

Full experimental verifications towards practical deployment of measurement-device-independent quantum key distribution

Yan-Lin Tang,^{1,2} Hua-Lei Yin,^{1,2} Si-Jing Chen,³ Yang Liu,^{1,2} Wei-Jun Zhang,³
Xiao Jiang,^{1,2} Lu Zhang,³ Jian Wang,^{1,2} Li-Xing You,³ Jian-Yu Guan,^{1,2}
Dong-Xu Yang,^{1,2} Zhen Wang,³ Hao Liang,^{1,2} Zhen Zhang,^{4,2} Nan Zhou,^{1,2}
Xiongfeng Ma,^{4,2} Teng-Yun Chen,^{1,2} **Qiang Zhang**,^{1,2} and **Jian-Wei Pan**^{1,2}

¹Department of Modern Physics and National Laboratory for Physical Sciences at Microscale, Shanghai Branch, University of Science and Technology of China, Hefei, Anhui 230026, China

²CAS Center for Excellence and Synergetic Innovation Center in Quantum Information and Quantum Physics, Shanghai Branch, University of Science and Technology of China, Hefei, Anhui 230026, China

³State Key Laboratory of Functional Materials for Informatics, Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, Shanghai 200050, China

⁴Center for Quantum Information, Institute for Interdisciplinary Information Sciences, Tsinghua University, Beijing, 100084, China

yltang@mail.ustc.edu.cn

University of Science & Technology of China



Outline



1

- **Previous experimental MDIQKD**

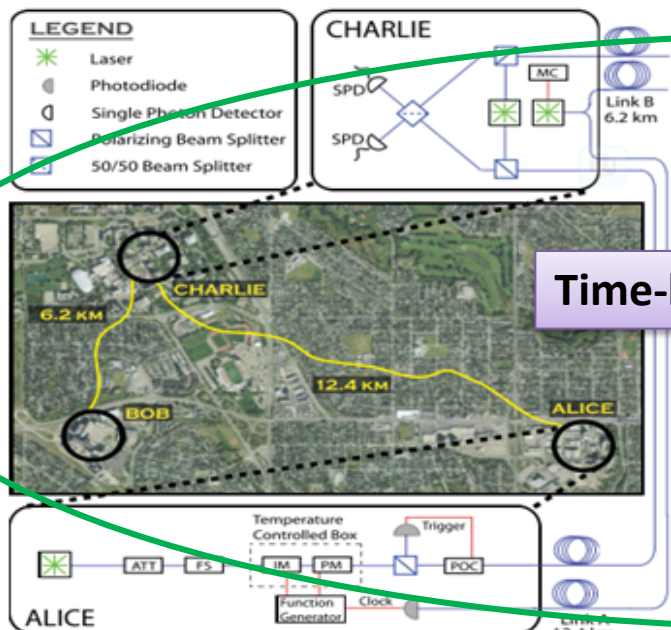
2

- **Long distance MDIQKD over 200 km spooled fiber**
- **Field test of MDIQKD over 30 km deployed fiber**

3

- **Conclusion and discussion**

1. Previous MDIQKD demonstrations



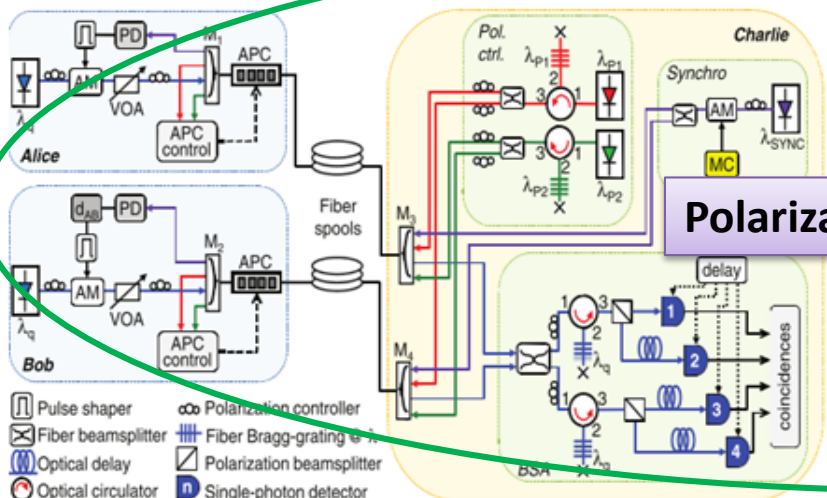
Time-bin phase encoding



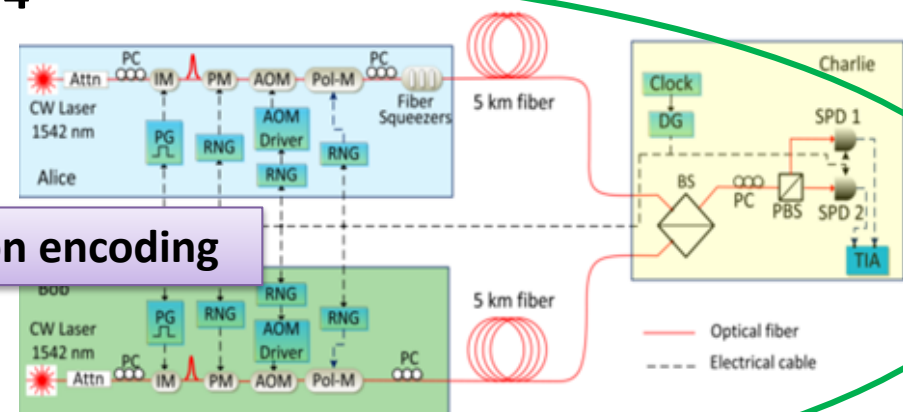
Y. Liu, et al., "Experimental measurement-device-independent quantum key distribution", Phys. Rev. Lett. 111, 130502 (2013).

1 2
3 4

A. Rubenok, et al., "Real-world two-photon interference and proof-of-principle quantum key distribution immune to detector attacks", Phys. Rev. Lett. 111, 130501 (2013).



Polarization encoding



Z. Tang, et al., "Experimental demonstration of polarization encoding measurement-device-independent quantum key distribution", Phys. Rev. Lett. 112, 190503 (2014).

J. T. Ferreira da Silva, et al., "Proof-of-principle demonstration of measurement-device-independent quantum key distribution using polarization qubits", Phys. Rev. A 88, 052303 (2013).

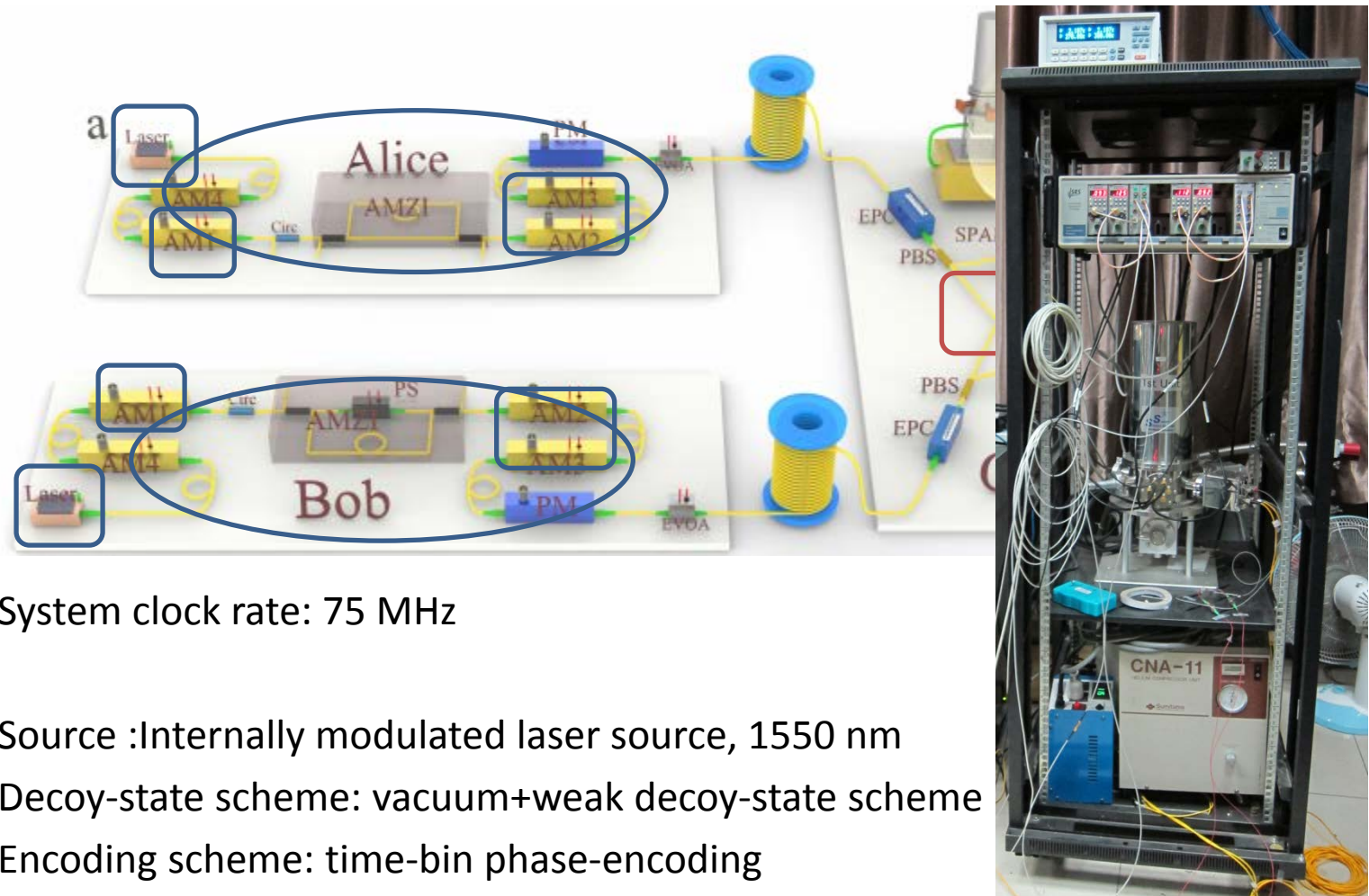
1. Previous MDIQKD demonstrations



	1	2	3	4
	Tittel's group	Pan's group	Weid's group	Lo's group
Encoding method	Time-bin phase	Time-bin phase	Polarization	Polarization
Arrangement	Field test	In lab	In lab	In lab
Maximum distance	18.6 km	50 km	17 km	10 km
System Frequency	2 Mhz	1 MHz	1 MHz	500 KHz
Total Time	Not reported	59.5 hours	Not reported	94 hours
Key rate	Not reported	0.12 bps	Not reported	0.0047 bps

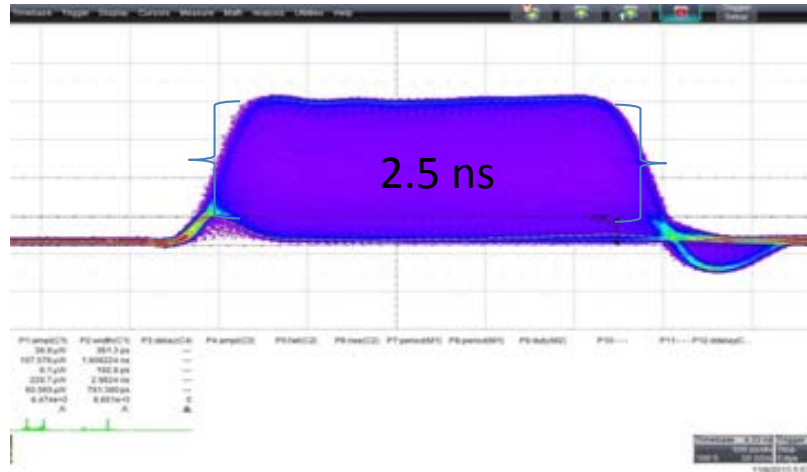
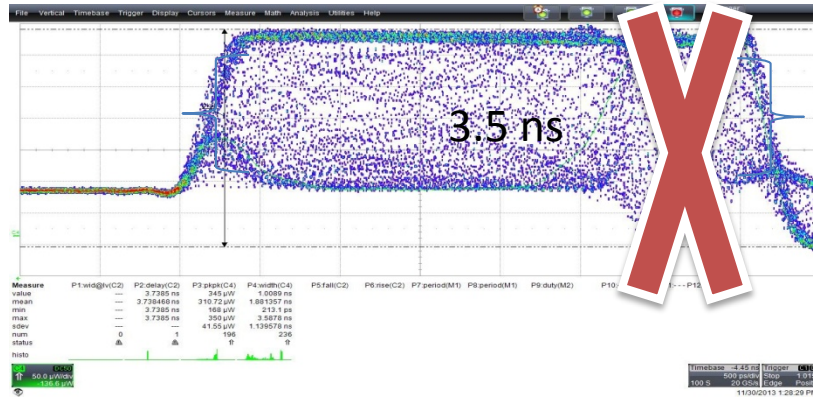
Goal:
long-distance, high-key-rate, practical MDIQKD system
& field test

2. 200 km MDIQKD

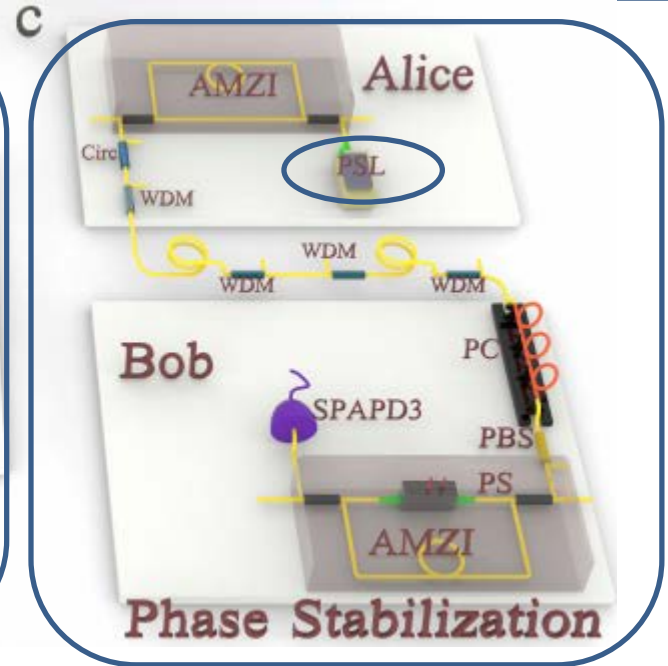
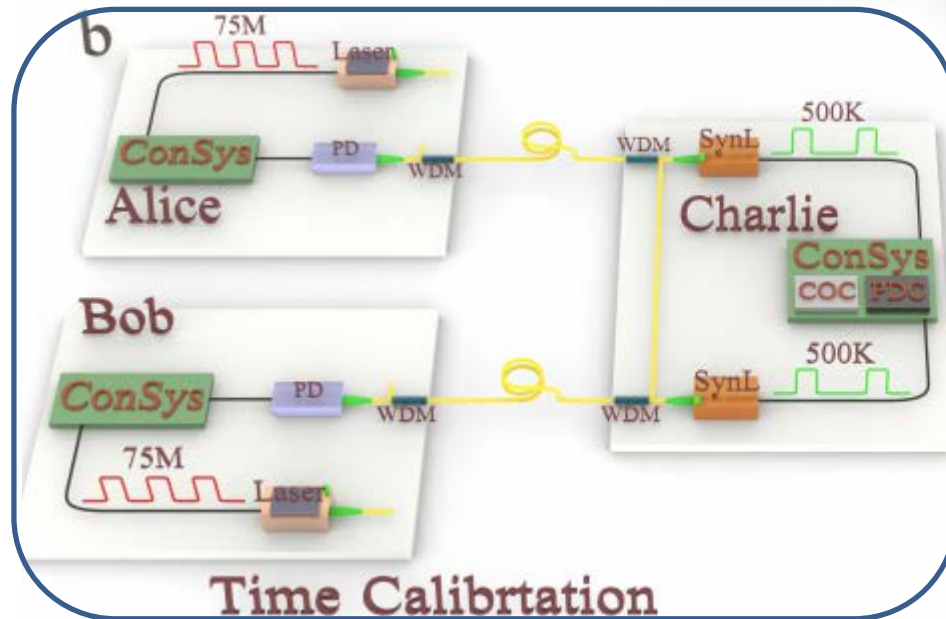


- System clock rate: 75 MHz
- Source :Internally modulated laser source, 1550 nm
- Decoy-state scheme: vacuum+weak decoy-state scheme
- Encoding scheme: time-bin phase-encoding
- Detector: superconducting nanowire single photon detector (SNSPD), >40% @ 10Hz

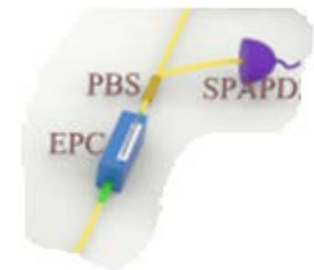
2. 200 km MDIQKD



2. 200 km MDIQKD



- **Automatic feedback systems:**
 - Time calibration system
(Synchronization laser, SNSPD, programmable delay chip)
 - Spectrum calibration system
(optical spectrum analyzer, temperature controlled circuit)
 - Polarization stabilization system
(EPC, PBS, APD)
 - Phase stabilization system
(phase-stabilization laser (1550 nm), APD, PS)



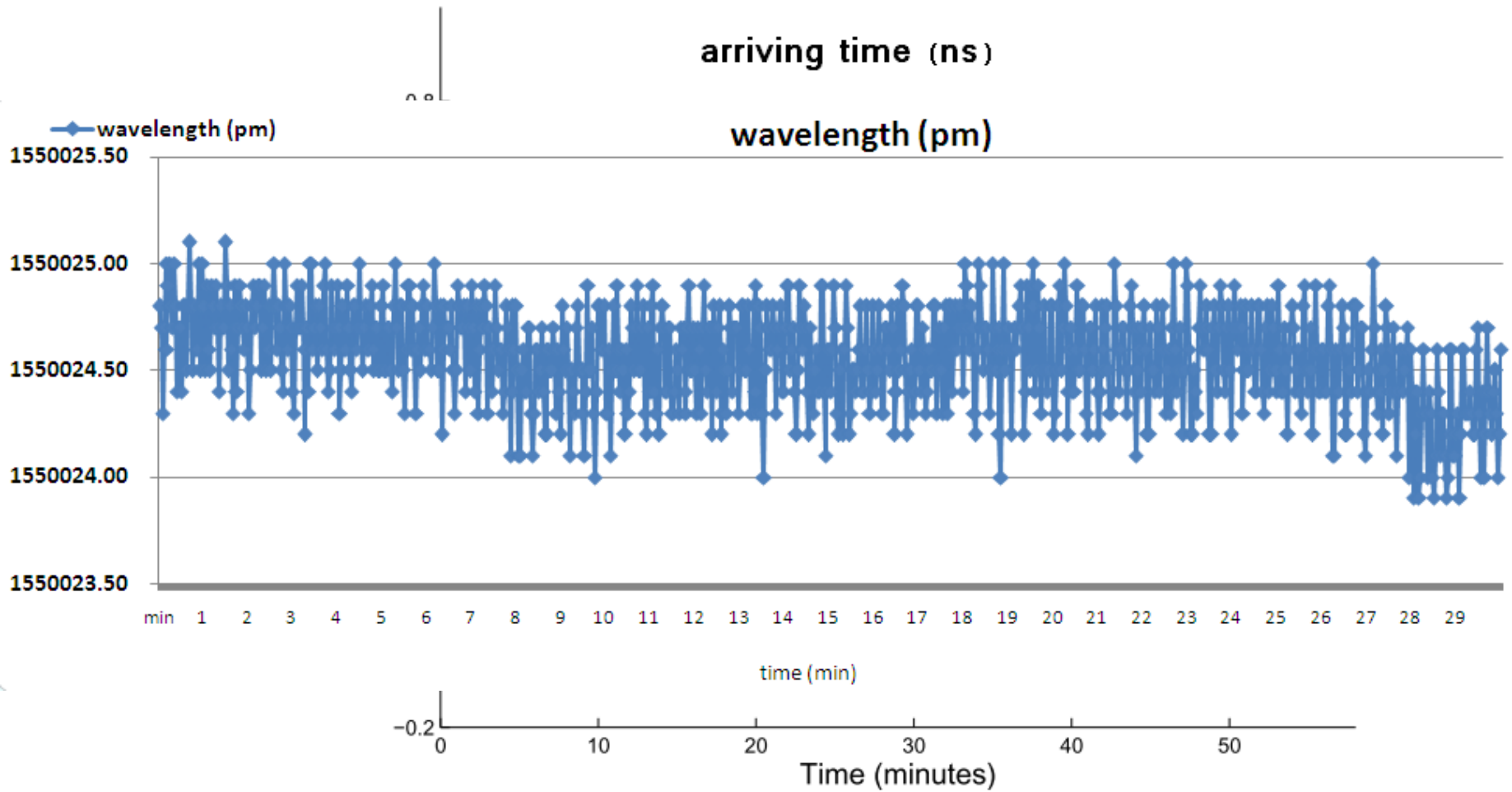
2. 200 km MDIQKD



The image displays a complex software interface for controlling a quantum optics experiment, specifically a 200 km MDIQKD setup. The interface is divided into several main sections:

- Alice - 等待连接 (Waiting Connection):** This panel on the top left contains controls for opening/closing USB ports, setting DAC values, and timing parameters. It includes a '常用命令' (Common Commands) section with buttons for '取消SpecialRnd' and '取消Special位置'. A '按随机数发送' (Send by random number) section allows for sending data to a specific channel (0004 080C 0004 080C).
- Bob - 等待连接 (Waiting Connection):** This panel on the top right is similar to Alice's, but with different channel addresses (0004 080C 0004 080C) and timing settings.
- Charlie - 等待连接 (Waiting Connection):** This panel at the bottom center provides controls for the central system, including '打开USB' (Open USB), '初始化模式' (Initialization mode), and '完整模式' (Full mode). It features a '分析扫描选数据' (Analyze scan selected data) section with file selection and analysis options.
- Control Panels:** Various smaller panels are overlaid, such as 'EVOA设置' (EVOA settings), '电可调整器' (Electro-optic modulator), and '高压板设置' (High voltage board settings), each with specific parameters and control buttons.
- Status and Monitoring:** The bottom right area includes '可调整器' (Adjustable modulator) and '高压板设置' (High voltage board settings) with 'OK(Save)' and 'Cancel(NoSave)' buttons.

3. Field test of MDIQKD



2. 200 km MDIQKD

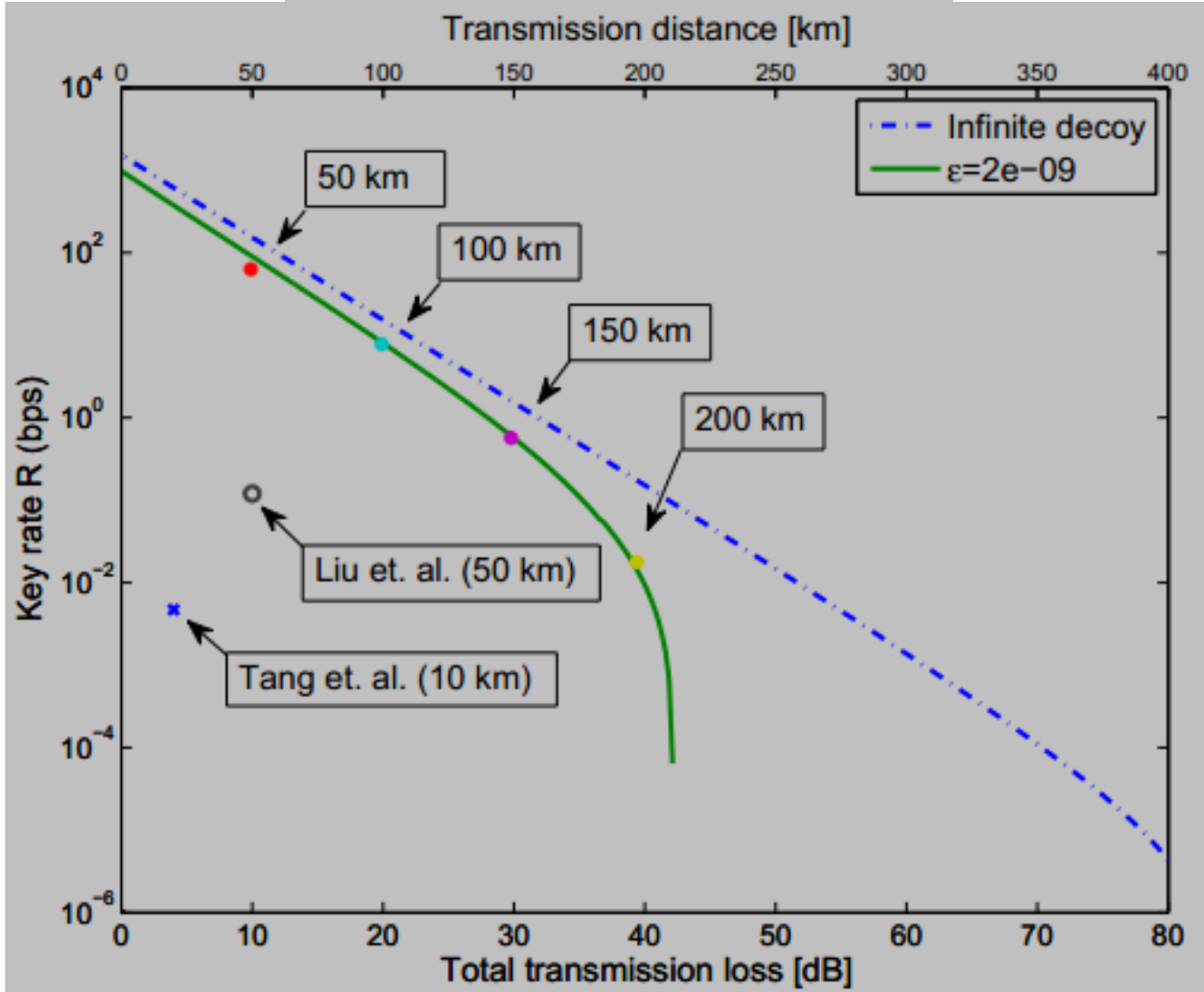


timing calibration precision	~20 ps
Time shift	< 200 ps /15 min
Spectrum calibration precision	0.5 pm
Spectrum shift	<1 pm / 15 min
Polarization shift	<3% (real time)
Phase shift	<1% (real time)

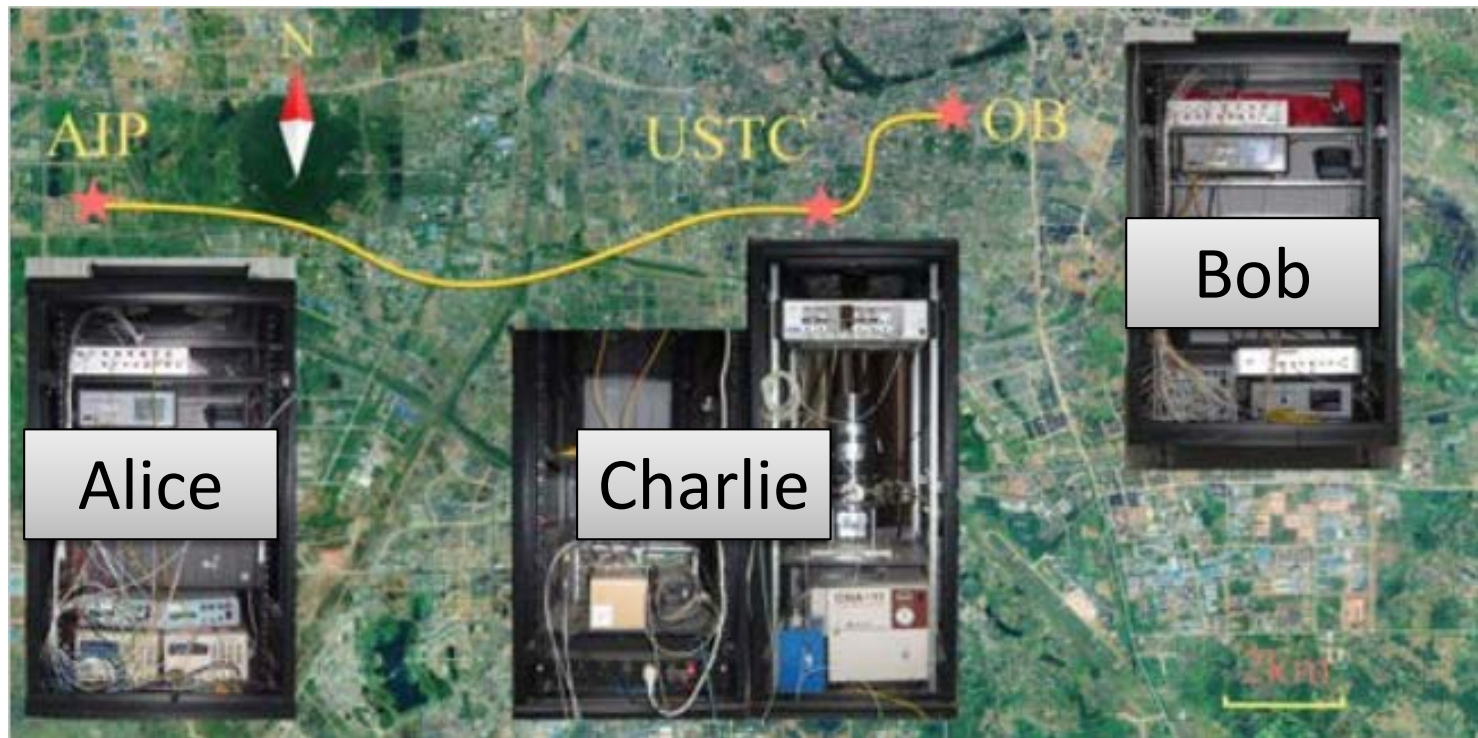
2. 200 km MDIQKD



$$R \geq Q_{11}^{\mu\mu} [1 - H(e_{11}^{\mu\mu})] - Q^{\mu\mu} f H(E^{\mu\mu})$$



2. Field test of MDIQKD



Alice-Charlie link: 25 km (7.9 dB)

Bob-Charlie link: 5 km (1.3 dB)

Total distance: 30 km (9.2 dB)

2. Field test of MDIQKD



TABLE I

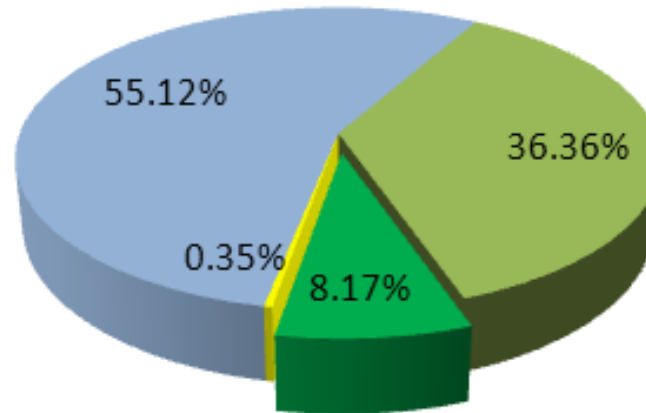
LIST OF THE TOTAL COINCIDENCE EVENT COUNTS OF BELL STATE $|\psi^-\rangle$ IN THE 30 KM FIELD TEST FOR 18.2 HOURS.

	μ_a/μ_b	0	ν	μ
$M_z^{\mu_a\mu_b}$	0	0.00×10^0	1.93×10^2	2.64×10^3
	ν	3.60×10^1	8.12×10^5	3.36×10^6
	μ	1.46×10^2	3.49×10^6	1.35×10^7
$M_x^{\mu_a\mu_b}$	0	0.00×10^0	8.58×10^5	2.03×10^7
	ν	4.30×10^4	2.72×10^6	4.42×10^7
	μ	9.94×10^5	6.55×10^6	4.48×10^7

TABLE II

LIST OF THE QBERS IN THE 30 KM FIELD TEST FOR 18.2 HOURS.

	μ_a/μ_b	0	ν	μ
$E_z^{\mu_a\mu_b}$	0	0.00%	52.33%	49.26%
	ν	52.78%	0.04%	0.10%
	μ	47.26%	0.01%	0.02%
$E_x^{\mu_a\mu_b}$	0	0.00%	51.49%	49.90%
	ν	52.10%	38.12%	46.85%
	μ	49.92%	27.72%	36.82%



■ EC Component
 ■ Multi-Photon Component
 ■ Phase-Error Component
 ■ Final Key Component

Secure key rate: 16.9 bps

3. Conclusion



- Summary:
 - In lab: 50 km \rightarrow 200 km
 - Field test: 30 km, robustness
 - Secure key rate: 16.9 bps (field test), 2~3 orders higher than previous experiments
- Outlook:
 - increase the system clock : (1 ~10) GHz
 - Higher detection efficiency and lower dark count rate
 - Optimization of Decoy-state parameters and basis choice

(Arxiv: 1407.8012 and Arxiv: 1408.2330)

About us: (the following people contributes to this work)

University of Science and Technology of China:

Yan-Lin Tang, Hua-Lei Yin, Yang Liu, Xiao Jiang, Jian Wang,
Jian-Yu Guan, Dong-Xu Yang, Hao Liang, Nan Zhou, Teng-Yun
Chen, **Qiang Zhang, Jian-Wei Pan**

Shanghai Institute

of Microsystem and Information Technology, Chinese Academy of Sciences

Si-Jing Chen, Wei-Jun Zhang, Lu Zhang, Li-Xing You, Zhen Wang

Tsinghua University:

Xiongfeng Ma, Zhen Zhang



Thank you!