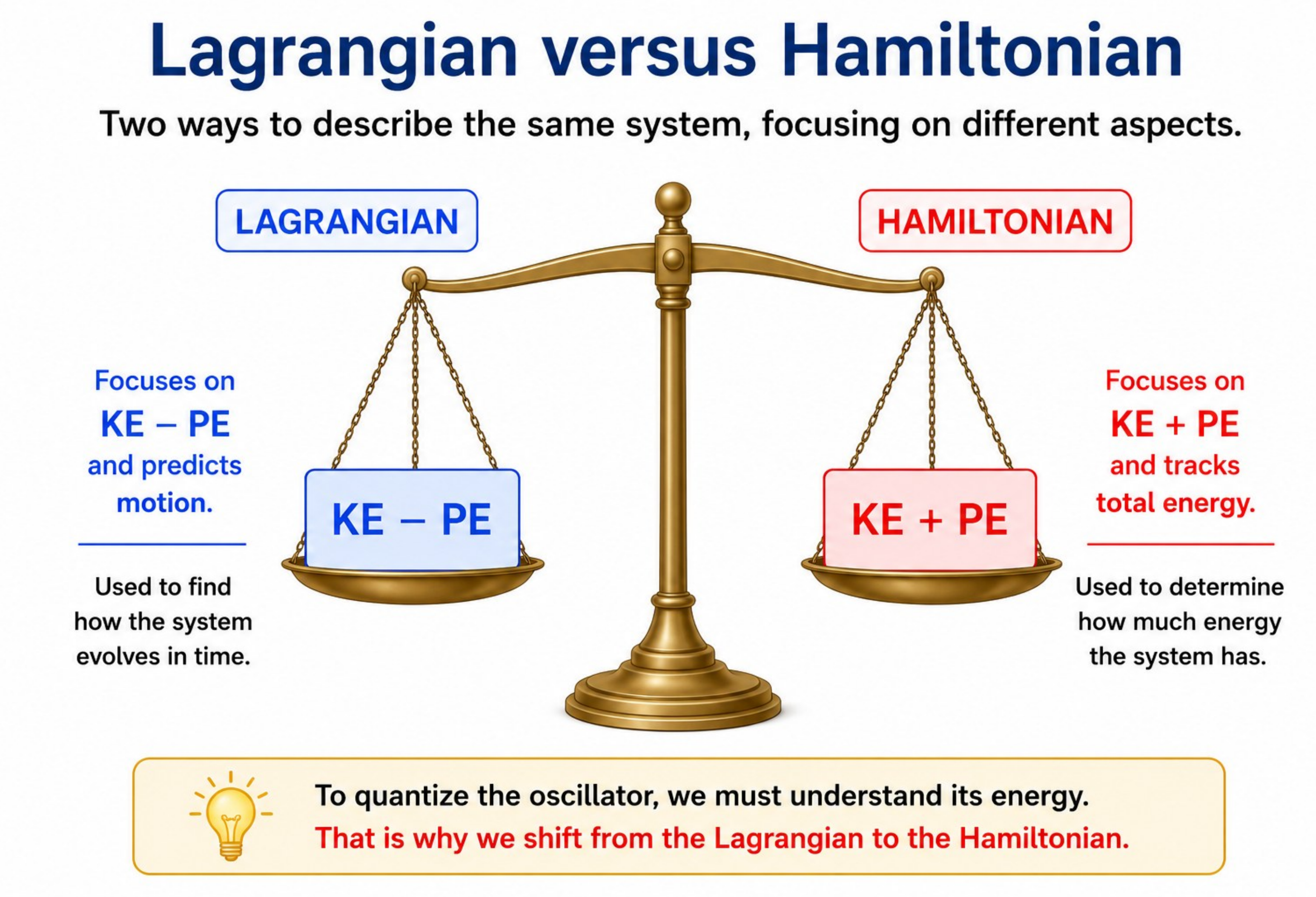
- KE – PE
- and predicts motion.

Hamiltonian Mechanics focuses on:

- KE + PE
- and tracks total energy.

To quantize the oscillator, we must understand its energy.

- The Lagrangian Blueprint allowed us to identify the harmonic oscillators
- It has now done its job and we need the Hamiltonian to continue



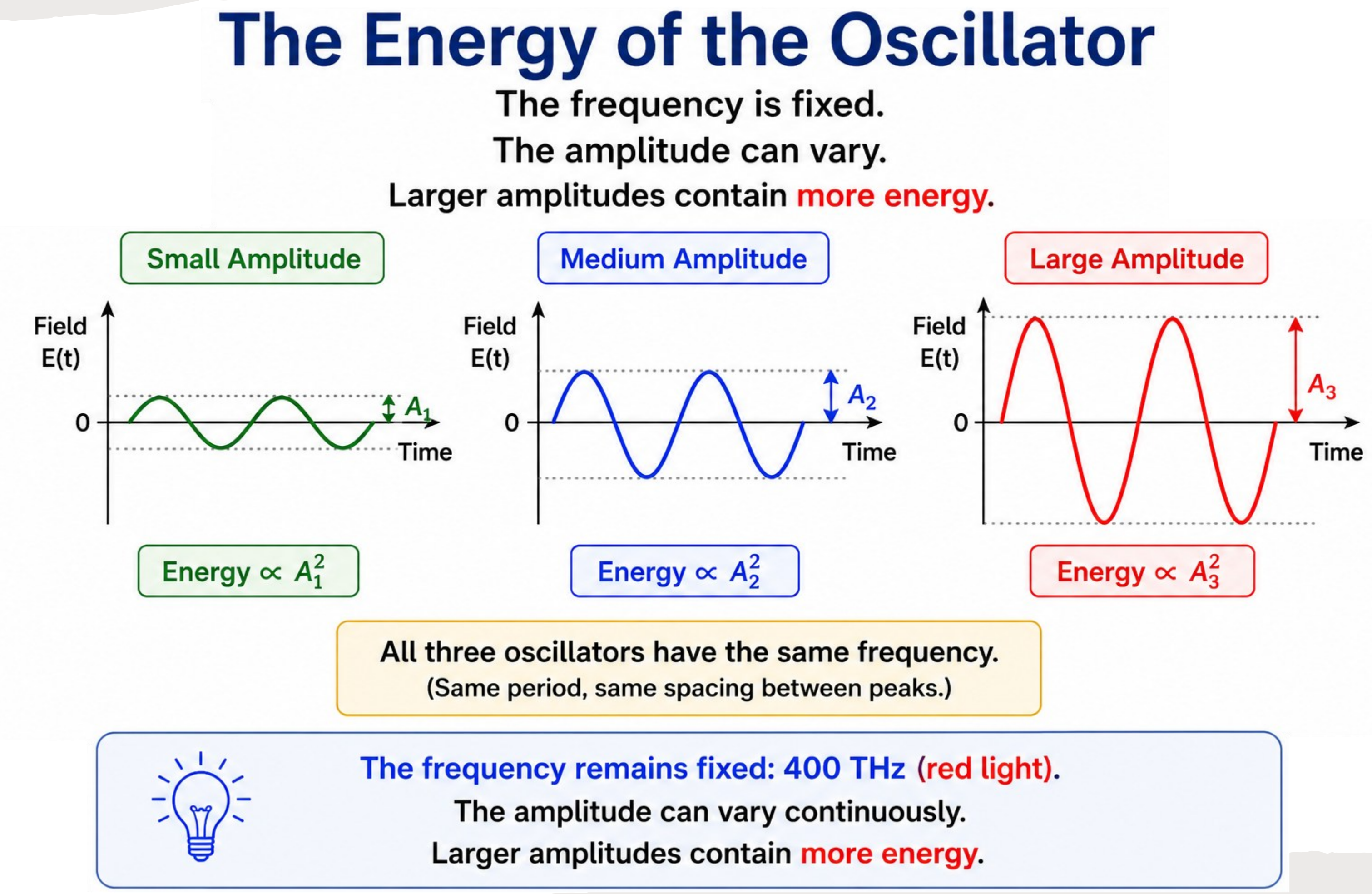
The Energy of the Harmonic Oscillator

The frequency remains fixed:

- 400 THz
- The amplitude can vary continuously.
- Larger amplitudes contai more energy.

At this stage:

- Energy is still continuous

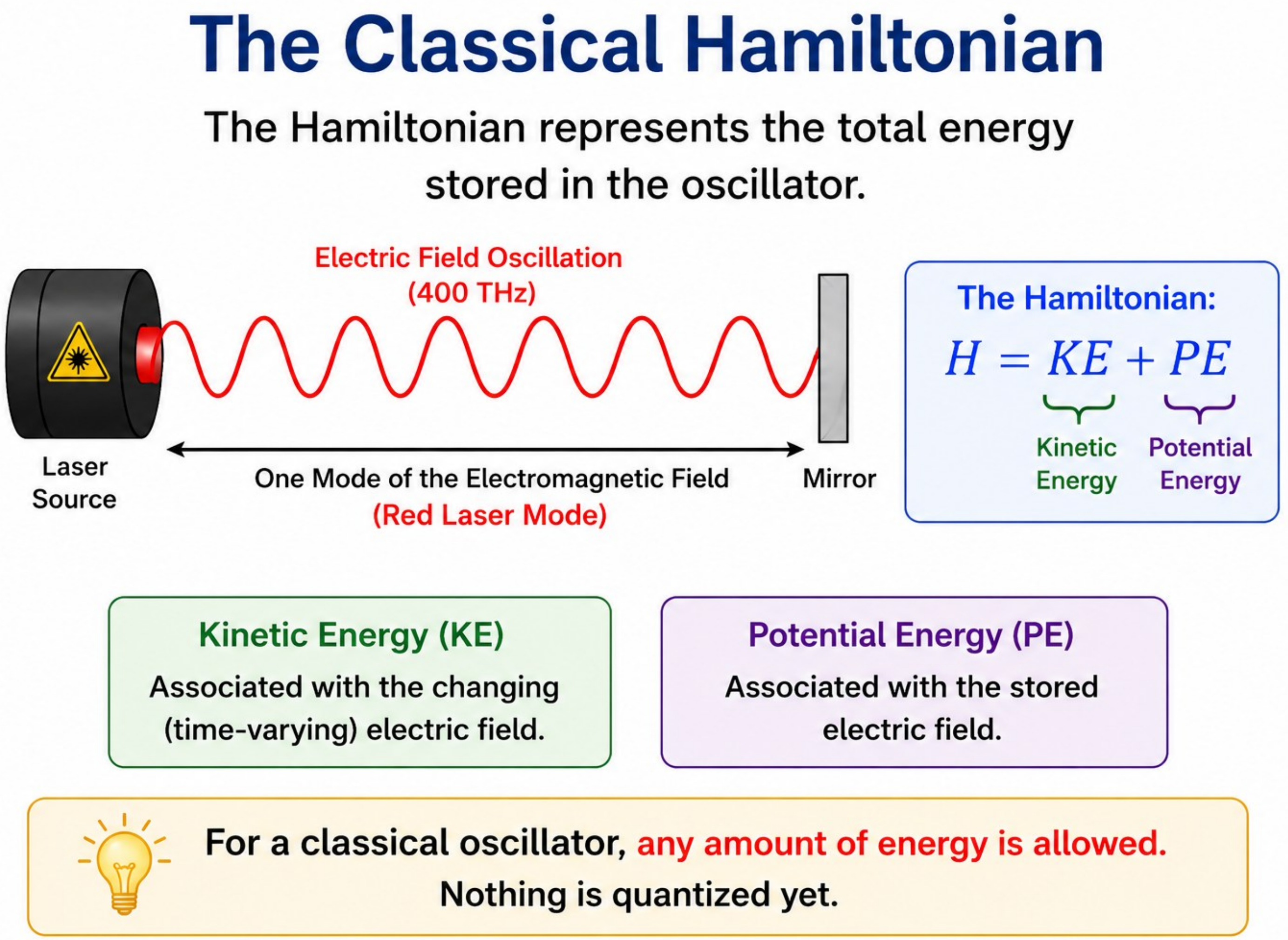


The Classical Hamiltonian

The Hamiltonian represents the total energy stored in the oscillator.

For a classical oscillator:

- **Any energy is allowed.**
- **Nothing is quantized yet.**



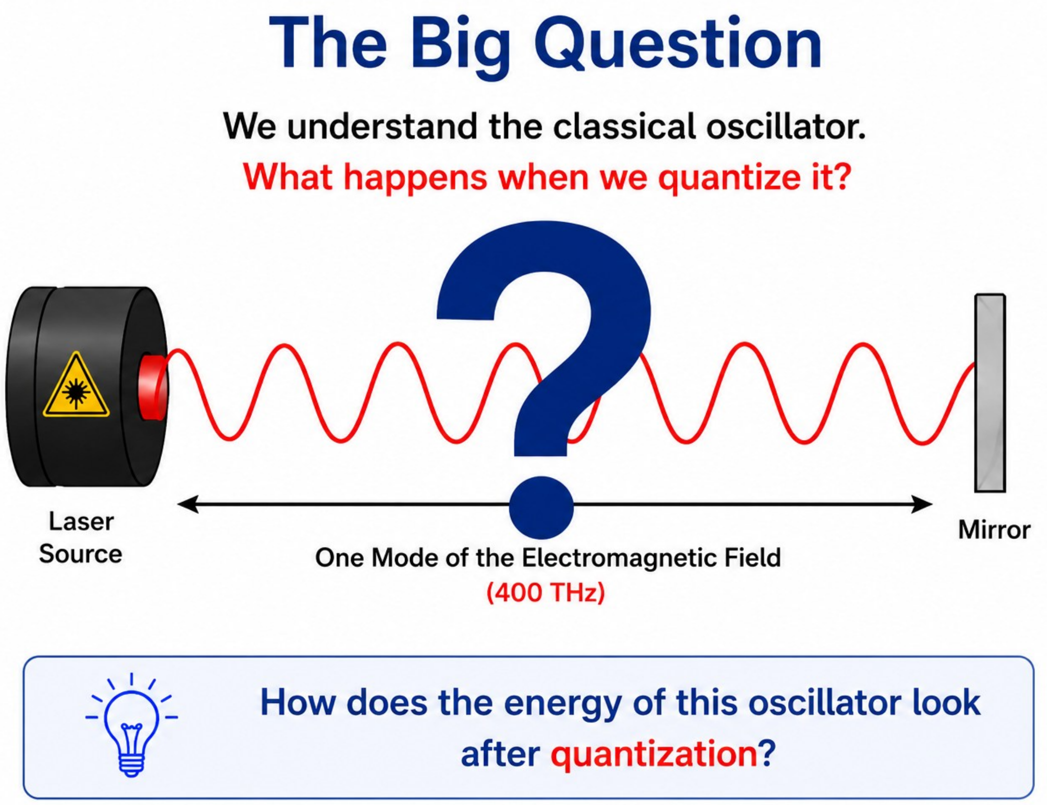
The Big Question

Our oscillator is still classical.

- Its energy can take any value.
- We know this is wrong.
- Only certain energy levels are allowed.

How can we quantize the oscillator?

- The frequency must stay the same.
- But the energy must be quantized.
- How can we do this?



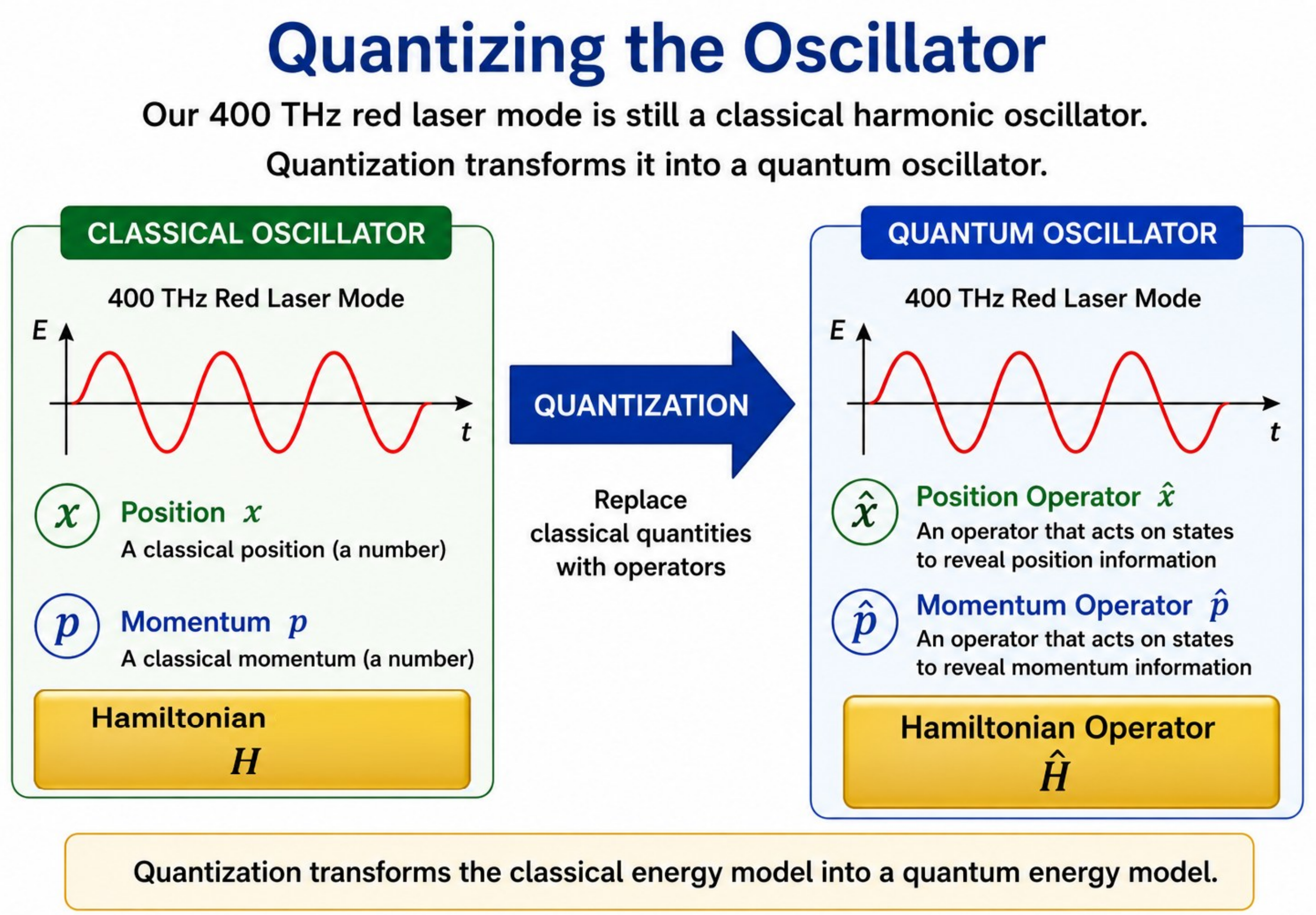
Quantizing the Harmonic Oscillator

Our 400 THz red laser mode is still a classical harmonic oscillator.

- **Its total energy is described by the classical Hamiltonian:** $H = KE + PE$

Quantization replaces the classical position and momentum variables with operators:

- $x \rightarrow \hat{x}$
- $p \rightarrow \hat{p}$



As a result, the classical Hamiltonian becomes a Hamiltonian operator:

$$H \rightarrow \hat{H}$$

Quantization transforms the classical energy model into a quantum energy model.

What Does Quantization of the Harmonic Oscillator Create?

Quantization produces two fundamental components of the Quantum State Machine.

1. **Hamiltonian Operator:**

$$\hat{H}$$

The Hamiltonian operator determines how the system evolves through time.

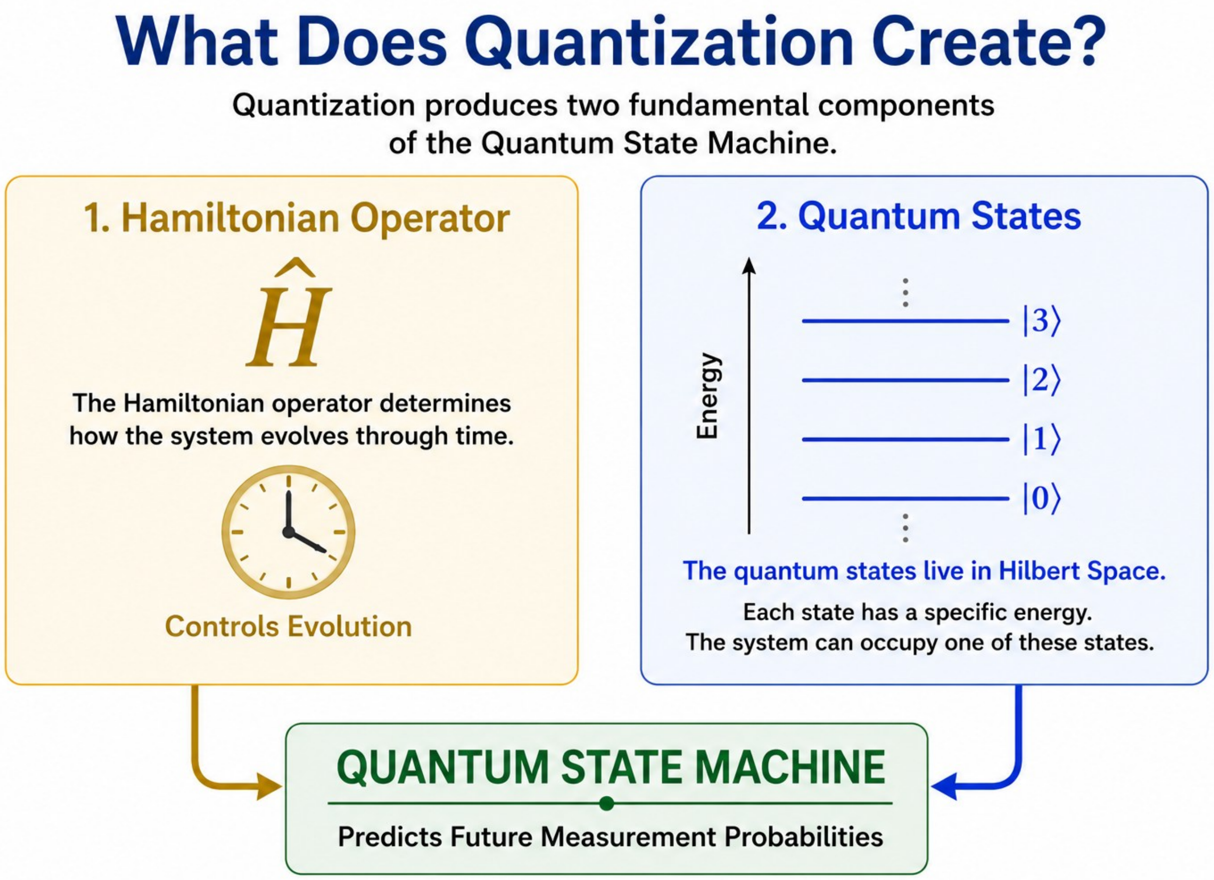
2. **Quantum States**

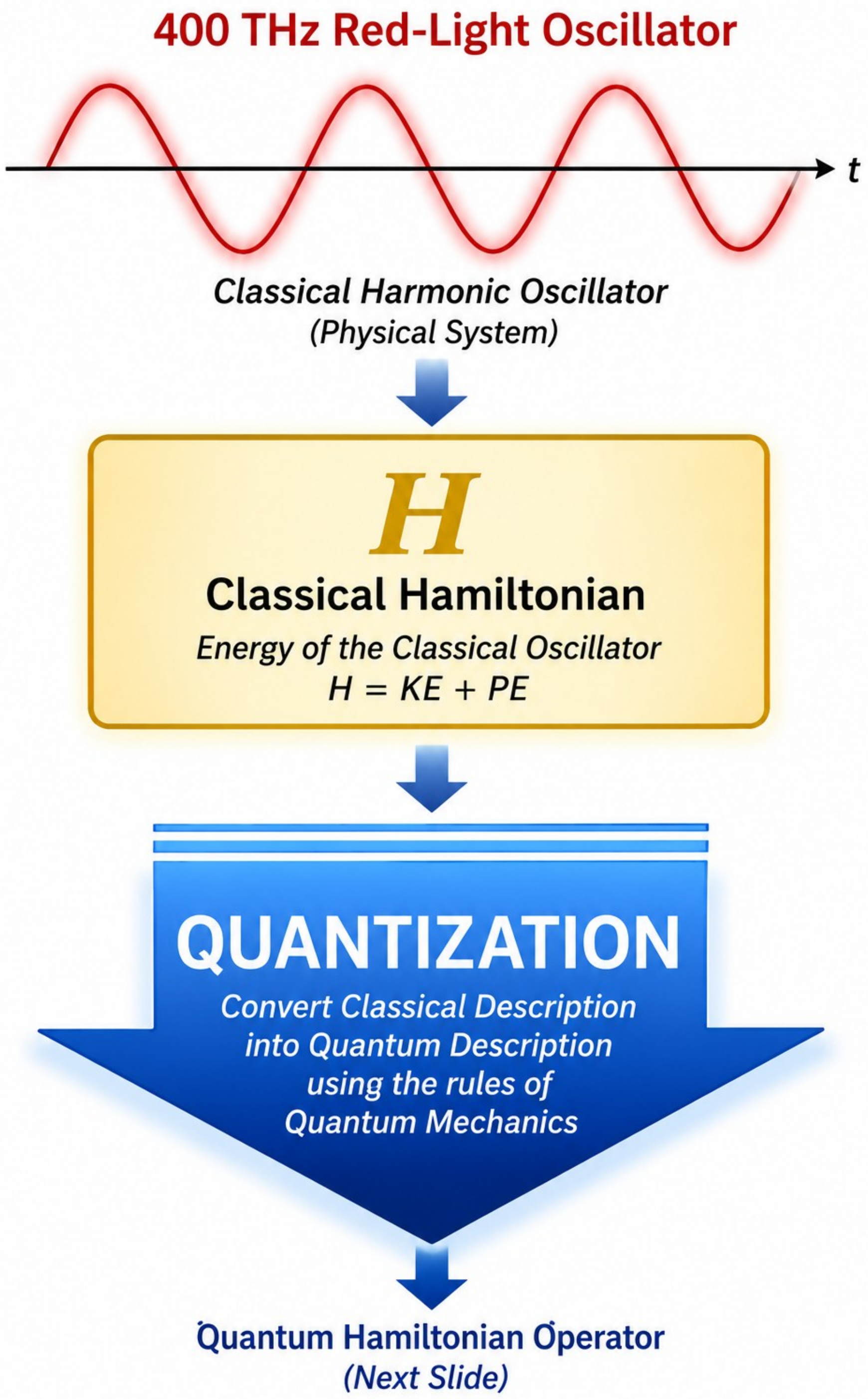
$$|0\rangle,\ |1\rangle,\ |2\rangle,\ |3\rangle, \ldots$$

The quantum states live in Hilbert Space.

Together:

- Hamiltonian Operator + Quantum States = Quantum State Machine





Quantization of the Hamiltonian

We begin with a classical harmonic oscillator.

- **For our example:**
  - **A 400 THz red-light oscillator**

The classical oscillator possesses:

- **Position x**
- **Momentum p**

These quantities determine the oscillator's energy:

- $H = KE + PE$

The goal of quantization is to convert this classical energy description into a quantum Hamiltonian operator.

Classical Quantities Become Operators

Quantization replaces classical quantities with mathematical operators.

- $x \rightarrow \hat{x}$
- $p \rightarrow \hat{p}$

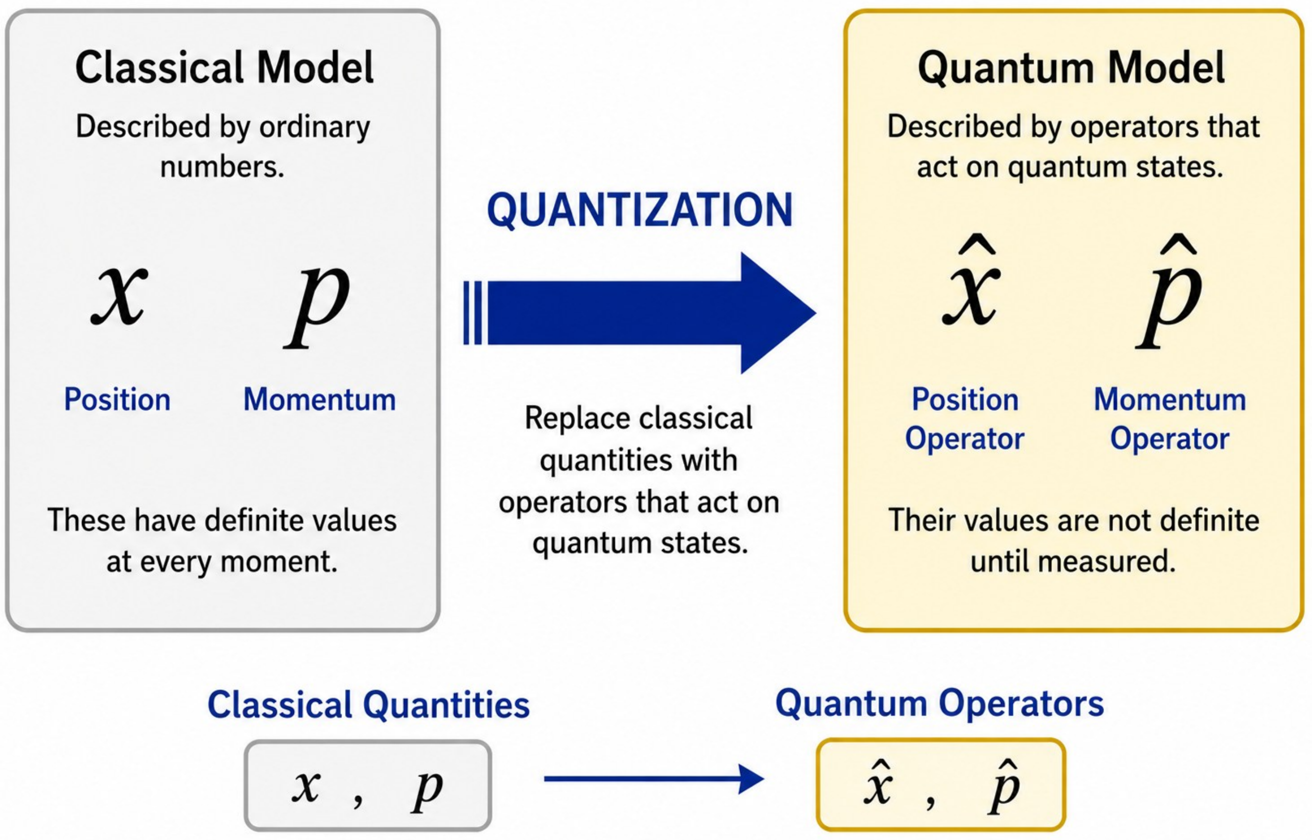
Instead of describing exact trajectories, the model now works with operations acting on quantum states.

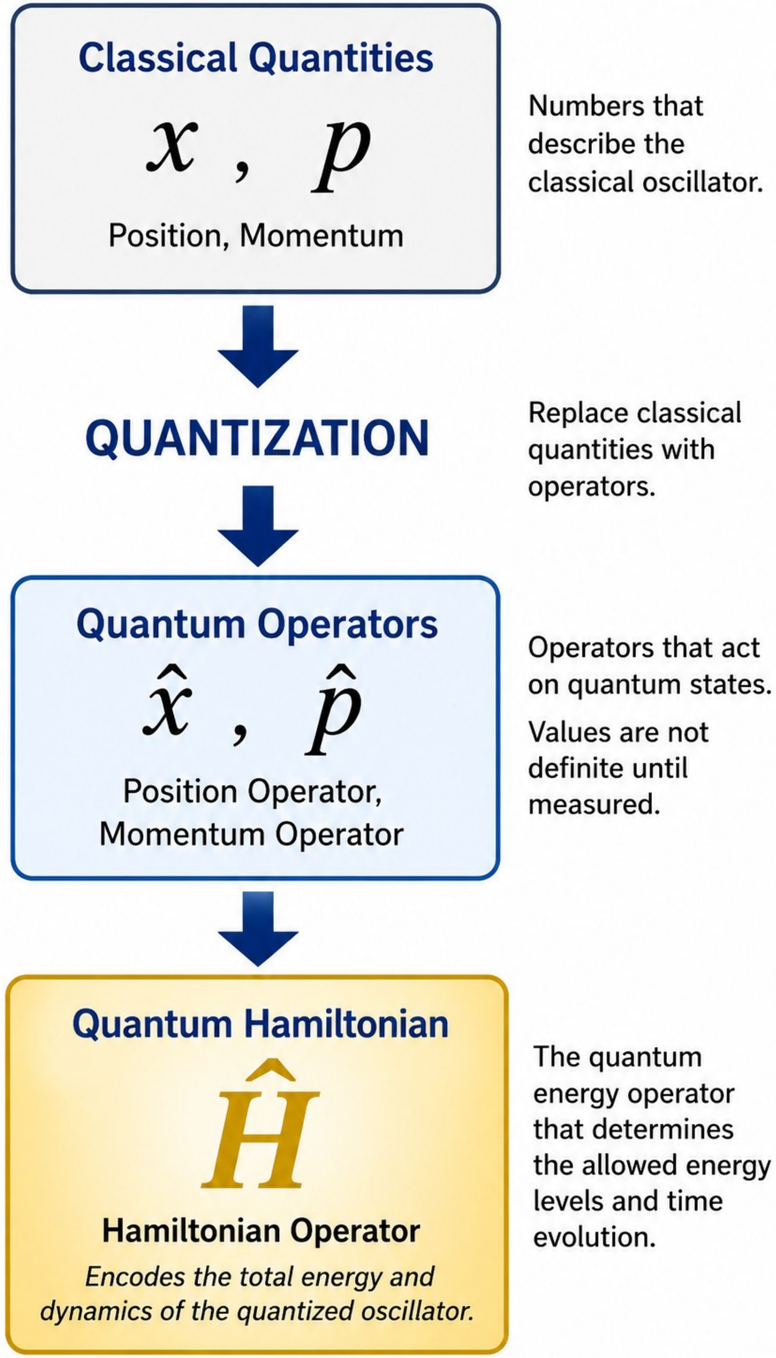
Position Operator

- **Asks: Where could the system be found?**

Momentum Operator

- **Asks: How could the system be moving?**





Building the Quantum Hamiltonian

The classical Hamiltonian depended on:

x **and** p

The quantum Hamiltonian is built from:

$\hat{x}$ **and** $\hat{p}$

The result is a new object:

$\hat{H}$

The Hamiltonian Operator.

A More Useful Language

For harmonic oscillators there is a simpler description.

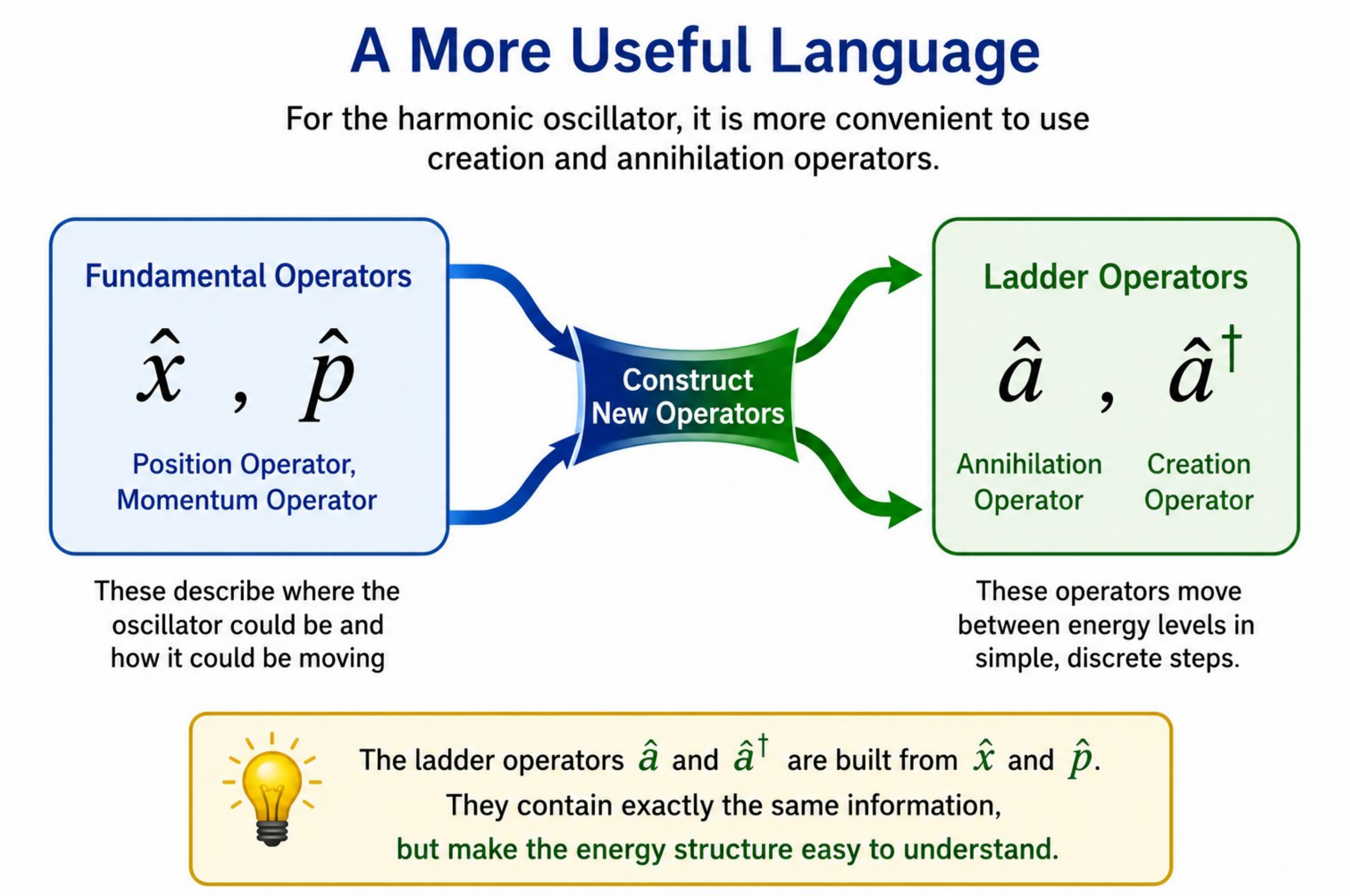
Instead of working directly with:

- $\hat{x}$ and $\hat{p}$

physicists define two new operators:

- Creation Operator: $\hat{a}^{\dagger}$
- Annihilation Operator: $\hat{a}$

These contain exactly the same information but make the energy structure easy to see.

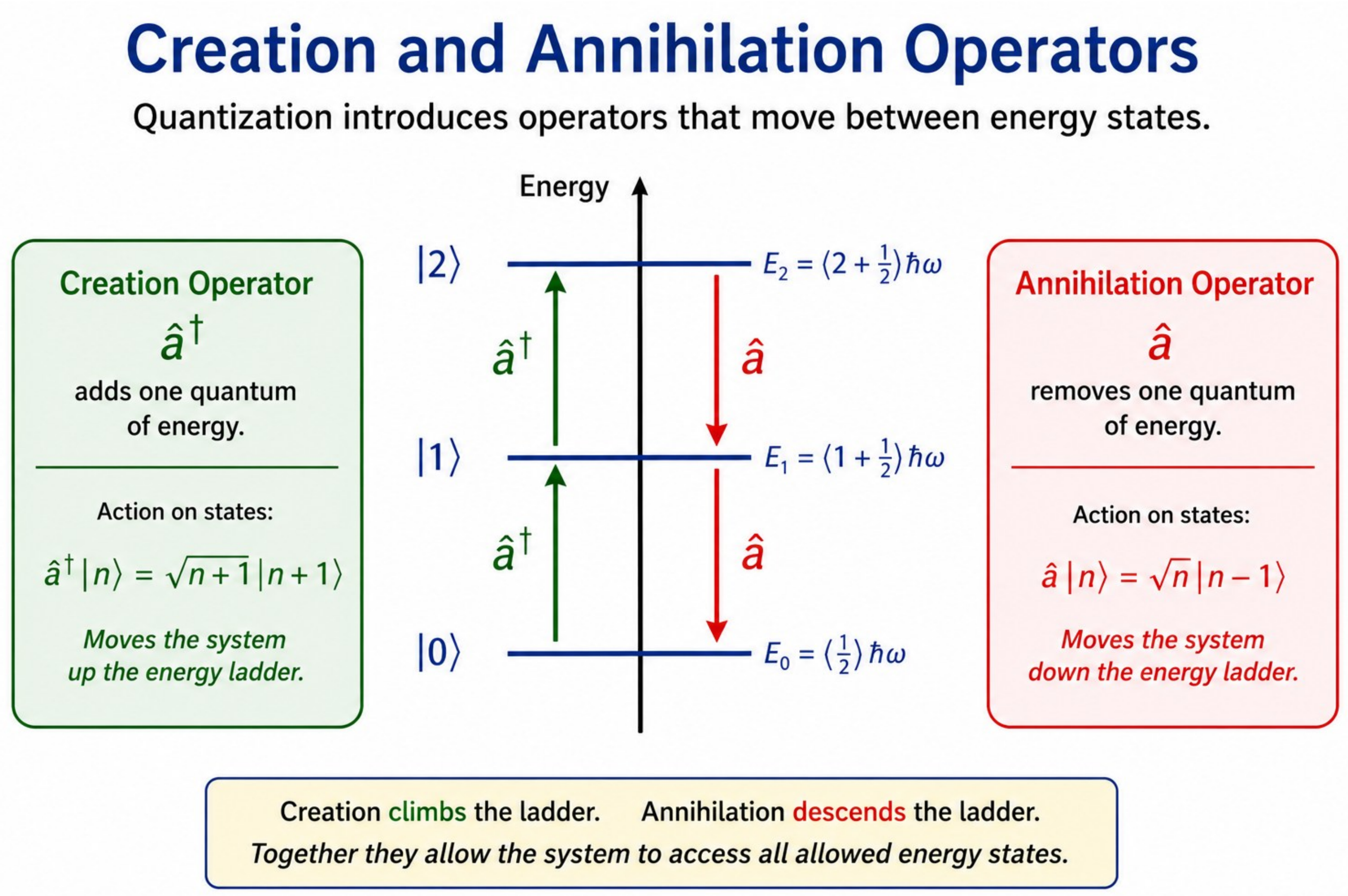


Moving Between Energy Levels

These operators do the same thing as the position and momentum operators, but they do it more directly

- The creation operator adds one quantum of energy.
- The annihilation operator removes one quantum of energy.

- These operators build the Hamiltonian structure of the quantized oscillator.



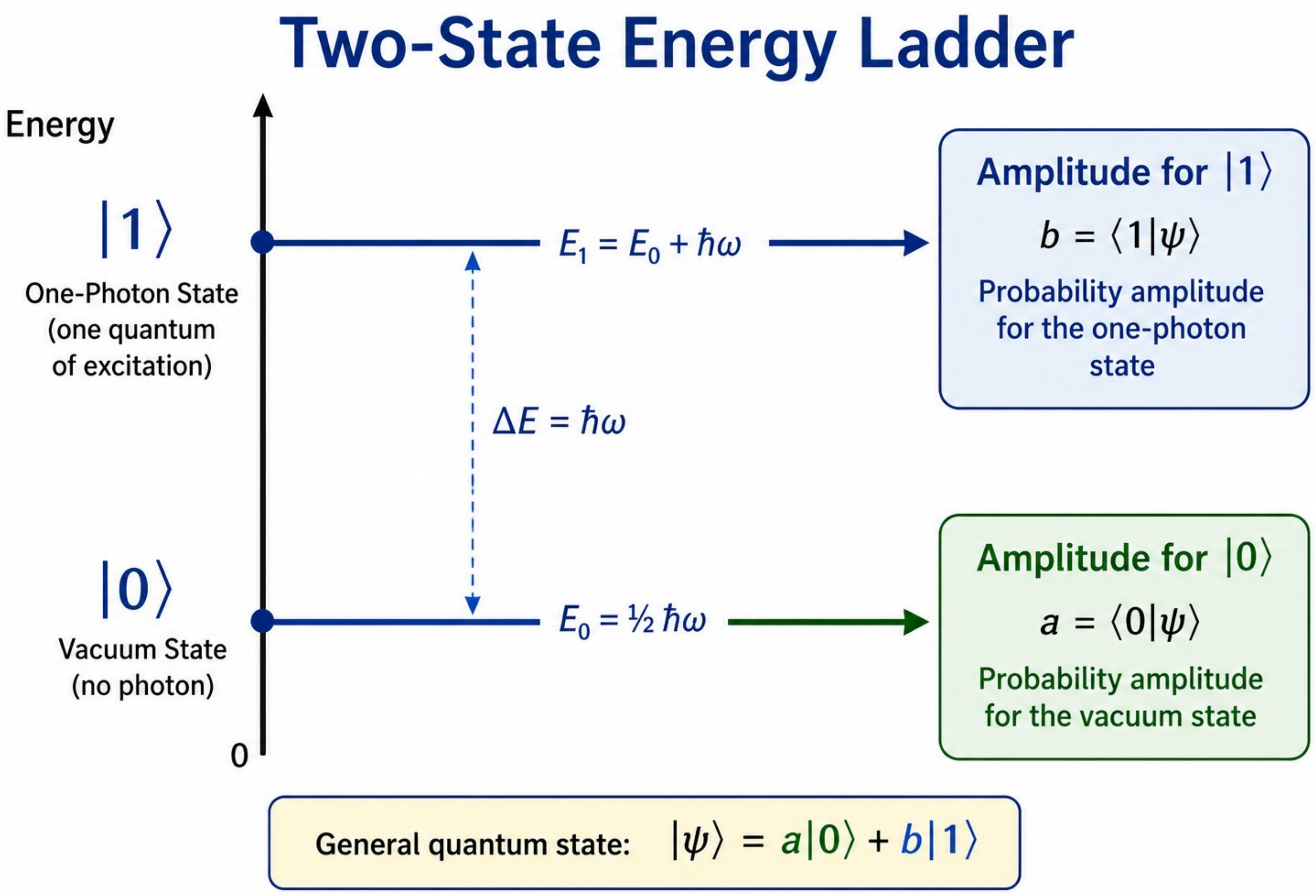
Quantization Also Creates Quantum States

Quantization does not only create a Hamiltonian Operator.

- It also creates the allowed quantum states of the oscillator.

For our laser example the most important states are:

- Vacuum State: $|0\rangle$
- One-Photon State: $|1\rangle$



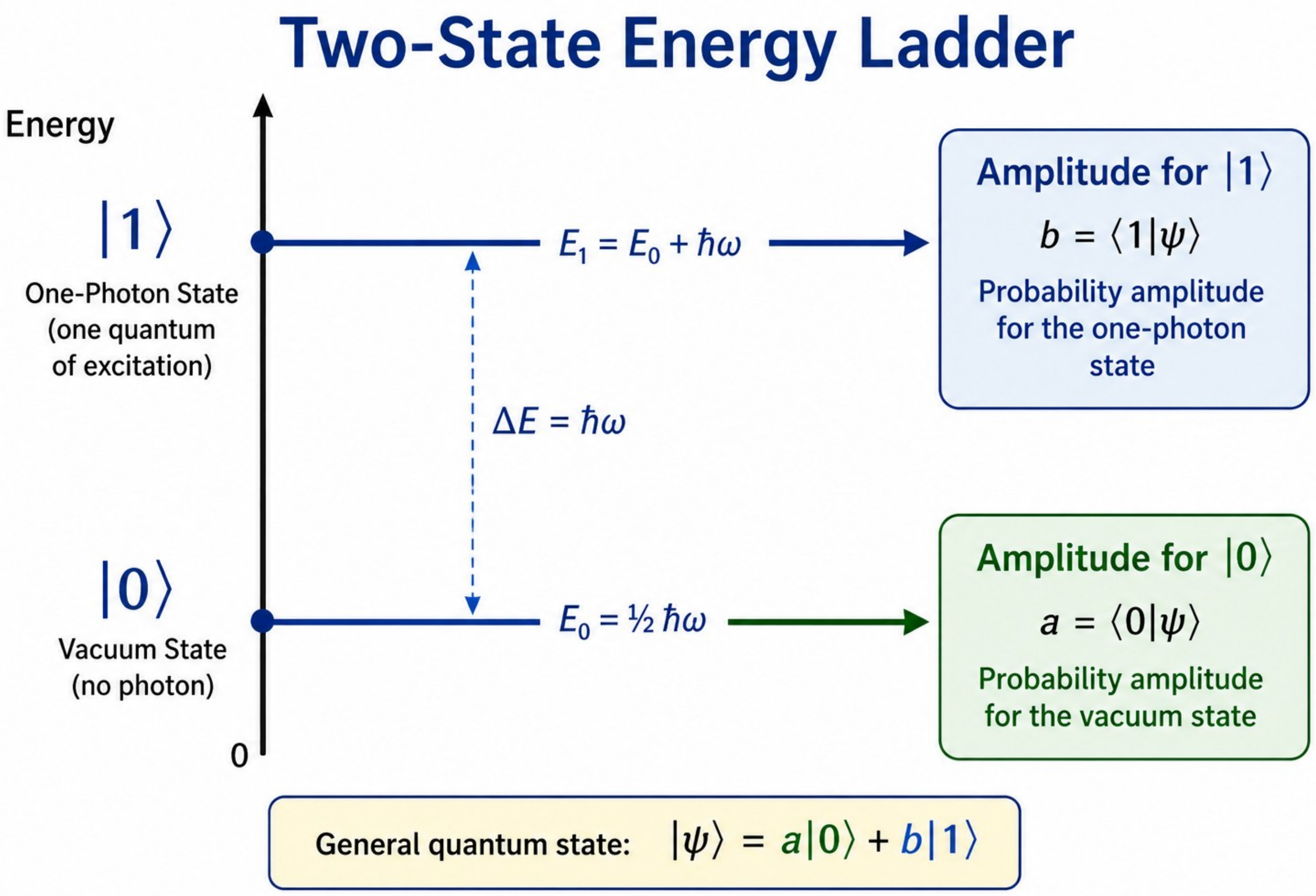
What Do These States Mean?

For our simple experiment:

- $|0\rangle$ **No photon present.**
- $|1\rangle$ **One photon present.**

A general quantum state can contain both:

- $|\psi\rangle = a|0\rangle + b|1\rangle$
- a **is the probability amplitude for the vacuum state.**
- b **is the probability amplitude for the one-photon state.**



Special cases:

$a = 1,\ b = 0$ **Vacuum**

$a = 0,\ b = 1$ **One photon**

The Energy Basis in Hilbert Space

The quantized harmonic oscillator possesses allowed energy states:

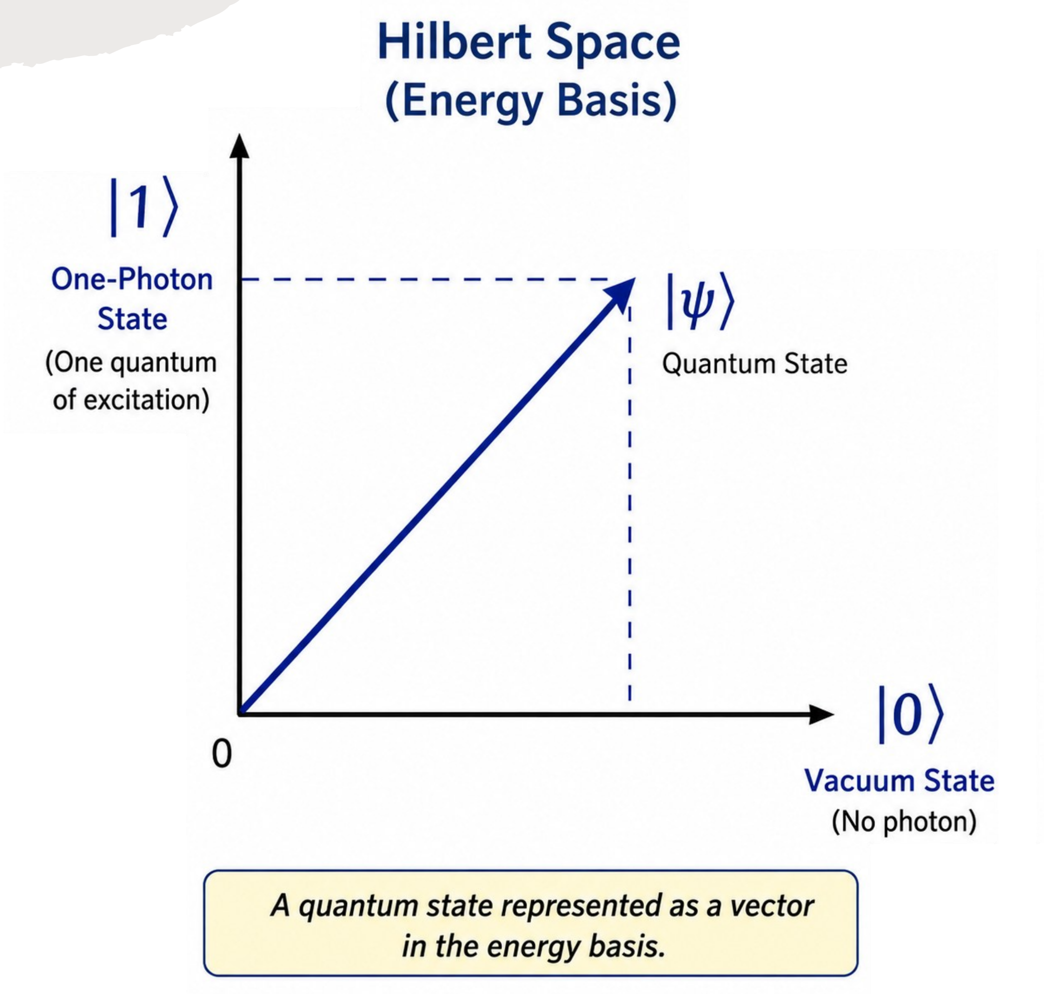
$$|\,0\rangle,\ \ |\,1\rangle,\ \ |\,2\rangle, \ldots$$

These states form a basis for describing the oscillator.

- **Just as a coordinate system makes geometry easier,**
- **An energy basis makes quantum calculations easier.**
- **Every quantum state can be represented as a combination of these basis states.**

For our experiment:

- $|\,0\rangle =$ ***vacuum state***
- $|\,1\rangle =$ ***one−photon state***



Primordial Nature: Ordered Possibility

Process Theology Lens

The Primordial Nature of God is the ordering of possibilities.

- Not every future is possible.
- Possibilities are constrained, structured, and related.

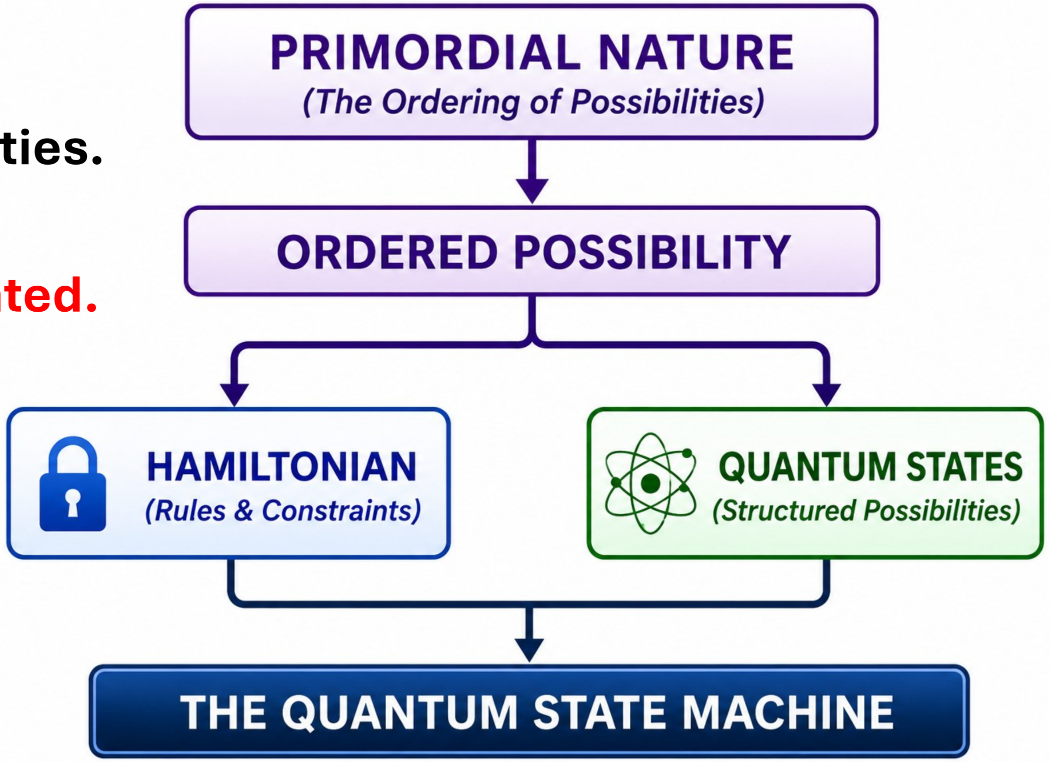
Quantum State Machine

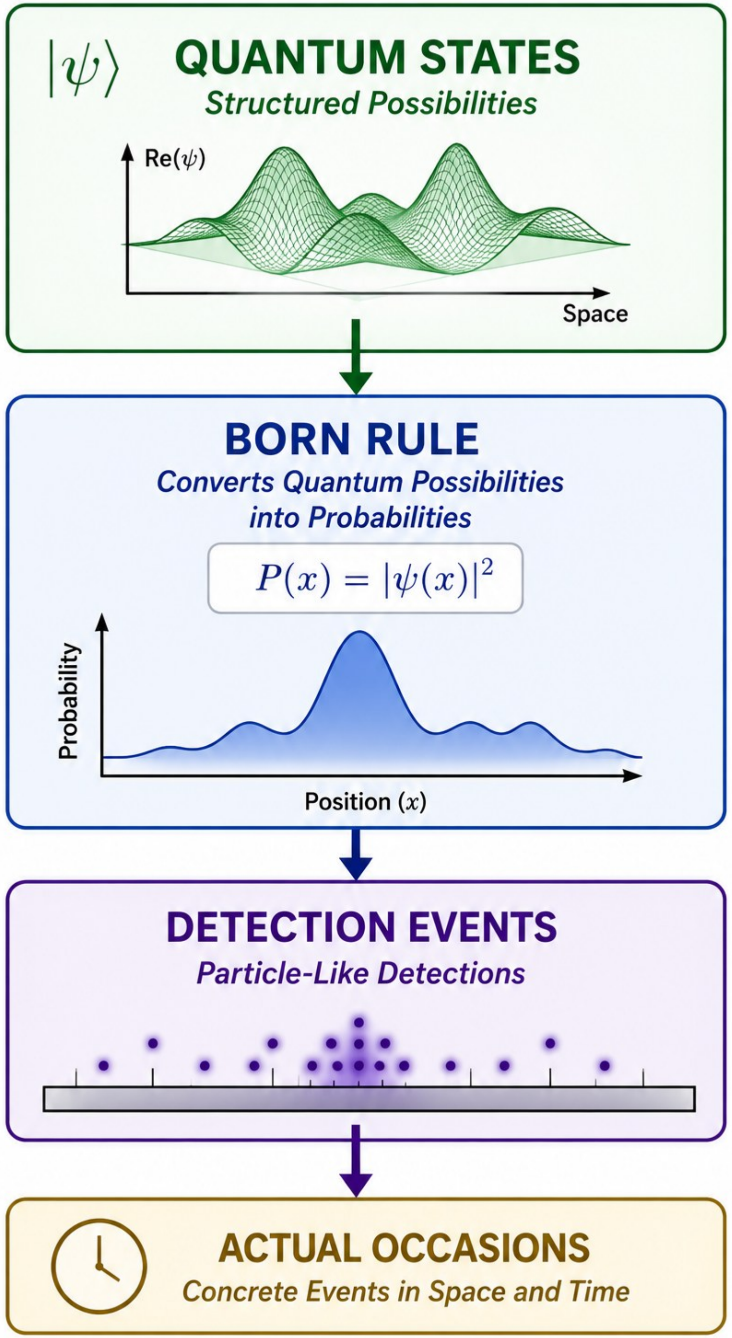
The Primordial Nature is represented by:

- The Hamiltonian (the rules and constraints)
- The Quantum State Space (the possibilities)
- Together they define what can and cannot occur.

Key Insight

- The Hamiltonian does not determine a single future.
- It structures the space of possible futures.





Consequent Nature: Actualized Events

Process Theology Lens

- The Consequent Nature of God includes the actual events that occur in the world.
- Possibilities become actual occasions.
- The world gains new facts.

Quantum State Machine

- The Born Rule predicts the probabilities of particle-like detections.
- These detections are the actual events observed in experiments.

Key Insight

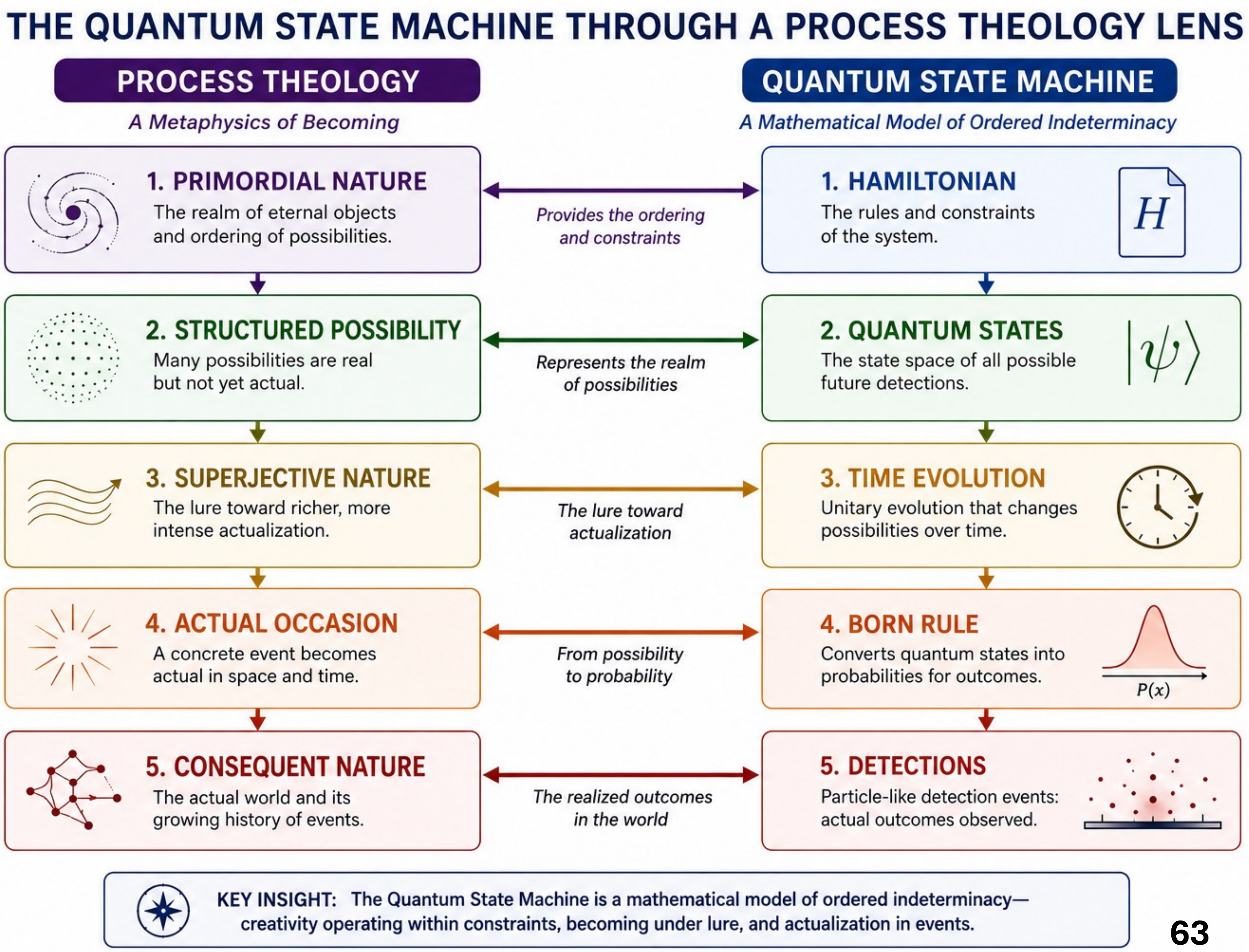
- The Quantum State Machine does not predict certainty.
- It predicts the probabilities of actual occasions.

Quantum State Machine

Hamiltonian
↓
Quantum States
↓
Time Evolution
↓
Born Rule
↓
Particle-Like Detections

Key Insight

- The Quantum State Machine is a model of:
- Creativity Operating Within Constraints



The Unfinished Story...

Tonight we built the Quantum State Machine.

We identified:

- The rules (Hamiltonian)
- The possibilities (Quantum States)
- The mechanism for predicting detections (Born Rule)

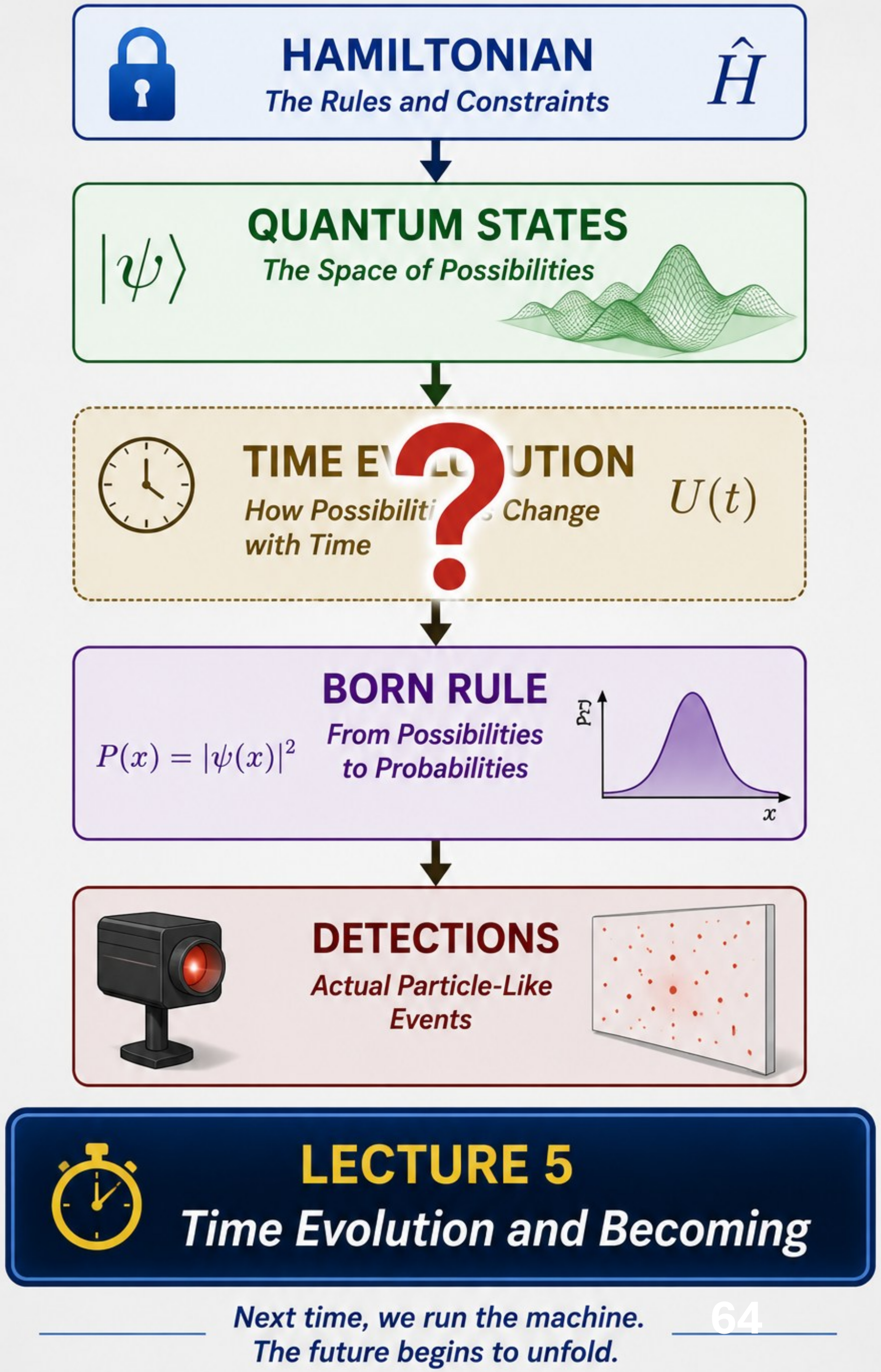
But one essential question remains:

How do the possibilities change with time?

- How does the machine evolve?
- How does the future emerge from structured possibility?
- How does the lure toward actualization operate?

Next Lecture

- Running the Quantum State Machine
- Time Evolution and Becoming




“That's all Folks!”
Isberg©