A History of the science of light from Galileo's telescope to the laser and the quantum information revolution

1. Light in the seventeenth and eighteenth centuries:

- How the invention of the telescope and the pendulum has started the scientific revolution. The roles of Galileo and Huygens.
- First determination of light's velocity by Römer's observation of Jupiter's moons
- Snell and Descartes.
- Fermat and the principle of least time.
- Huygens and the emergence of the wave theory.
- Newton, the emission theory and the spectrum of light.
- The aberration of stars.
- Connection between optics and the exploration of the Earth: the measure of the meridian and the oblateness of the planet.

2. Light in the nineteenth century:

- Thomas Young and interferences
- Malus and the polarization of light
- Fresnel, the diffraction theory and the vector model of light's vibrations
- Fourier and spectral analysis
- Measurement of light velocity in air and in a medium: Fizeau and Foucault
- The birth of electromagnetism: Oersted, Ampère and Faraday
- The notion of field
- Maxwell's equations
- What was known about light at the end of the nineteenth century

3. **The first cloud of Lord Kelvin: Relativity**

- The Ether puzzle
- Michelson Morley experiment
- The principle of special relativity: from Galileo to Einstein
- Relativity of simultaneity
- Relativity of time and lengths
- The twin paradox
- Lorentz transformations
- Minkowsky four-dimensional space
- $E=mc^2$
- The principle of equivalence and general relativity
- The curvature of space-time
- The proofs of relativity

4. The second cloud of Lord Kelvin: quantum physics

- The puzzle of blackbody radiation and Planck's law
- Einstein, the photoelectric effect and the photon
- How the quanta extended to matter: the heat capacity of solids
- The planetary model of the atom: Rutherford, Bohr and Sommerfeld
- Einstein and stimulated emission
- The Bose Einstein statistics and the identity of particles

- Bosons and fermions
- De Broglie and matter waves
- Schrödinger, Heisenberg, Dirac and Feynman: the modern quantum theory.

5. The principles of quantum physics

- The Superposition principle
- Measurement and complementarity
- Uncertainty relations
- Discussion of thought experiments
- Entanglement and non-locality
- Bell's inequalities
- The quantum-classical limit: Feynman's diagrams
- Decoherence theory

6. The first quantum revolution in technology

- Discovery of the spin: the Stern Gerlach experiment
- Rabi and the molecular beam method
- Nuclear magnetic resonance
- Magnetic resonance imaging
- The atomic clock
- The GPS
- Optical pumping
- The invention of the laser

7. The laser revolution

- The precision revolution: high resolution spectroscopy
- The sensitivity revolution: manipulating single particles
- The light intensity revolution: Non-linear optics
- Ultra-short pulses and ultra-high intensities: extreme light

8. Laser cooling and trapping

- Principle of Doppler cooling
- Sub-Doppler cooling
- Optical tweezers and optical lattices
- Magnetic traps
- Atomic interferometry
- Evaporative cooling
- Degenerate quantum gases

9. Ion trapping

- Principle of ion trapping
- Ion manipulation
- Ion quantum jumps
- Laser cooling of ions
- Ions as quantum bits
- Quantum information with trapped ions

10. The physics of Rydberg atoms

- Orders of magnitude
- Preparation and detection of Rydberg atoms
- Rydberg atom spectroscopy
- Interaction between Rydberg atoms
- Applications of Rydberg atoms to quantum information

11. Cavity quantum electrodynamics

- Coupling two-level atoms to a cavity field mode
- Enhancement and suppression of spontaneous emission: the Purcell factor
- The Jaynes Cummings model
- Vacuum Rabi oscillation
- Quantum information in Cavity QED
- Realizing thought experiment in Cavity QED

12. Quantum non-demolition experiments:

- Detecting photons without destroying them: the principle of QND methods
- QND Photon counting illustrating a quantum measurement
- Tomographic reconstruction of quantum states
- Quantum feedback experiments
- Quantum Zeno experiments

13. Schrödinger cat states and decoherence studies

- Preparation of quantum state superpositions by dispersive methods
- Preparation of cat states by resonant methods
- Experimental study of decoherence
- Comparing Cavity QED, circuit QED and ion trap physics

14. Quantum metrology

- Principle of quantum metrology
- The standard quantum limit
- Sensitivity beyond the standard quantum limit: squeezed states
- Sensitivity beyond the standard quantum limit: Entangled sates
- Quantum electrometers and magnetometers

15. Conclusion: coming back to the history of time measurement

- The importance of precise time measurement, from Huygens to the lasers
- The gain in precision from the 17^{th} to the 20^{th} century
- The optical clocks
- Frequency combs
- Ion clocks versus neutral atom lattice clocks
- Relativity tests
- Cosmology tests
- General conclusion of lectures.

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