

# Source distinguishability; Certification and audit



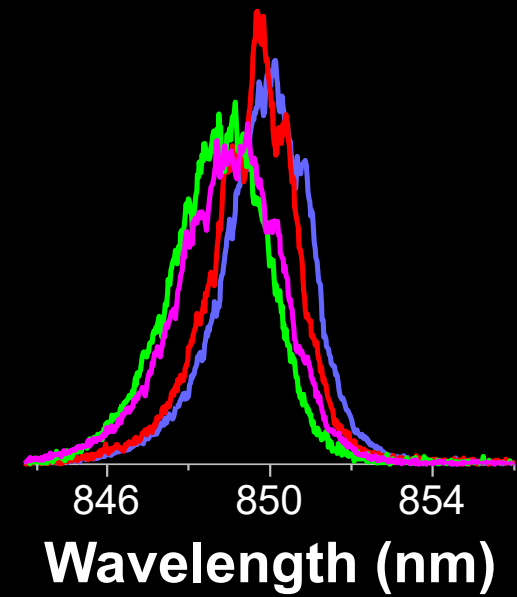
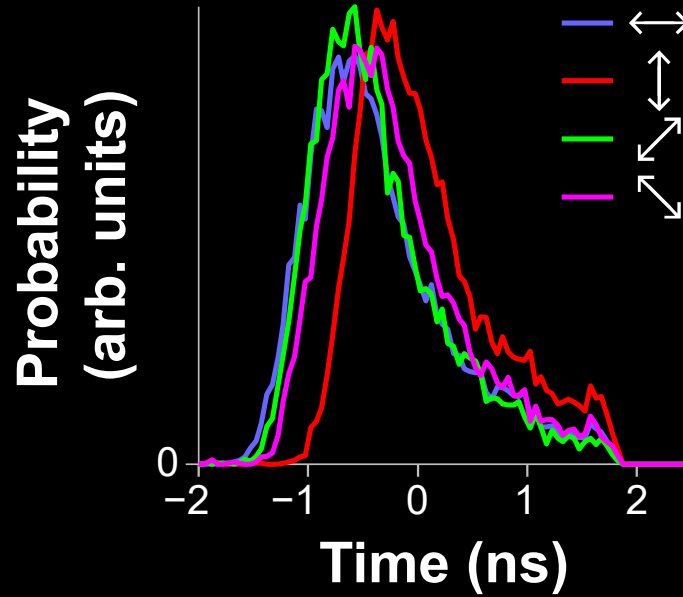
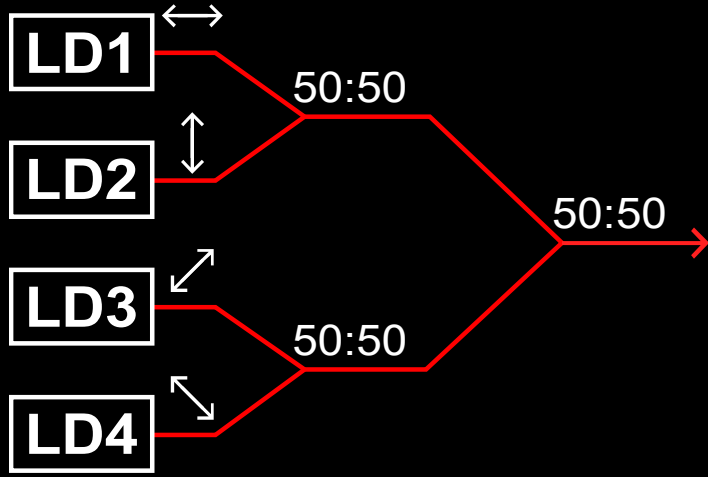
Quantum hacking lab  
[vad1.com/lab](http://vad1.com/lab)

Lecture 14 in Quantum  
communications course,  
14 Nov 2023

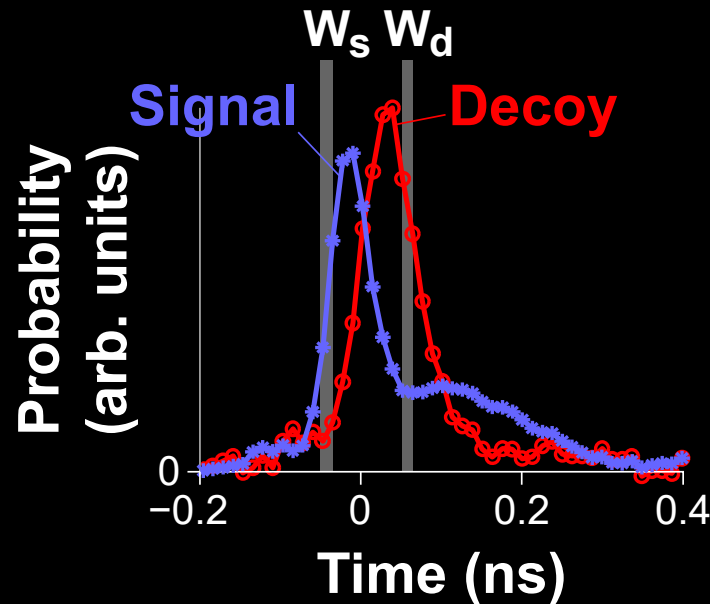
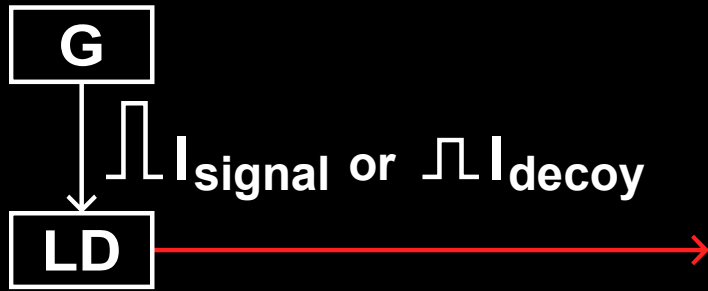
## 3 ways to deal with an imperfection

- ★ Technical countermeasure that attempts to stop the attack
- ★ Make a scheme intrinsically insensitive to imperfection
- ★ Characterise imperfection, upper-bound *partial* information leakage, eliminate it by privacy amplification

# Distinguishability of source states

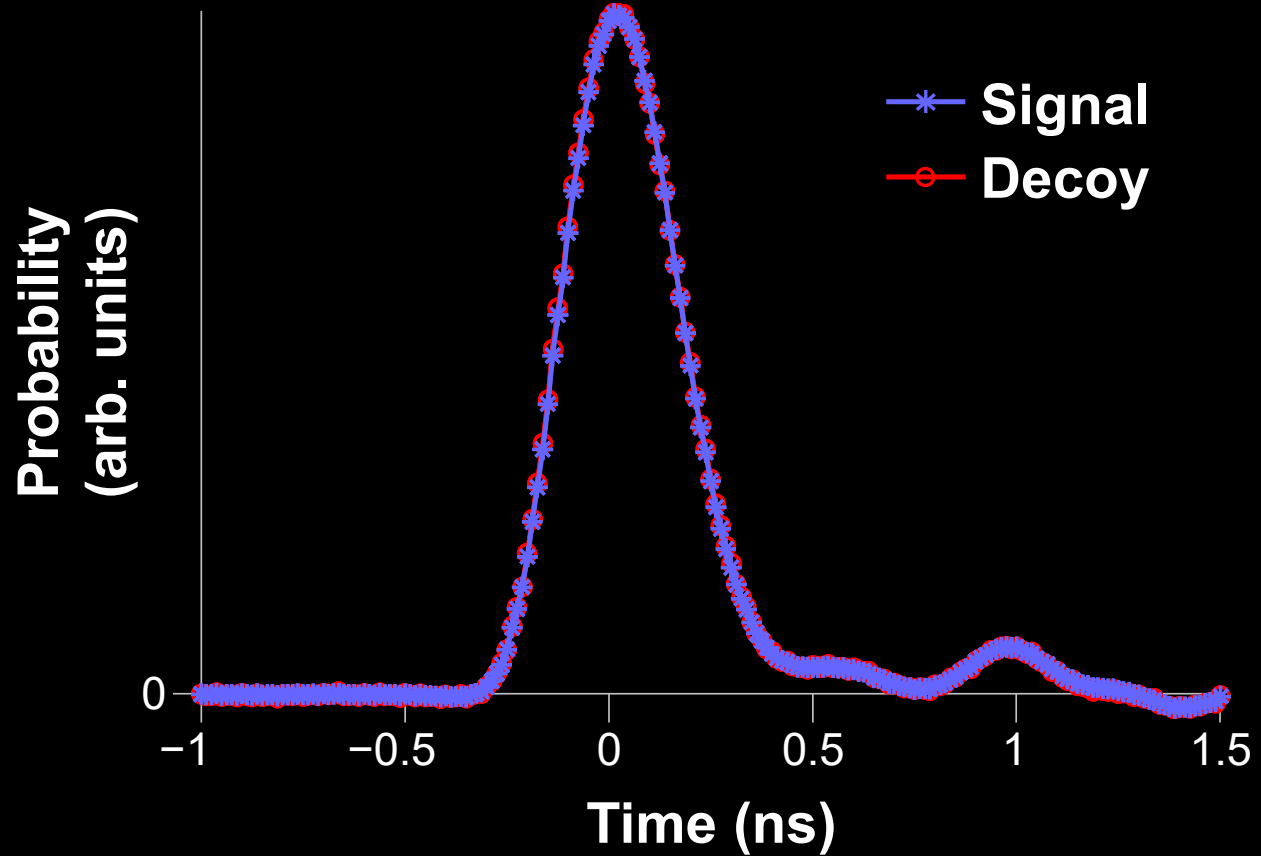
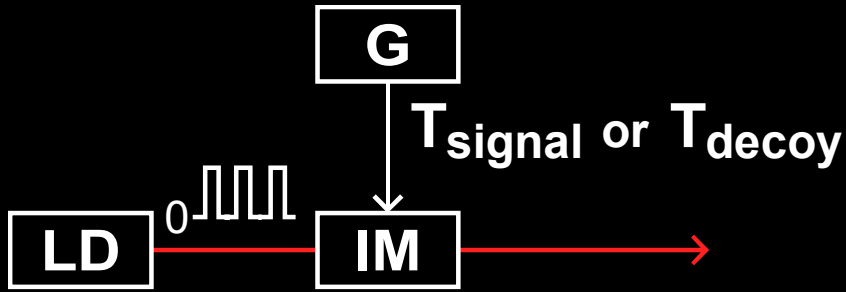


S. Nauerth *et al.*, New J. Phys. **11**, 065001 (2009)



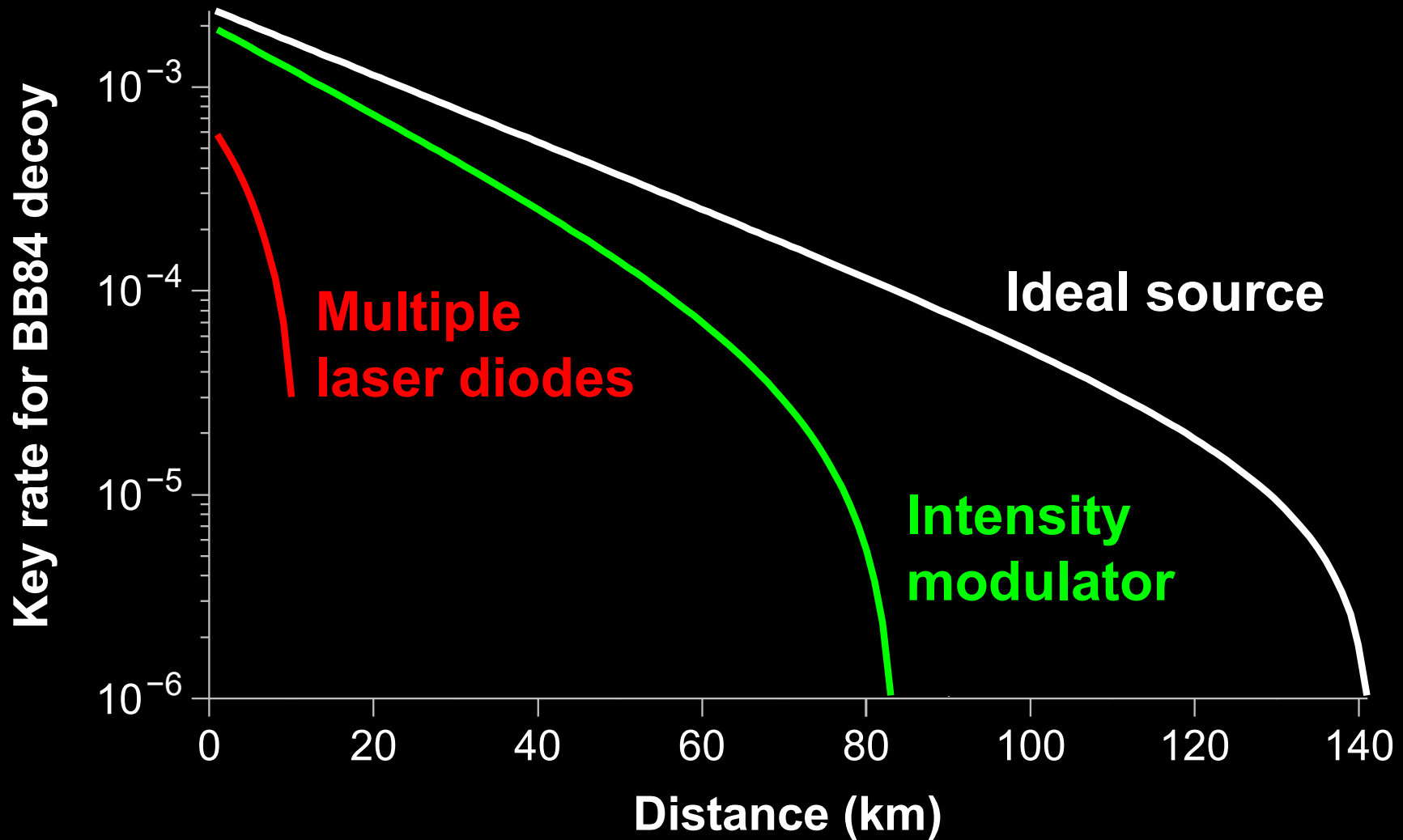
A. Huang, S.-H. Sun, Z. Liu, V. Makarov, Phys. Rev. A **98**, 012330 (2018)

# Distinguishability of source states





# Distinguishability of source states



**Pump-current modulation: zero key rate**

# Certification of cryptographic tools



**Government**



**National  
security agency**

Legal  
requirements



Approval

**Accredited lab**

System



Engineering  
documentation



**Certificate**



**Manufacturer**

Sale

**Customer**

# Certification of cryptographic tools

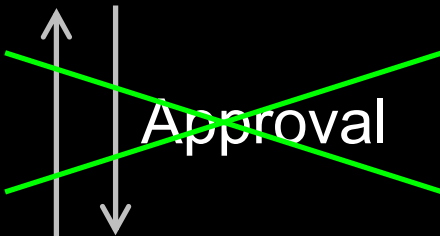


Government



National security agency

Legal requirements



Accredited lab

System



Engineering documentation



Certificate

Russia:  
optional for  
commercial  
uses



Manufacturer

Sale

Customer

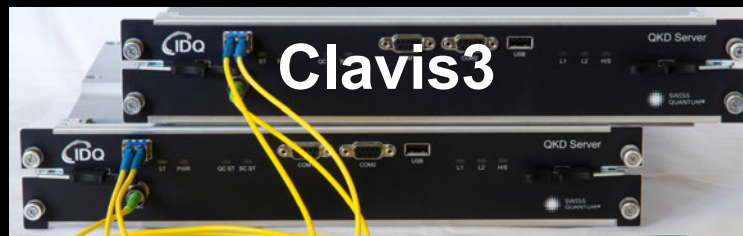


# Security audit

# System

# Report

# Tests



2016

-2018  
interrupted



国盾量子  
QuantumCTek



40 MHz

2016,  
2018-19

ongoing



ITMO UNIVERSITY

(ООО Квантовые коммуникации)

Subcarrier scheme

2018

-2021

S. Sajeed *et al.*, *Sci. Rep.* 11, 5110 (2021)



312.5 MHz

2022

ongoing

V. Makarov *et al.*, arXiv:2310.20107

Certification standards are being drafted since 2019 in



Industry standards  
group in QKD



# Example of initial analysis report

TABLE I: Summary of potential security issues in [redacted] system.

Potential security issue	C	Q	Target component	Brief description	Requirements for complete analysis	Lab testing needed?	Risk evaluation
[redacted]	CX	Q1–5,7	[redacted]	[redacted]	Complete circuit diagram of [redacted]	Yes	High
[redacted]	CX	Q1–3	[redacted]	See Ref. [3].	Complete circuit diagram of [redacted]	Yes	High
[redacted]	CX	Q1,2	[redacted]	See Ref. [4].	Complete circuit diagram of [redacted]	Yes	High
[redacted]	C0	Q2,3	[redacted]	Manufacturer needs to implement [redacted]	Known issue. The manufacturer should patch it.	No	High
[redacted]	CX	Q3–5,7	[redacted]	[redacted]	Known issue. The manufacturer should [redacted]	No	Medium
[redacted]	CX	Q1	[redacted]	[redacted]	Model numbers of all optical components; complete receiver for testing.	Yes	High
[redacted]	CX	Q1–5	[redacted]	[redacted]	Complete circuit diagram of [redacted] settings of [redacted]	Yes	Insufficient information
[redacted]	CX	Q1–3	[redacted]	[redacted]	Algorithm of [redacted]	Yes	Low
[redacted]	CX	Q1,2	[redacted]	See Ref. [13].	Model numbers of [redacted]	Yes	Medium
[redacted]	CX	Q4,5	[redacted]	[redacted]	Full system algorithms; complete system if decided to test.	Maybe	Low
[redacted]	CX	Q1,3–5	[redacted]	Eve can [redacted]	Algorithm for [redacted]	Maybe	Low

# ISO/IEC 23837: Security requirements, test and evaluation methods for quantum key distribution

## 7 Supplementary activities for the evaluation of quantum optical components in the transmitter module

### 7.1 General

**7.2 Evaluation activity to test the photon-number distribution of optical pulses**

**7.3 Evaluation activity to test the mean photon number and stability of optical pulses**

7.4 Evaluation activity to test the independence of the intensities of optical pulses

7.5 Evaluation activity to test the accuracy of state encoding

**7.6 Evaluation activity to test the indistinguishability of encoded states from the perspective of non-encoding degrees of freedom**

7.7 Evaluation activity to test the uniform distribution of the global phase of optical pulses

**7.8 Evaluation activity to test the degree of optical isolation of the TX module**

**7.9 Evaluation activity to test the sensitivity of the injected light monitor in the TX module**

7.10 Evaluation activity to test the robustness of the TX module against laser injection

## 8 Supplementary activities for the evaluation of quantum optical components in the receiver module

### 8.1 General

8.2 Evaluation activity to test the consistency of detection probability in the RX module

8.3 Evaluation activity to test if back-flashes from the RX module can leak information

8.4 Evaluation activity to test the degree of optical isolation of the RX module

**8.5 Evaluation activity to test the sensitivity of the injected light monitor in the RX module**

**8.6 Evaluation activity to test the robustness of the RX module against bright light blinding**

8.7 Evaluation activity to test the appropriateness of dead time settings of single-photon detectors

8.8 Evaluation activity to test the temporal profile of the detection efficiency for single-photon detectors

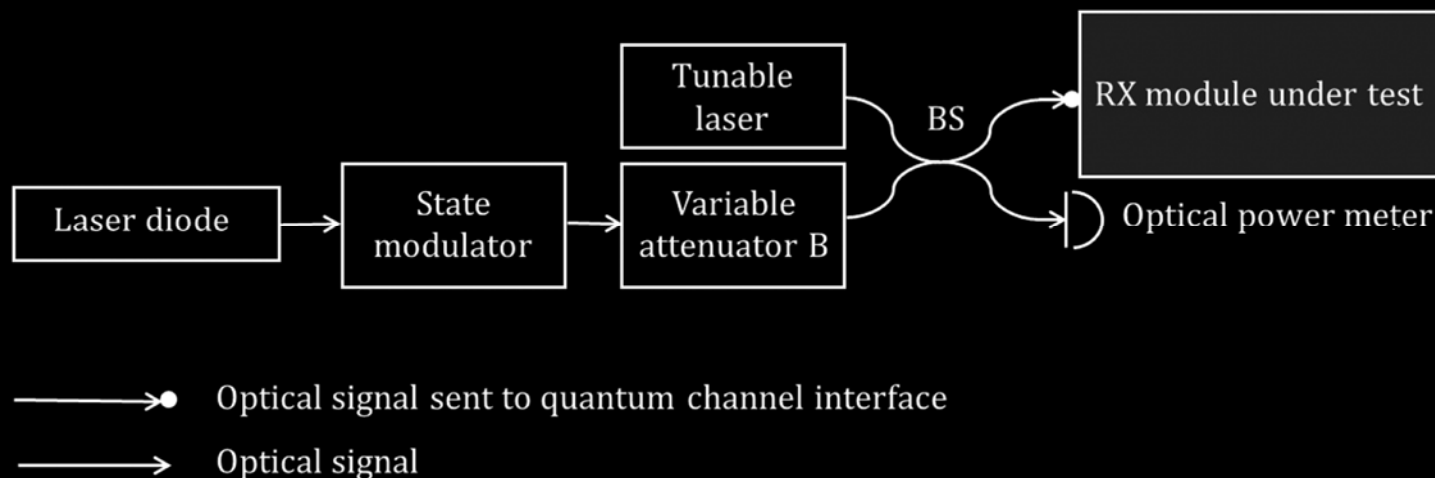
8.9 Evaluation activity to test the robustness of the RX module against laser injection

8.10 Evaluation activity to test the detection limits of homodyne detectors in the RX module

**8.11 Evaluation activity to test the appropriateness of double-click events handling**



# ISO/IEC 23837: Security requirements, test and evaluation methods for quantum key distribution



**Figure 11 — Schematic of the setup for testing the robustness of the RX module against bright light blinding**

## 8.6.2 Test procedure

### a) Main procedure

Step 1: Turn on the RX module under test, and let it work in the stage of raw data generation.

Step 2: Turn on the tunable laser at wavelength  $wavelength\_min$  and set it to work in the continuous-wave mode.

Step 3: Set the output power of the tunable laser to be  $power\_min$ . Gradually increase the output laser power until the laser power reaches  $power\_max$ . When increasing the laser power, observe the detection output of the RX module under test over an appropriate acquisition time for each power. For each time without detection output, run the trigger test in b). After all related output powers are tested, go to Step 4.

Step 4: Increase the wavelength by a step of size  $step\_wavelength$ , and repeat Step 3 until the wavelength reaches  $wavelength\_max$ . After all related wavelengths are tested, go to Step 5.

Step 5: Switch the working mode of the tunable laser to pulsed mode and let the tunable laser work at

~~COMINT~~

Declassified and approved for  
release by NSA on 12-10-2008  
pursuant to E.O. 12958, as  
amended. MDR 54498

~~VII~~ - 26 - X

**A HISTORY OF U.S. COMMUNICATIONS SECURITY (U)  
(The David G. Boak Lectures)**

**NATIONAL SECURITY AGENCY  
FORT GEORGE G. MEADE, MARYLAND 20755**

Revised July 1973

**TENTH LECTURE:**

**TEMPEST**

In 1962, an officer assigned to a very small intelligence detachment in Japan was performing the routine duty of inspecting the area around his little cryptocenter. As required he was examining a zone 200 ft. in radius to see if there was any "clandestine technical surveillance". Across the street, perhaps a hundred feet away, was a hospital controlled by the Japanese government. He sauntered past a kind of carport jutting out from one side of the building and, up under the eaves, noticed a peculiar thing—a carefully concealed dipole antenna, horizontally polarized, with wires leading through the solid cinderblock wall to which the carport abutted. He moseyed back to his headquarters, then quickly notified the counter-intelligence people and fired off a report of this "find" to Army Security Agency, who, in turn, notified NSA. He was directed to examine this antenna in detail and perhaps recover it, but although the CIC had attempted to keep the carport under surveillance that night, the antenna had mysteriously disappeared when they checked the next day. Up on the roof of the hospital was a forest of Yagi's, TV-antennas, all pointing towards Tokyo in the normal fashion, except *one*. That one was aimed right at the U.S. cryptocenter.

able impact on most of our cryptosystems, and because we view it as the most serious technical security problem we currently face in the COMSEC world.

First, let me state the general nature of the problem as briefly as I can, then I will attempt something of a chronology for you. In brief: any time a machine is used to process classified information electrically, the various switches, contacts, relays, and other components in that machine may emit radio frequency or acoustic energy. These emissions, like tiny radio broadcasts, may radiate through free space for considerable distances—a half mile or more in some cases. Or they may be induced on nearby conductors like signal lines, power lines, telephones lines, or water pipes and be conducted along those paths for some distance—and here we may be talking of a mile or more.

When these emissions can be intercepted and recorded, it is frequently possible to analyze them and recover the intelligence that was being processed by the source equipment. The phenomenon affects not only cipher machines but any information-processing equipment—teleprinters, duplicating equipment, intercomms, facsimile, computers—you name it. But it has special significance for cryptomachines because it may reveal not only the plain text of individual messages being processed, but also that carefully guarded information about the internal machine processes being governed by those precious keys of ours. Thus, conceivably, the machine could be radiating information which could lead to the reconstruction of our key lists—and that is absolutely the worst thing that can happen to us.

Now, let's go back to the beginning. During WW II, the backbone systems for Army and Navy secure TTY communications were one-time tapes and the primitive rotor key generator then called SIGTOT. Bell Telephone rented and sold the military a mixing device called a 131-B2 and this combined with tape or SIGTOT key with plain text to effect encryption. They had one of these mixers working in one of their laboratories and, quite by accident, noted that each time the machine stepped, a spike would appear on an oscilloscope in a distant part of the lab. They examined these spikes more carefully and found, to their real dismay, that they could read the plain text of the message being enciphered by the machine. Bell Telephone was kind enough to give us some of their records of those days, and the memoranda and reports of conferences that ensued after this discovery are fascinating. They had sold the equipment to the military with the assurance that it was secure, but it wasn't. The only thing they could do was to tell the Signal Corps about it, which they did. There they met the charter members of a club of skeptics (still flourishing!) which could not believe that these tiny pips could really be exploited under practical field conditions. They are alleged to have said something like: "Don't you realize there's a war on? We can't bring our cryptographic operations to a screeching halt based on a dubious and esoteric laboratory phenomenon. If this is really dangerous, prove it." The Bell engineers were placed in a building on Varick Street in New York. Across the street and about 80 feet away was Signal Corps' Varick Street cryptocenter. The Engineers recorded signals for about an hour. Three or four hours later, they produced about 75% of the plain text that was being processed—a fast performance, by the way, that has rarely been equalled. (Although, to get ahead of the story for a moment, in some circumstances now-a-days, either radiated or conducted signals can be picked up, amplified, and used to drive a tele-

# Today's digital

**Crypto module** - Bus - Memory - Software - Bus - Signal proc. - DAC - Amplifier

## vs. quantum

**Crypto module** — **Optical line**

## [vs. future quantum]

**Crypto module** — Quantum bus, computer, memory... —

# ~~Twin-field QKD protocol~~

M. Lucamarini, Z. L. Yuan, J. F. Dynes, A. J. Shields, *Nature* **557**, 400 (2018)

# **Twin-field *sending-or-not-sending* QKD protocol**

X.-B. Wang, Z.-W. Yu, X.-L. Hu, *Phys. Rev. A* **98**, 062323 (2018)

# **Current distance record ~1000 km in fiber**

Y. Liu *et al.*, *Phys. Rev. Lett.* **130**, 210801 (2023)

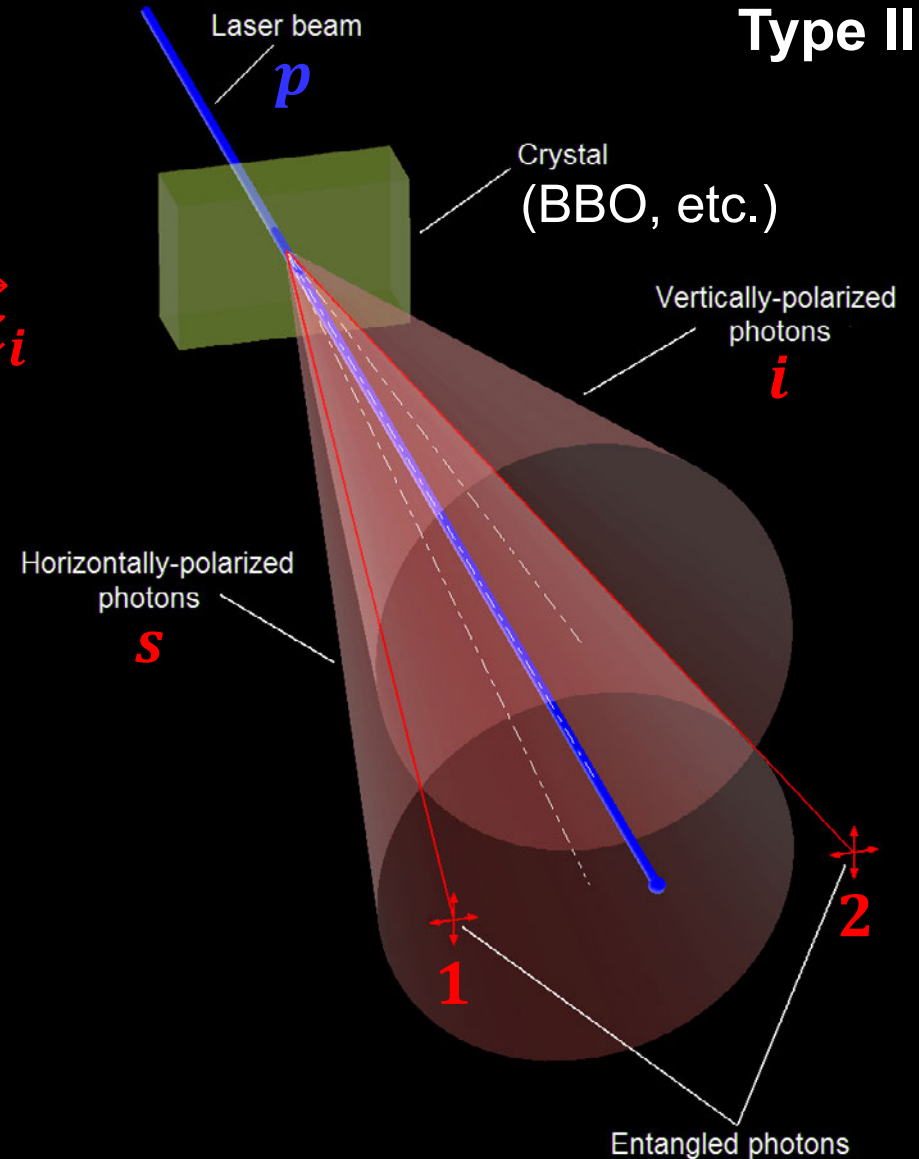
# Spontaneous parametric down-conversion

Type II

Energy conservation:  $\omega_p = \omega_s + \omega_i$

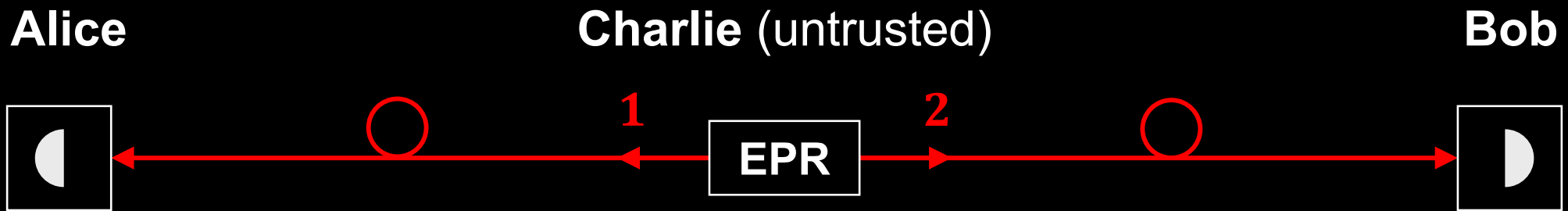
Momentum conservation:  $\vec{k}_p = \vec{k}_s + \vec{k}_i$

$$|\psi\rangle = (|H_1, V_2\rangle + |V_1, H_2\rangle) / \sqrt{2}$$
$$= (|D_1, A_2\rangle + |A_1, D_2\rangle) / \sqrt{2}$$





# Entangled-pair QKD



$$\begin{aligned} |\psi\rangle &= (|H_1, V_2\rangle + |V_1, H_2\rangle) / \sqrt{2} \\ &= (|D_1, A_2\rangle + |A_1, D_2\rangle) / \sqrt{2} \end{aligned}$$

# Entangled-pair QKD over 1120 km



# Quantum repeater network

1. Entanglement swapping
2. Quantum memory
3. Error correction (entanglement distillation)