Quantum Key Distribution with BB84

BY @QUANTUMCHEAP

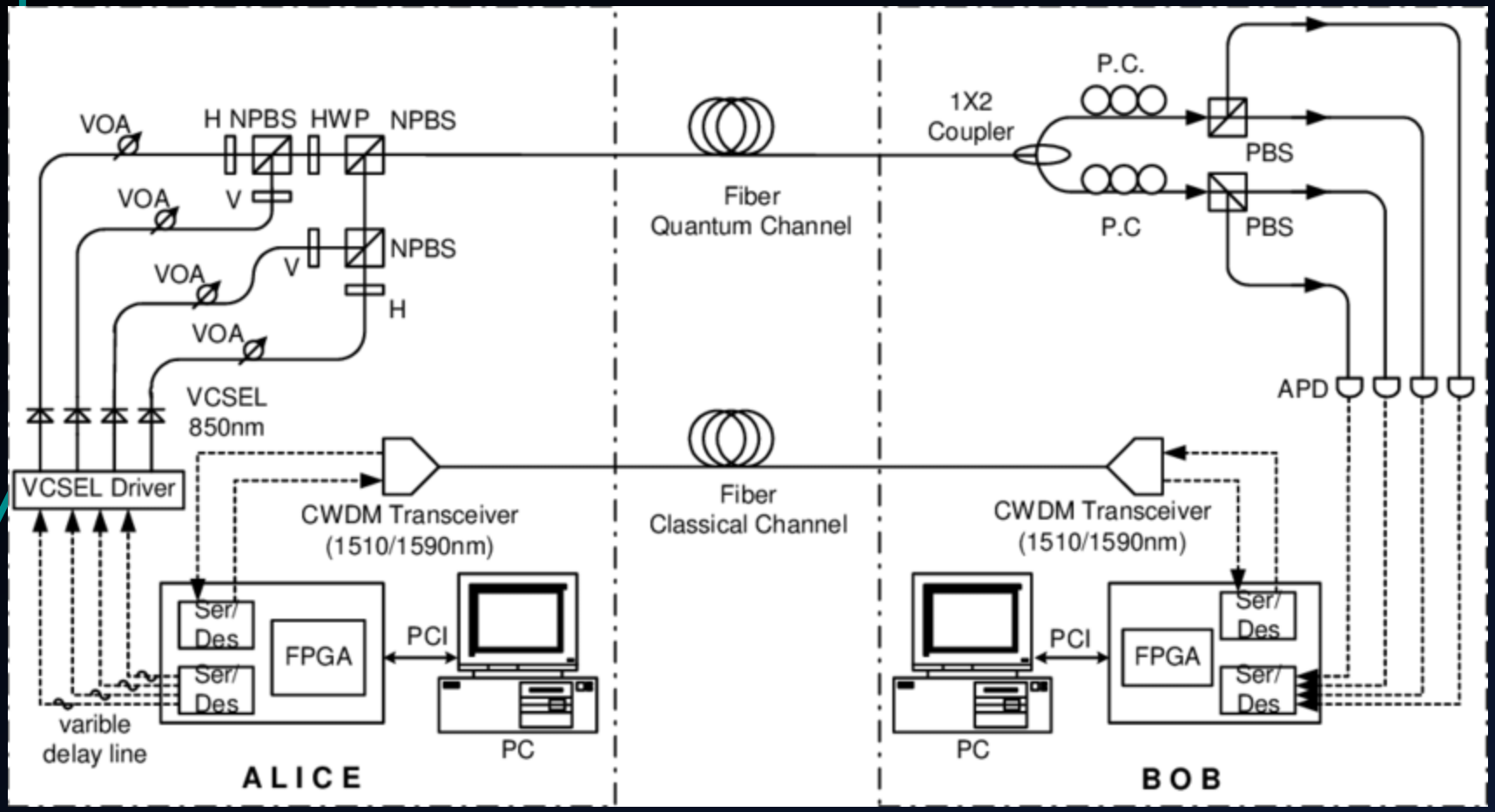
Quantum Key Distribution

- is a secure communication method which implements a cryptographic protocol involving components of quantum mechanics
- There's an inherent ability for the two communicators to detect the presence of an eavesdropper (since measuring a quantum system disturbs the system)

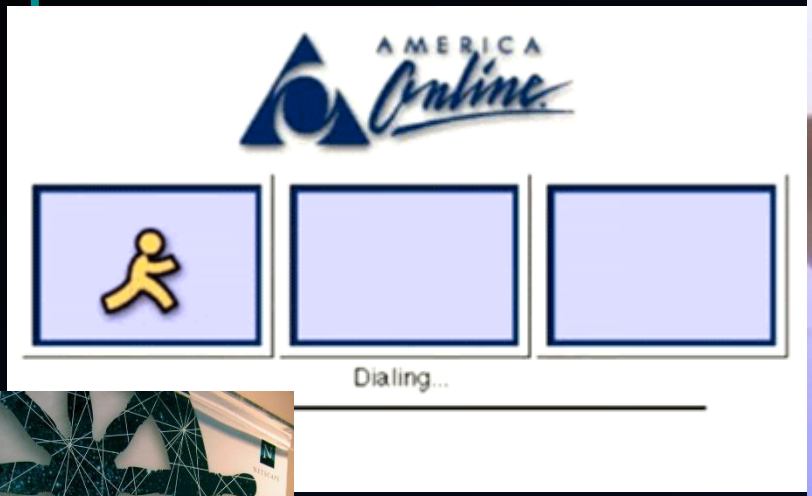
BB84

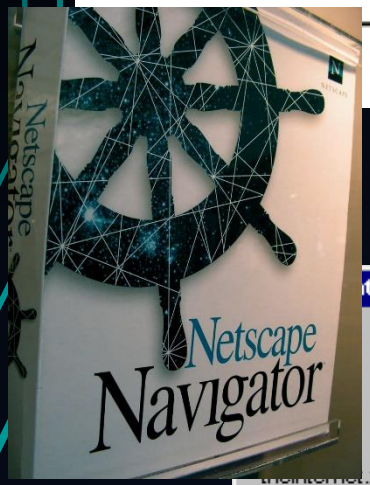
- developed by Charles Bennett and Gilles Brassard in 1984
- It is the first quantum cryptography protocol
- It is usually explained as a method of securely communicating a private key from one party to another for use in one-time pad encryption.

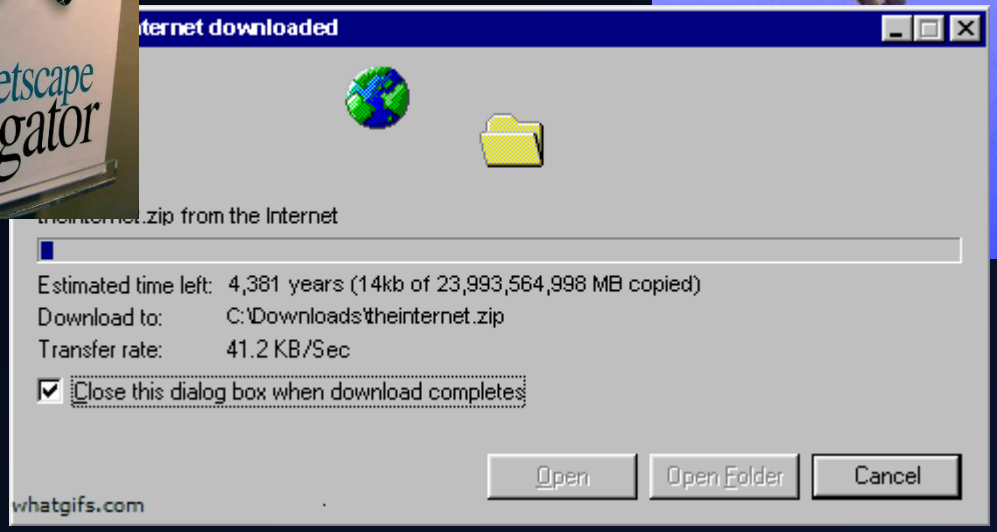
The Setup


VOA
H NPBS
HWP
NPBS
VOA
V
VOA
V
NPBS
H
VOA
VCSEL
850nm
VCSEL Driver
varible
delay line
CWDM Transceiver
(1510/1590nm)
Ser/
Des
Ser/
Des
FPGA
PCI
PC
ALICE
Fiber
Quantum Channel
Fiber
Classical Channel
1X2
Coupler
P.C.
P.C
PBS
PBS
APD
CWDM Transceiver
(1510/1590nm)
PCI
FPGA
Ser/
Des
Ser/
Des
PC
BOB

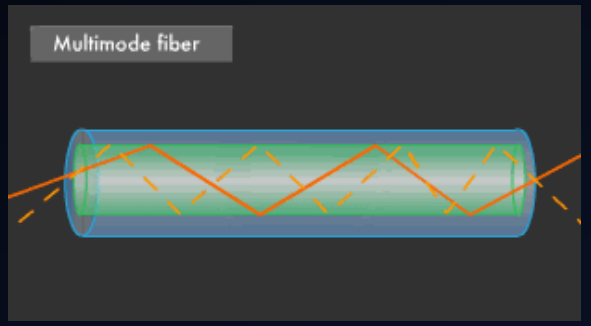
The Setup – Classic Channel

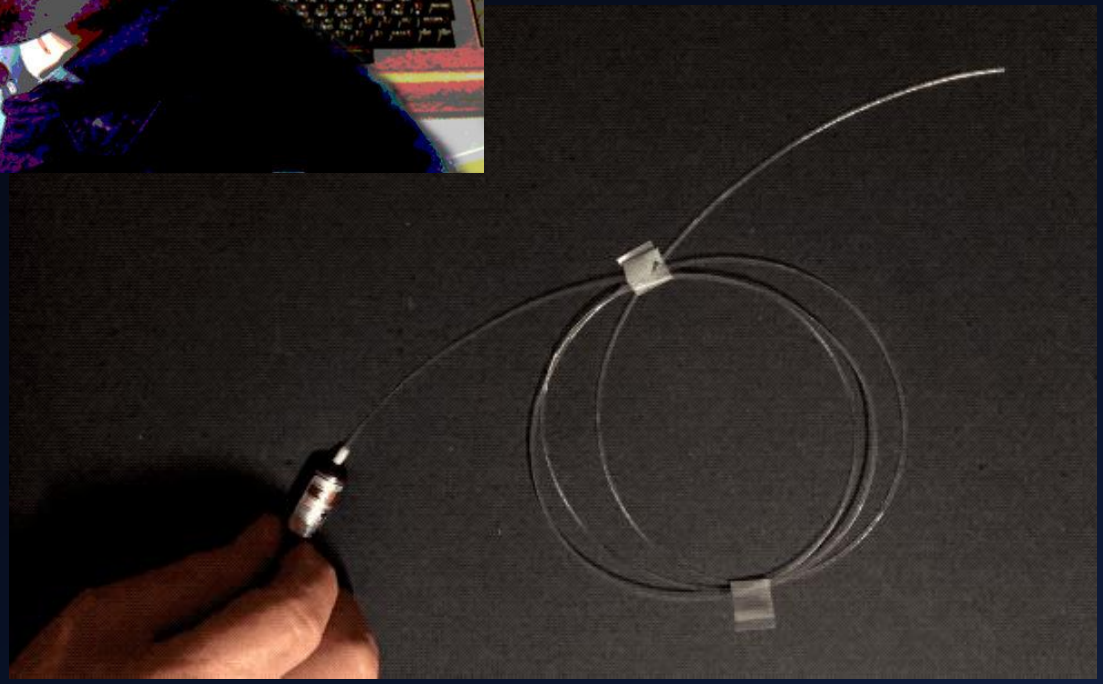






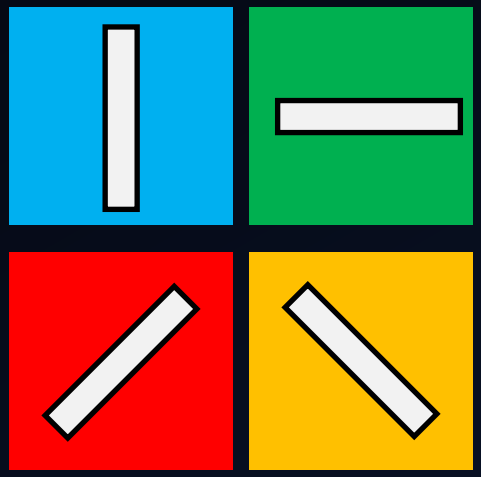
The Setup – Quantum Channel





The Setup – Quantum Channel

1 0



Measurement Basis

Rectilinear

Diagonal

The Setup – Quantum Channel

Alice has two pairs or polarizers to send photons through. Each pair are perpendicular to each other (0° and 90°) and (45° and 135°).

single-photon light source

The Setup – Quantum Channel

Measurement Basis

Bob measures the polarization of the photons with two special polarizers. There is a rectilinear polarizer (0° and 90°) and a diagonal polarizer (45° and 135°).

Rectilinear

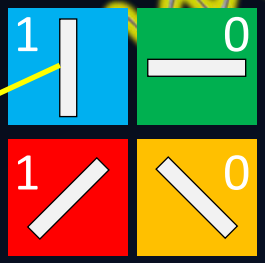
Diagonal

The receiver randomly selects which bases to measure each photon.

Polarization Demo

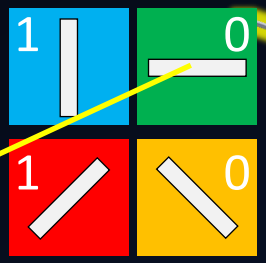
0° rotation	45° rotation	90° rotation
100%	50%	0%
pass-through	pass-through	pass-through

Photon polarization Alice sends								
Bob's random measuring basis								
Photon polarization Bob measures								



single-photon light source

Photon polarization Alice sends								
Bob's random measuring basis								
Photon polarization Bob measures								

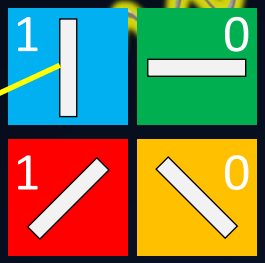


single-photon light source

Photon polarization Alice sends								
Bob's random measuring basis								
Photon polarization Bob measures								

single-photon light source

Photon polarization Alice sends	1	0	0	1				
Bob's random measuring basis	+	×	×	×				
Photon polarization Bob measures	1	1	0	1				



single-photon light source

Photon polarization Alice sends	1	0	0	1	0			
Bob's random measuring basis	+	×	×	×	+			
Photon polarization Bob measures	1	1	0	1	0			

single-photon light source

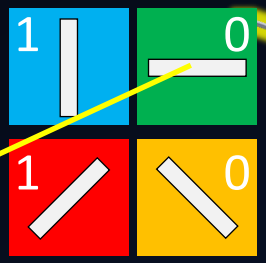
Photon polarization Alice sends	1	0	0	1	0	1		
Bob's random measuring basis	+	×	×	×	+	×		
Photon polarization Bob measures	1	1	0	1	0	1		

single-photon light source

Photon polarization Alice sends	1	0	0	1	0	1	1	
Bob's random measuring basis	+	×	×	×	+	×	+	
Photon polarization Bob measures	1	1	0	1	0	1	0	

single-photon light source

Photon polarization Alice sends	1	0	0	1	0	1	1	0
Bob's random measuring basis	+	×	×	×	+	×	+	+
Photon polarization Bob measures	1	1	0	1	0	1	0	0



single-photon light source

Back on the classic channel…

Bob and Alice compare which basis they used to send and receive each qubit

Photon polarization Alice sends								
Alice's sending basis								
Bob's random measuring basis								
Photon polarization Bob measures								
PUBLIS DISCUSSION OF BASIS								
Shared secret key	1		0			1		0

The bits corresponding to matching basises become the key!

Key = “1010”

Why Does This Work?

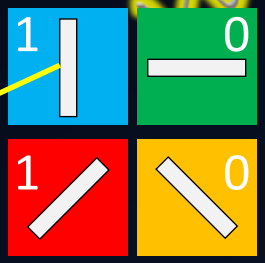
Mission accomplished?

…or “mission accomplished”?

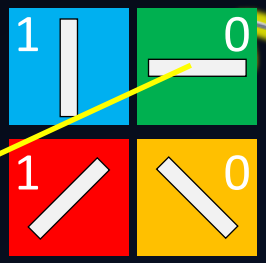
We’ve got an eavesdropper!

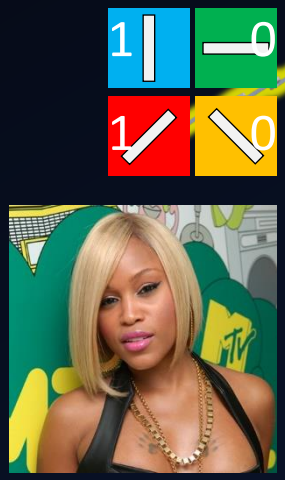
Photon polarization Alice sends								
Eve's random measuring basis								
Polarization Eve measures and sends								
Bob's random measuring basis								
Photon polarization Bob measures								

single-photon light source



Photon polarization Alice sends								
Eve's random measuring basis								
Polarization Eve measures and sends								
Bob's random measuring basis								
Photon polarization Bob measures								

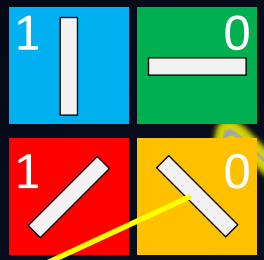




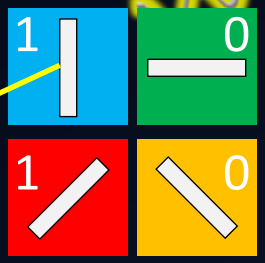
single-photon light source

Photon polarization Alice sends	1 |	— 0	\ 0					
Eve's random measuring basis	+	×	+					
Polarization Eve measures and sends	1 |	1 /	— 0					
Bob's random measuring basis	+	×	×					+
Photon polarization Bob measures	1 |	1 /	1 /					

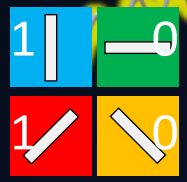
single-photon light source



Photon polarization Alice sends	1	0	0	1				
Eve's random measuring basis	+	×	+	+				
Polarization Eve measures and sends	1	1	0	1				
Bob's random measuring basis	+	×	×	×				+
Photon polarization Bob measures	1	1	1	0				



single-photon light source



Photon polarization Alice sends								
Eve’s random measuring basis								
Polarization Eve measures and sends								
Bob's random measuring basis								
Photon polarization Bob measures								

single-photon light source

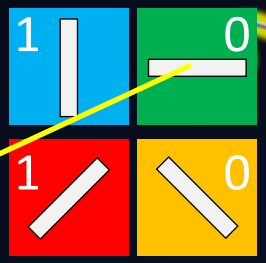
Photon polarization Alice sends	1 |	— 0	\ 0	1 |	\ 0	1 /		
Eve's random measuring basis	+	×	+	+	×	+		
Polarization Eve measures and sends	1 |	1 /	— 0	1 |	\ 0	— 0		
Bob's random measuring basis	+	×	×	×	+	×		+
Photon polarization Bob measures	1 |	1 /	1 /	\ 0	— 0	1 /		×

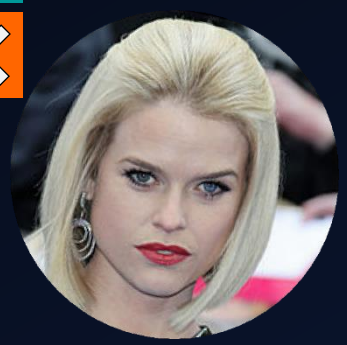
single-photon light source

Photon polarization Alice sends	1	0	0	1	0	1	1	
Eve's random measuring basis	+	×	+	+	×	+	×	
Polarization Eve measures and sends	1	1	0	1	0	0	1	
Bob's random measuring basis	+	×	×	×	+	×	+	
Photon polarization Bob measures	1	1	1	0	0	1	1	

single-photon light source

Photon polarization Alice sends	1 |	— 0	\ 0	1 |	\ 0	1 /	1 /	— 0
Eve's random measuring basis	+	×	+	+	×	+	×	+
Polarization Eve measures and sends	1 |	1 /	— 0	1 |	\ 0	— 0	1 /	— 0
Bob's random measuring basis	+	×	×	×	+	×	+	+
Photon polarization Bob measures	1 |	1 /	1 /	\ 0	— 0	1 /	1 |	— 0





single-photon light source

Back on the classic channel…

Photon polarization Alice sends								
Alice's sending basis								
Eve's random measuring basis								
Polarization Eve measures and sends								
Bob's random measuring basis								
Photon polarization Bob measures								
PUBLIS DISCUSSION OF BASIS								
Shared secret key	1		1			1		0
Errors in key	✓		✗			✓		✓

What do we do now?

- (Assuming Alice chooses randomly) the probability Eve chooses the incorrect basis is 50%.
- If Bob measures Eve's photon in the same basis that Alice sent, he gets a random result, i.e., an incorrect result with probability of 50%.
- So, the probability an intercepted photon generates an error in the key string is then 50% × 50% = **25%**

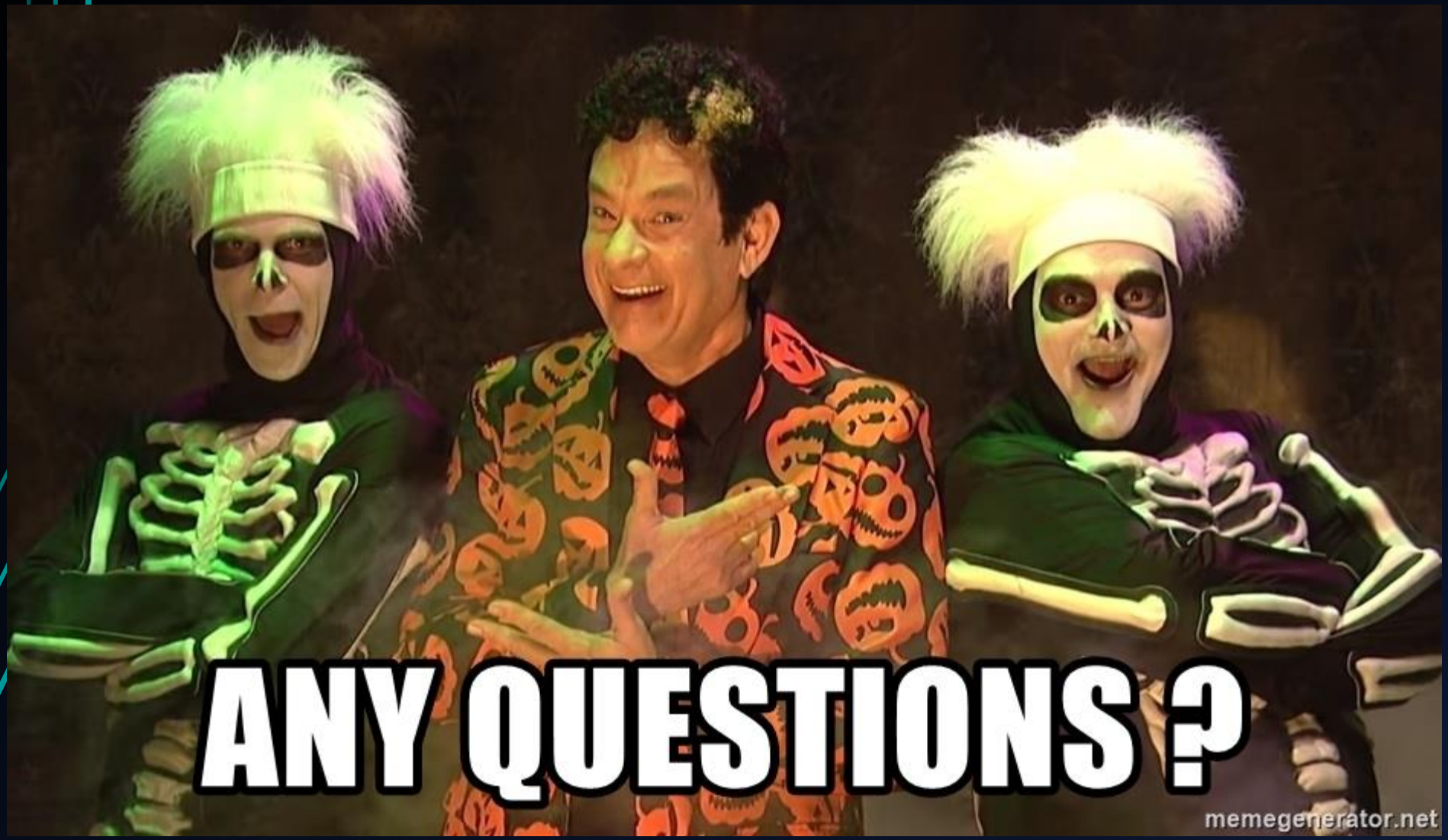
Alice and Bob will then publicly compare n of their key bits. The probability of finding mis-matched bits and the eavesdropper is

$$P = 1 - \left(\frac{3}{4}\right)^n$$

So, to detect an eavesdropper with probability 99.9999999%, Alice and Bob would only need to compare **72** bits.

The Steps

- Alice sends a bunch of qubits
  - Random bits with random polarizations
- Bob measures the qubits
  - With either rectilinear (+) or diagonal (X) basis
- Bob and Alice find out which qubits were measured correctly by publicly comparing each others' basiseseses
  - The bits with matching basis become the key
- They publicly compare a set of those bits
  - if they match, the remaining bits become the key
  - If they don't match, there may have been an eavesdropper. So they start all over again.


ANY QUESTIONS ?
memegenerator.net