POLARIZATION IN QUANTUM KEY DISTRIBUTION

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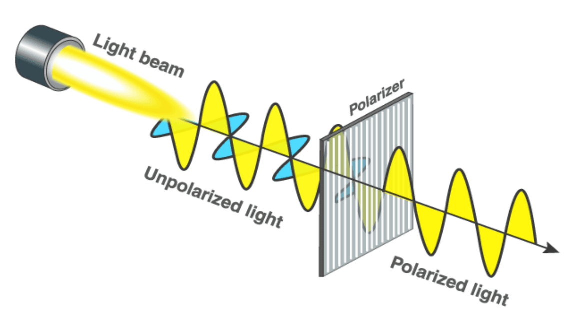
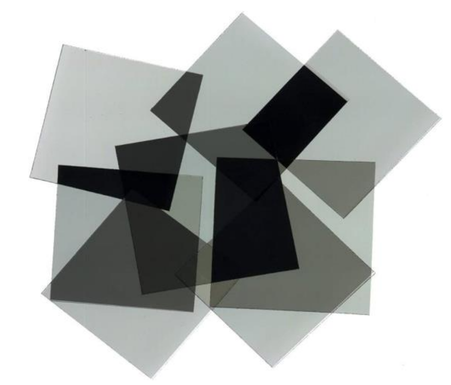
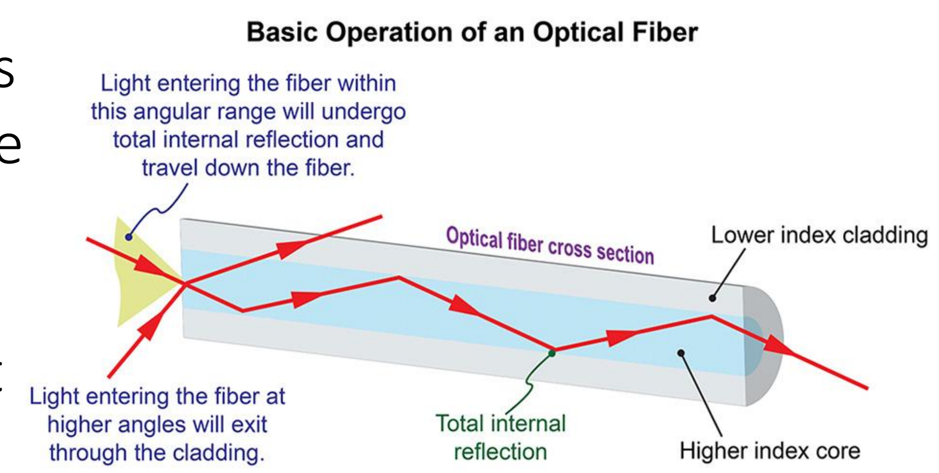
How Polarization and Optical Fibers Work

Polarization refers to the restriction of light to one basis (orientation). This is an example of light acting as a wave, rather than a particle.





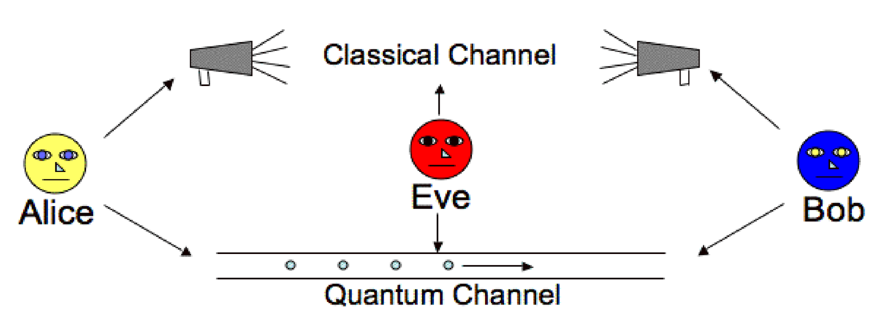
Optical fibers are used to transmit information over long distances at high speeds. Light travels through the denser glass core, which has a higher index of refraction than the less dense plastic cladding.
Due to **total internal reflection**, 100% of light is trapped inside the core and reflects off the sides at a critical angle, allowing it to travel through the optical fiber.



Explaining Quantum Key Distribution

Quantum Key Distribution (QKD) is a set of instructions detailing how to establish a secure communication channel.

For example, Alice (the sender) is trying to send Bob (the receiver) information through light using a sequence of classical bit values of 0 and 1. By polarizing the light, Alice encodes each bit into either the:



1) Standard Basis using the respective classical bits into corresponding quantum bits
$0 \rightarrow |\uparrow\rangle$ y-basis
$1 \rightarrow |\rightarrow\rangle$ x-basis
2) Hadamard Basis using equal superpositions of the standard basis states
$0 \rightarrow |\nearrow\rangle = 1/\sqrt{2}\,(|\uparrow\rangle + |\rightarrow\rangle)$
$1 \rightarrow |\nwarrow\rangle = 1/\sqrt{2}\,(|\uparrow\rangle - |\rightarrow\rangle)$

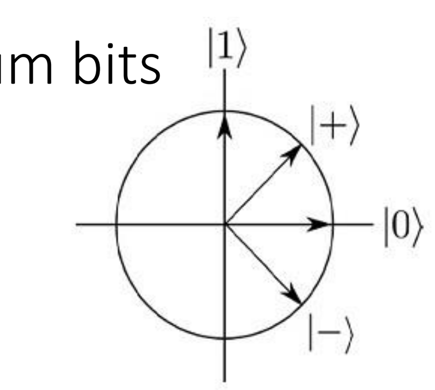
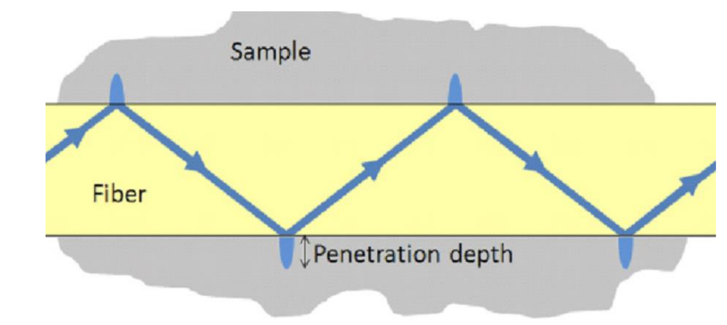


Figure 3.1: Standard and Hadamard basis states represented on the real plane.

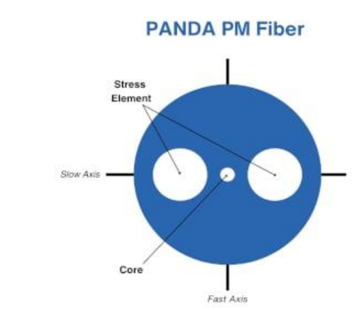
Eve, a 3rd-party eavesdropper, does not know which basis Alice is using and thus, measures incorrectly 50% of the time. This collapses the qubit, meaning there will be a 25% chance that Bob measures a different bit value than the one Alice sent. Afterwards, Alice and Bob compare the bases they used for each qubit through the classical channel and conclude that either they have a **secure private key** OR they have detected that an **eavesdropper is present**. Both situations allow Alice and Bob to run little risk of establishing a compromised key.

Benefits and Applications

In an optical fiber, light sometimes travels through the boundary as an **evanescent wave** into the cladding, attributed to its wave nature. As a result, **dispersion** occurs, which changes the speed that light travels, due to the differences in index of refraction in the materials.



Polarization can be used inside an optical fiber, known as **polarization-maintaining (PM) fibers** to prevent this disruption and improve signal integrity.



In classic **cryptography,** communicating parties share a secret sequence of numbers called a key which is used to encrypt/decrypt data. Current intrusion detection systems however, frequently alert for false positives. **QKD** protocols (establishing keys by encoding qubits into polarization states) prevent the decryption of data because intruders will always be detected.
Quantum Communications can be used in:

- Banking to protecting details about clients' accounts
- Government & Defense to ensure protection of classified data from espionage
- Finances/Credit Cards to safeguard business data and credit card information

Limitations

There are several communication and security requirements in **QKD** as it is highly implementation dependent rather than assured through the laws of physics:

1. Only a partial solution: **QKD** ensures a secure secret code but does not guarantee that the message came from the right person or hasn't been tampered with.
2. Cannot be easily implemented: **QKD** cannot be implemented as a network service or in a software and lacks flexibility for upgrades.
3. Extra infrastructure: Long distances require the use of relays or special stations that are costly.

References/Acknowledgements

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1. National Security Agency/Central Security Service > Cybersecurity > Quantum Key Distribution (QKD) and Quantum Cryptography QC, National Security Agency/Central Security Service, https://www.nsa.gov/Cybersecurity/Quantum-Key-Distribution-QKD-and-Quantum-Cryptography-QC/