QUANTUM HOLOGRAPHY

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OUTLINE

01

What is Holography?

02

Quantum Holography Setup

03

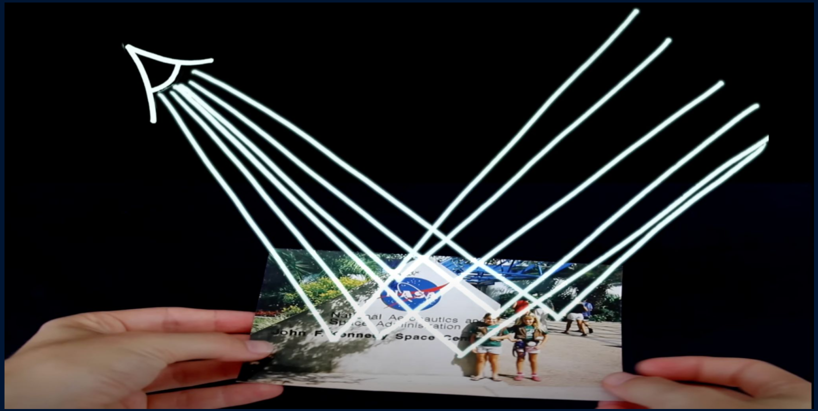
Results & Implications

01 HOLOGRAPHY BACKGROUND

CLASSICAL HOLOGRAPHY

- A technique used to capture and reproduce three-dimensional images of objects.
- Relies on the **principle of interference** to record both the amplitude and phase information
- Various types of holograms have been developed over the years
  - Transmission Holograms
  - Rainbow Holograms

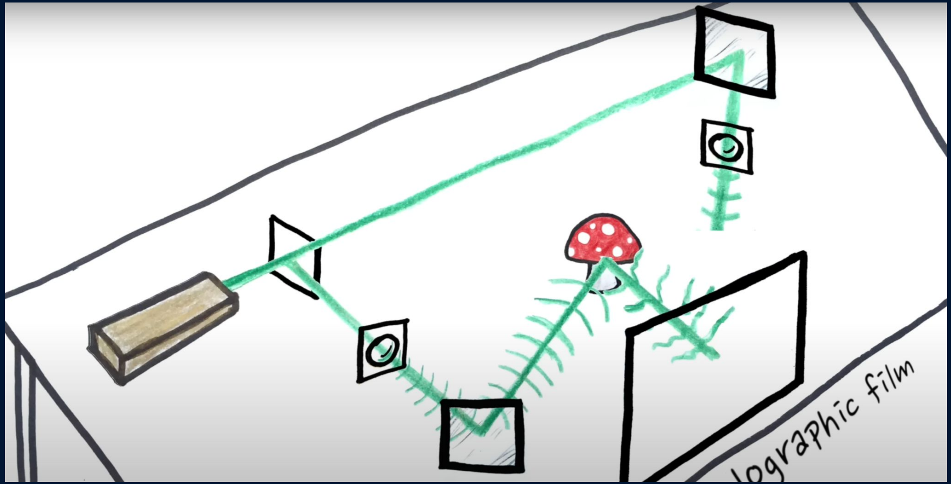
PHOTOGRAPHS



- White light
  - Freezing different frequencies of light
  - Photograph is static - **2D**
- Laser light
  - Same Direction
  - Same Wavelength
  - **Coherent**
    - All light waves are in phase/unison

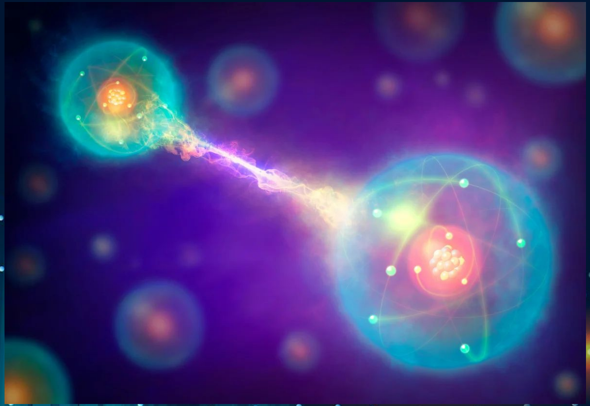
TRANSMISSION HOLOGRAM

- Objects illuminated with coherent light (typically through laser)
- Interacts with a reference beam to create an interference pattern on a light-sensitive medium like film
  a. Interference pattern formed where the object's light waves and the reference beam overlap
  b. Encodes both the amplitude and phase information of the object's light
- After exposure, the medium records the interference pattern

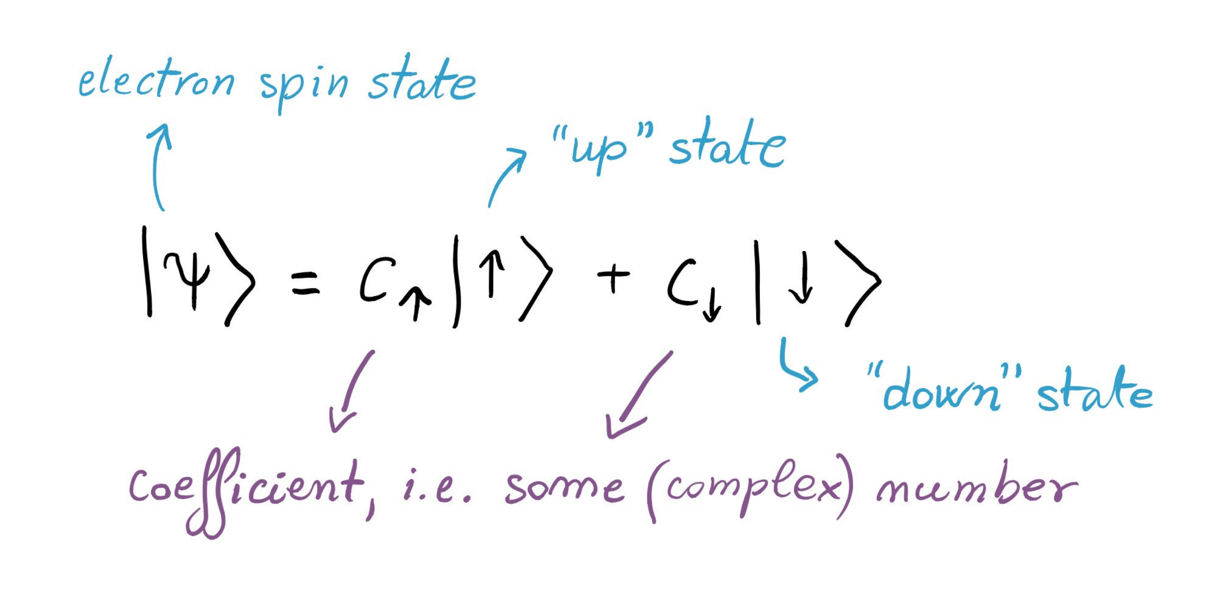


QUANTUM ENTANGLEMENT

- **Quantum Entanglement:** phenomenon where two or more particles become correlated where the state of one is dependent on other particles
    a. First proposed in 1935 by physicist Erwin Schrödinger
    b. Hated by Einstein: “God does not play dice.”
    c. Can be physically separated by large distances



QUANTUM ENTANGLEMENT EXPLAINED



QUANTUM ENTANGLEMENT EXPLAINED

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|+\rangle_1 |-\rangle_2 - |-\rangle_1 |+\rangle_2)$$

- Spin-0 particle split into two particles
- First particle - 50% chance of being spin-up, 50% chance of being spin-down
    - If one particle is spin-up, then we know with 100% certainty that the other particle is spin-down
    - Anticorrelated
    - They can never recombine and we can still get all the information needed

RESEARCH QUESTION

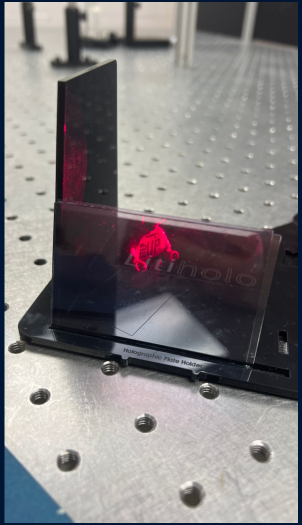
- Can we utilize quantum entanglement along with other quantum properties to enhance the performance and capabilities of holographic systems compared to classical approaches?
- Can we form real-time holographics utilizing entangled quantum photon pairs?

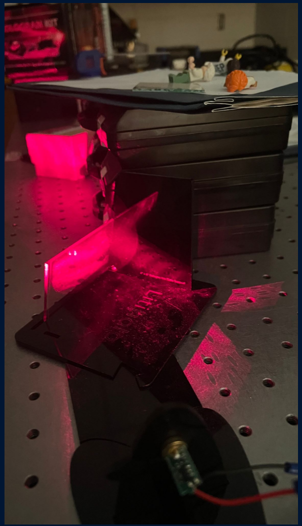
02

EXPERIMENTAL SETUP

Quantum Holography

Classical Hologram





How Does it Work?

- Transmission hologram
  - Needs a laser light to see the hologram
- Laser light reflecting off object interferes with light coming from the laser in front of the plate

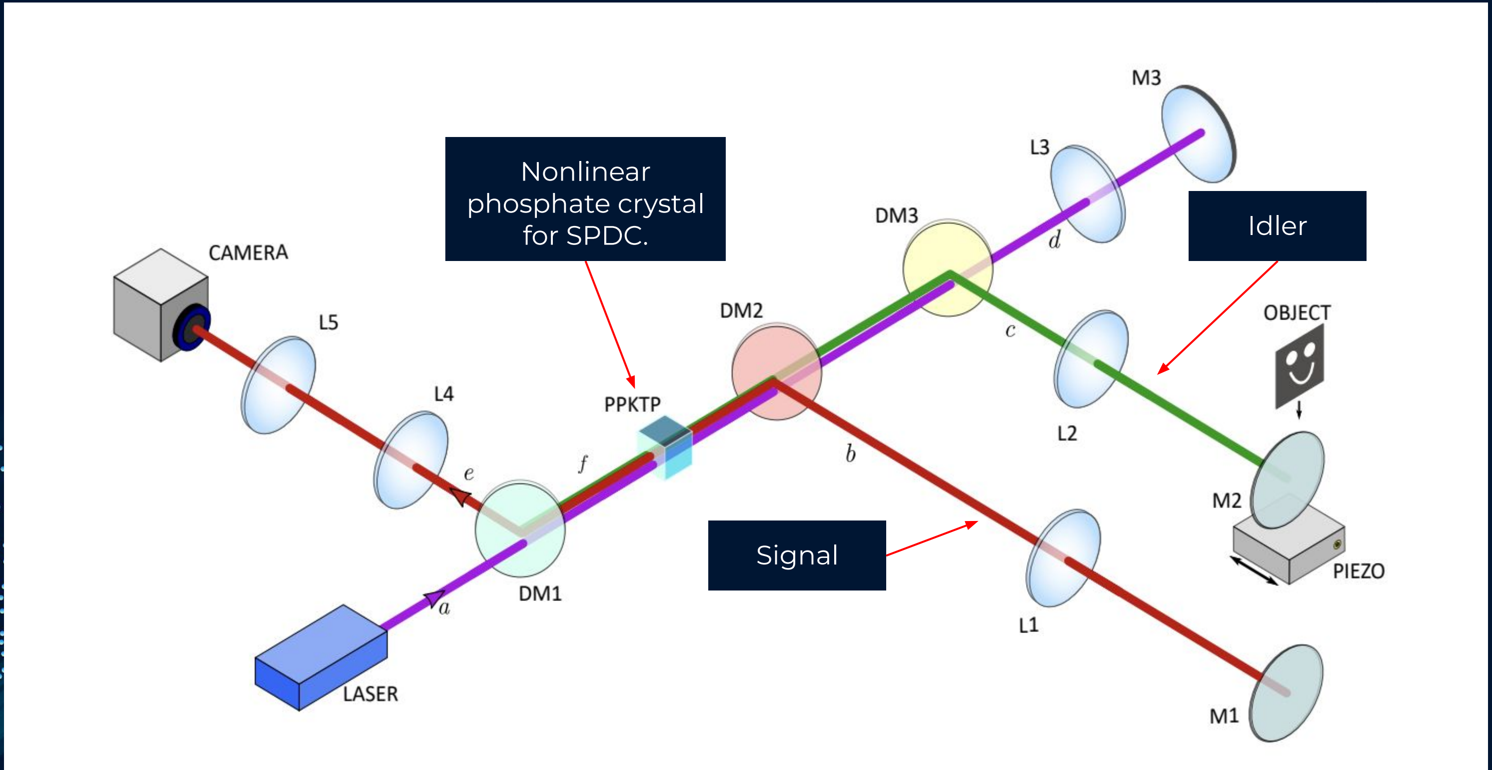
QUANTUM HOLOGRAM

1. A collimated* laser is pumped through a ppKTP^ crystal
2. Reference and object beams are generated by means of spontaneous parametric down-conversion (SPDC)
3. The crystal is imaged upon itself through mirrors and lenses
4. Quantum interference occurs after beams return to the crystal, transferring object information to the signal beam.
5. The combined beams then approach the camera to capture the hologram

*parallel rays (minimal spread)

^poled potassium titanyl phosphate

QUANTUM HOLOGRAM



QUANTUM HOLOGRAM

03 DISCUSSION

And Quantum Implications

DISCUSSION AND IMPLICATIONS

- Expensive materials and not enough time
- Simplified the experiment by:
  - Reducing number of mirrors
  - Using less effective materials
- Current techniques are still in early stages and face complex/delicate setups and limitations in scalability

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- New ways to create sharper, more detailed holograms
- Less noise, higher resolution medical images
  - Reveal finer details of near-transparent cells
- Enabling visualization of material at subatomic level

WHY CONTINUE?

- Established connection with leading quantum holography researcher Sebastian Töpfer
  - Researches at the Technical University of Darmstadt
- Materials list compiled
- Never created before in a high school
- Experimental setup established

SUMMARY

What is Holography?

Quantum Incorporation

Experimental Setup & Theoretical Understanding

Quantum Implications for the Future

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QUESTIONS?