Joint SECANT Meeting and ONR Program Review

July 21-23, 2014 | Phillips Technology Institute Collaboration Center

Kirtland Air Force Base | Albuquerque, NM

SAND2014-17751PE

Monday, July 21, 2014

(Light refreshments and continental breakfast available)

8:30-8:35	Welcome—Dan Barton, Sandia National Laboratories
8:35-8:50	Opening Remarks—Duane Dimos, Sandia National Laboratories
8:50-9:00	Purpose and Charge for the Meeting—Ryan Camacho, Sandia National Laboratories
9:00-9:30	SECANT Overview—Ryan Camacho, Sandia National Laboratories
9:30-10:10	Technical Talk—Paul Davids, Sandia National Laboratories
10:10-10:50	Technical Talk— Matt Shaw, JPL and Jeff Shainline, NIST
10:50-11:00	Break
11:00-11:40	Technical Talk— Dirk Englund, Massachusetts Institute of Technology
11:40-12:20	Maturing continuous variable QKD— Mohan Sarovar, Sandia National Laboratories
12:20-1:30	Lunch
1:30-2:10	Technical Talk— Art Fischer, Sandia National Laboratories
2:10-2:50	Technical Talk—Edo Waks, University of Maryland
2:50-3:30	Technical Talk— Ray Newell, Los Alamos National Laboratory
3:30-4:10	Technical Talk— Junji Urayama, Sandia National Laboratories
4:10-5:00	Discussion Question:—Ryan Camacho, Sandia National Laboratories What are the hardest problems to solve for quantum communication?
5:00-5:15	Closing Remarks—Ryan Camacho, Sandia National Laboratories
5:15	Adjourn – Day One

Discussion Question

What are the most important challenges for quantum communications? How should we rank the following potential bottlenecks? What are we missing?

1. Security questions (i.e. can quantum *really* be more secure?)
2. Size, weight, and power (SWAP) scalability of current hardware
3. Fundamental distance/loss constraints
4. Cost to implement
5. Existing infrastructure incompatibilities
6. Misunderstanding of potential vulnerabilities in existing communications systems (by classical and/or quantum cryptographers, policy makers, etc.)
7. Absence of immediate enthusiastic adopters (e.g. no pain or killer opportunities perceived by decision makers)

What is the smallest subset of these challenges that, if solved, would lead to an explosion in quantum communications interest?

SECANT QKD Grand Challenge

Sandia Enabled Communications and Authentication Network using Quantum Key Distribution

SECANT QKD Team
Dan Barton (PM)
Ryan Camacho (PI)

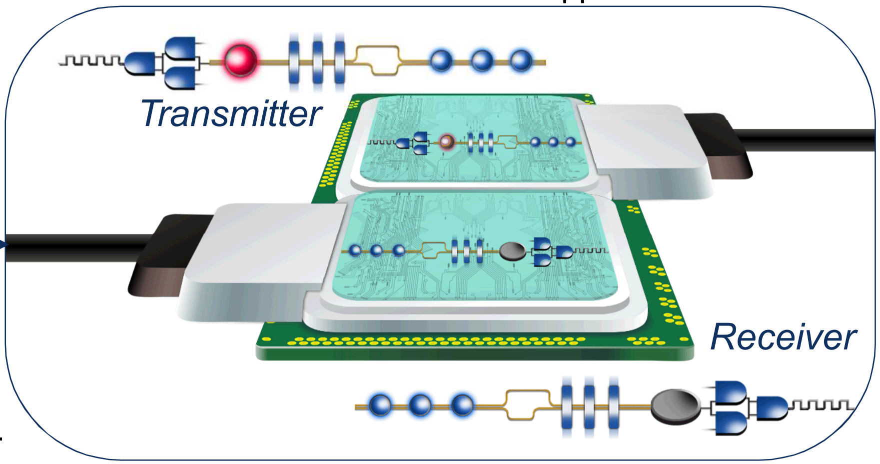
SECANT QKD
A Grand Challenge in Quantum Communications

Goals

1. Construct chip-scale, handheld **quantum transceivers** that can implement DV, CV, free-space, and fiber based QKD.
2. Demonstrate hybrid QKD network with chip-scale transceiver nodes.

Potential Impact

1. Quantum-based key generation for hybrid networks of mobile devices without central hub.
2. First step towards micro-fabricated low cost QKD for ground-to-plane, plane-to-plane, metro, satellite etc. applications.
3. Toolbox for other applications in photonic QIP.



Challenges

1. Develop robust CMOS compatible room temp single-photon detectors.
2. Develop integrated quantum sources.
3. Low-loss quantum signal processing.
4. Combine all components onto one integrated chip.

Capabilities

1. World class teams in integrated photonics, quantum theory, and systems.
2. MESA/CINT microfabrication facilities.

3 yr program, 10 months in...
(FY 2014 – FY 2016)

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The Current State of Quantum Communications Hardware

- Bulk Optics Based (>10g / component)
- Expensive (> $50k per system)
- Slow or Short distance (Mbt/s or 10's of km)
- Secure?

This program

Quantum Communications

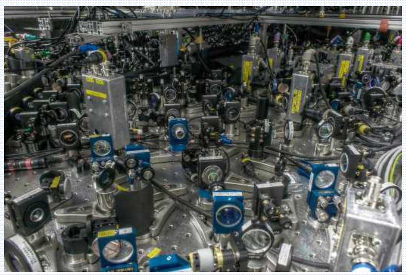
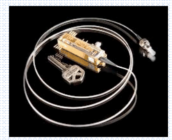
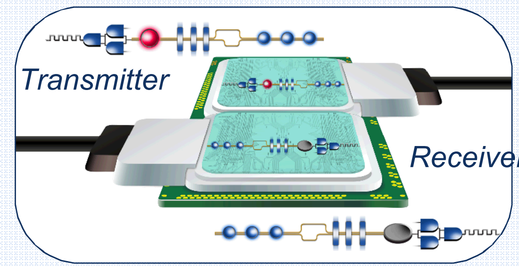


Photo: Toshiba


LANL

ID Quantique



Electronic Circuits

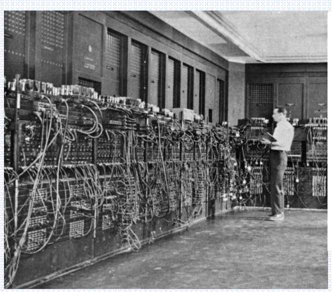


Photo: U.S Army

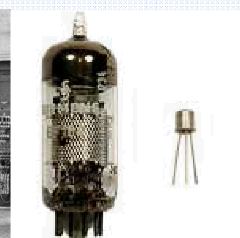



Photo: Texas Instruments

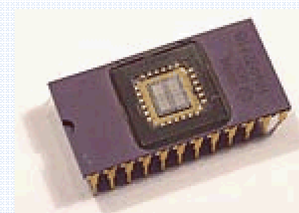
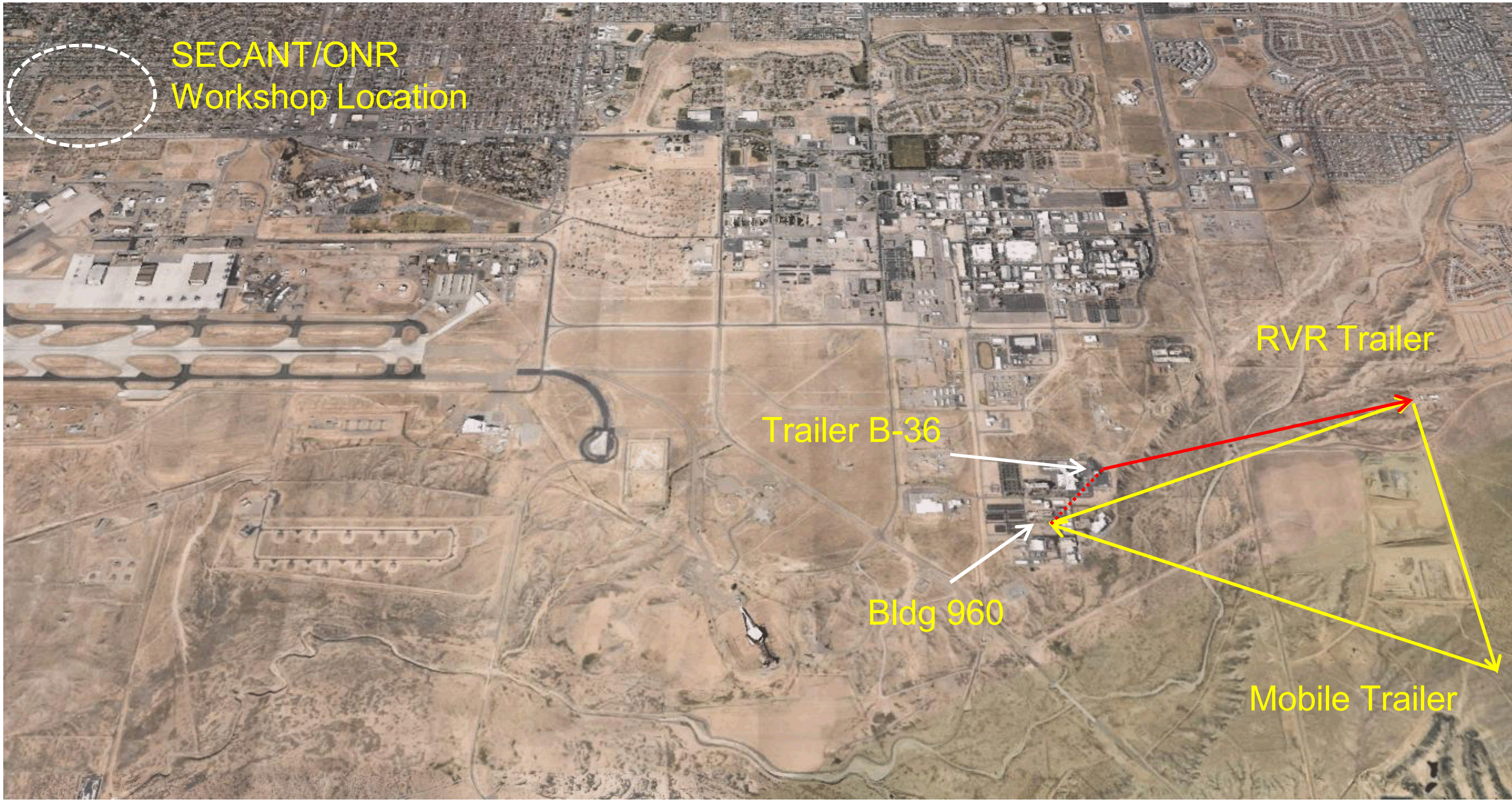


Photo: nobelprize.org

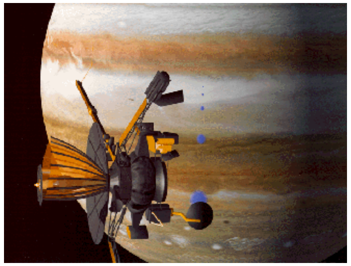
Proposed Quantum Links



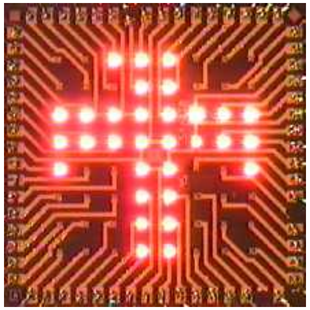
Sandia's History of Microfabrication

Laminar Flow Clean Room

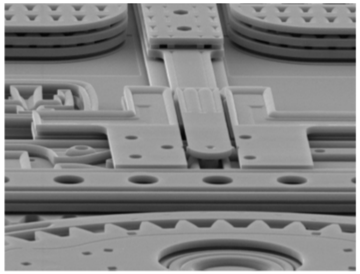
Design/Build Galileo ICs



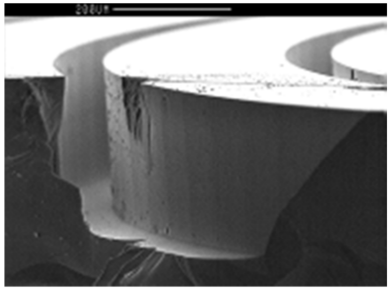
High Efficiency VCSEL

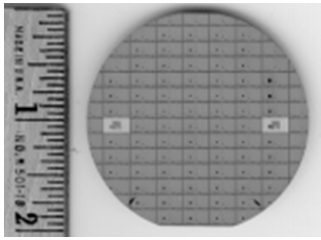


5-Level Surface Micromachining

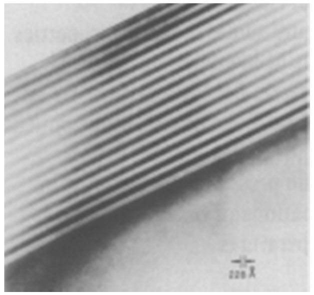


Chem Lab on a Chip

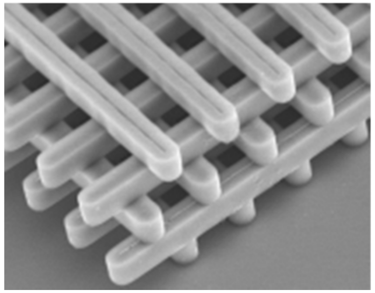




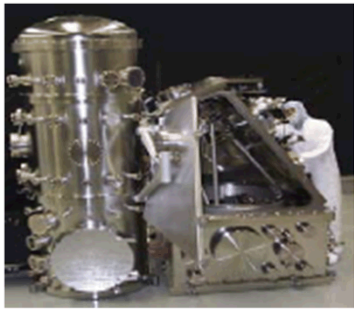
Radiation Hardened CMOS



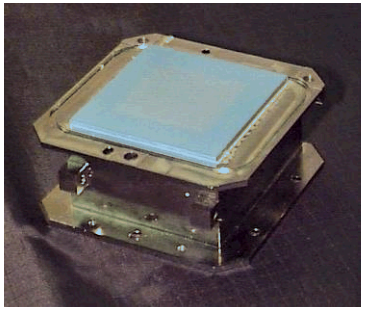
Strained-layer Superlattices



Photonic Lattice



Extreme Ultra Violet Lithography

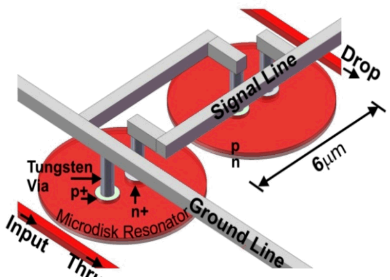


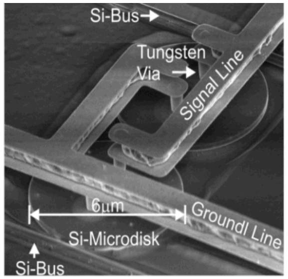
3-D Microsystems Integration

1960s → **2000s**

Silicon Photonics At Sandia

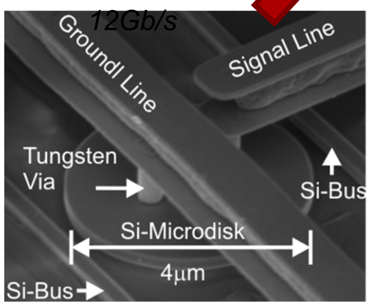
Free-carrier Effect (high-speed)

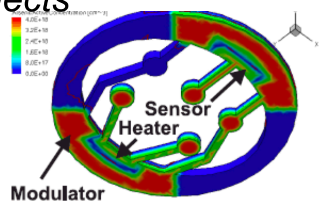


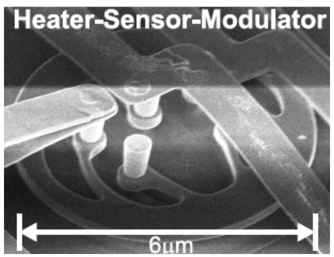


Fast Reconfigurable Interconnects

3.2fJ/bit at 12Gb/s





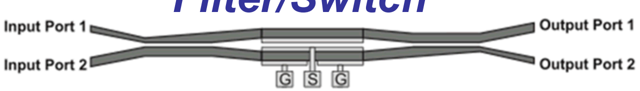


Resonant Optical Modulator/Filter

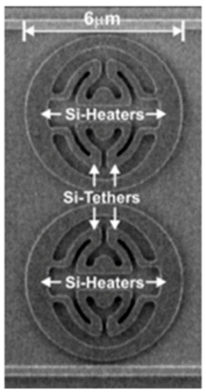
Thermally stabilized modulator

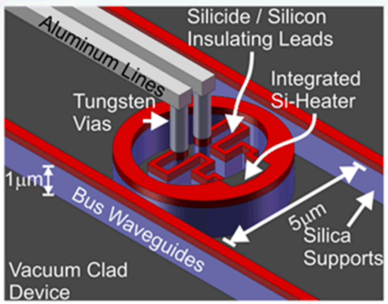
Broadband Mach-Zehnder Filter/Switch

< 1V-cm at 10 Gb/s

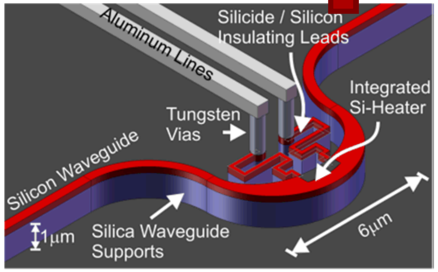


Thermal Optic Effect (wide-band)

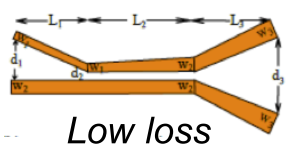




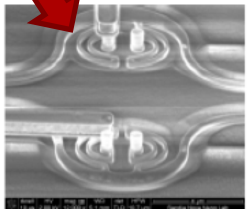
Tunable Resonant Filter



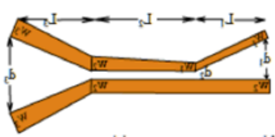
Thermo-optic Phase Shifter



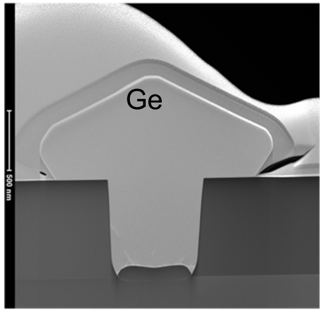
Low loss optical coupler



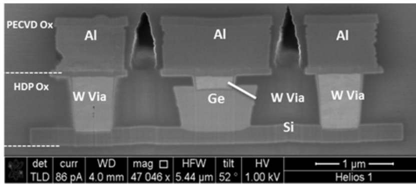
Switch Arrays



High-speed Ge Detector

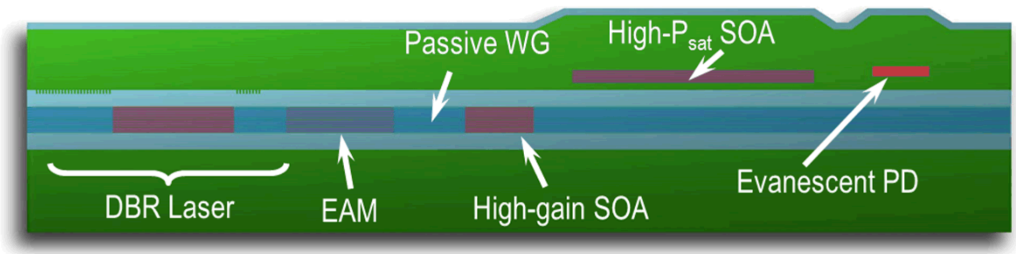


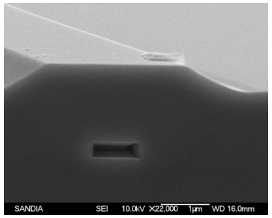
Si Photonics-CMOS Process

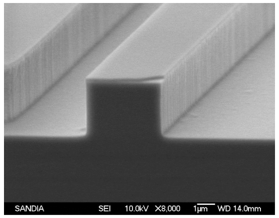


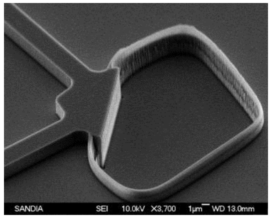
InP Photonic Integrated Circuits at Sandia

- Building Blocks: Lasers, EAMs, passive waveguides, high-gain SOAs, high-saturation power SOAs, evanescently-coupled photodetectors, quantum well photodetectors

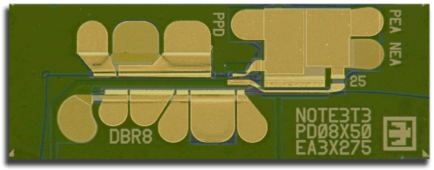


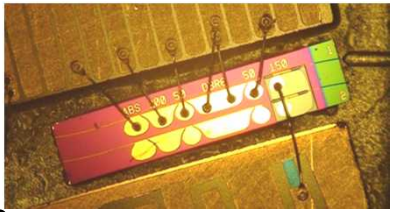

BH waveguides

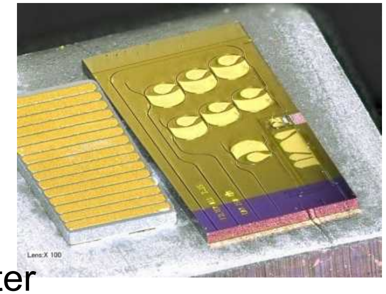

Ridge waveguides

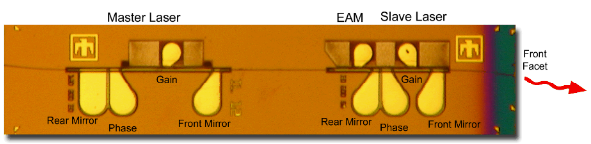

Turning mirrors

- Highly Functional PICS: optical RF channelizers, high-Q active filters, transmitters, receivers, optical logic gates, multi-section lasers


40 GHz Optical NOT Gate

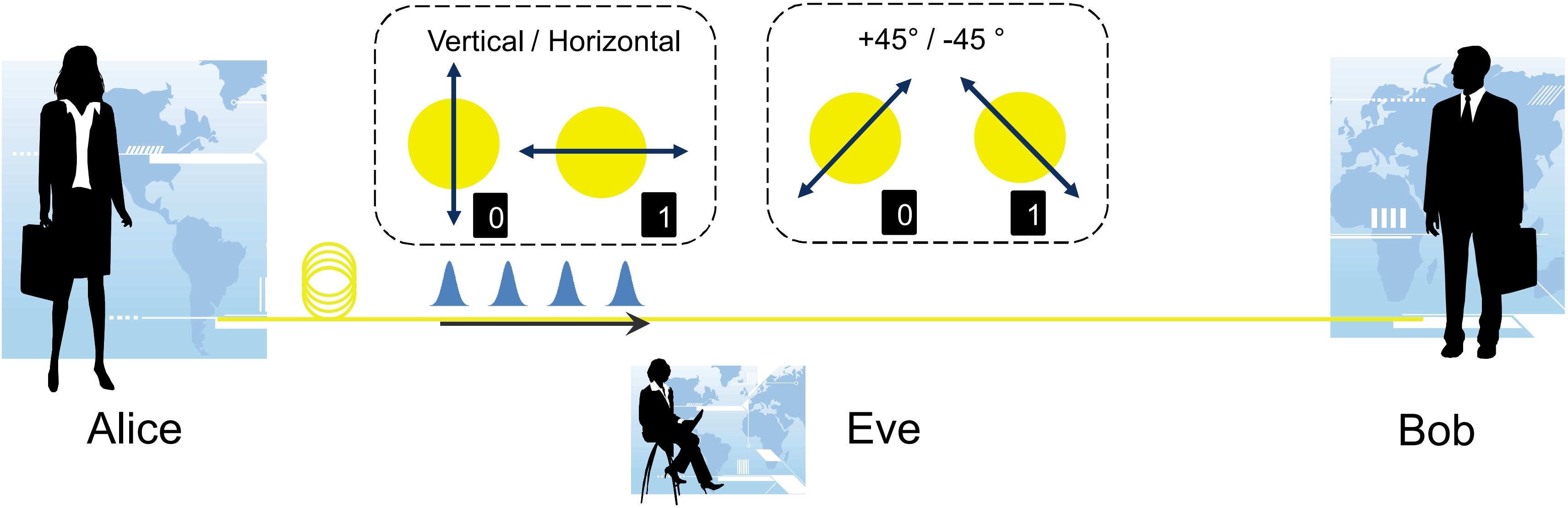

25 GHz Optical Transmitter


RF Optical Channelizer



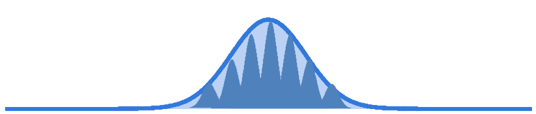
Coupled-cavity Laser with EAM

Choices: CV/DV, Free Space/Fiber



Discrete Variable

Continuous Variable



IDQ FROM VISION TO TECHNOLOGY
TOSHIBA Leading Innovation
MagiQ
NTT
AIT AUSTRIAN INSTITUTE OF TECHNOLOGY
quintessencelabs
SeQureNet A Quantum Key to Network Security
QKD Corp.

QKD unifies the program as a minimum viable system, but…

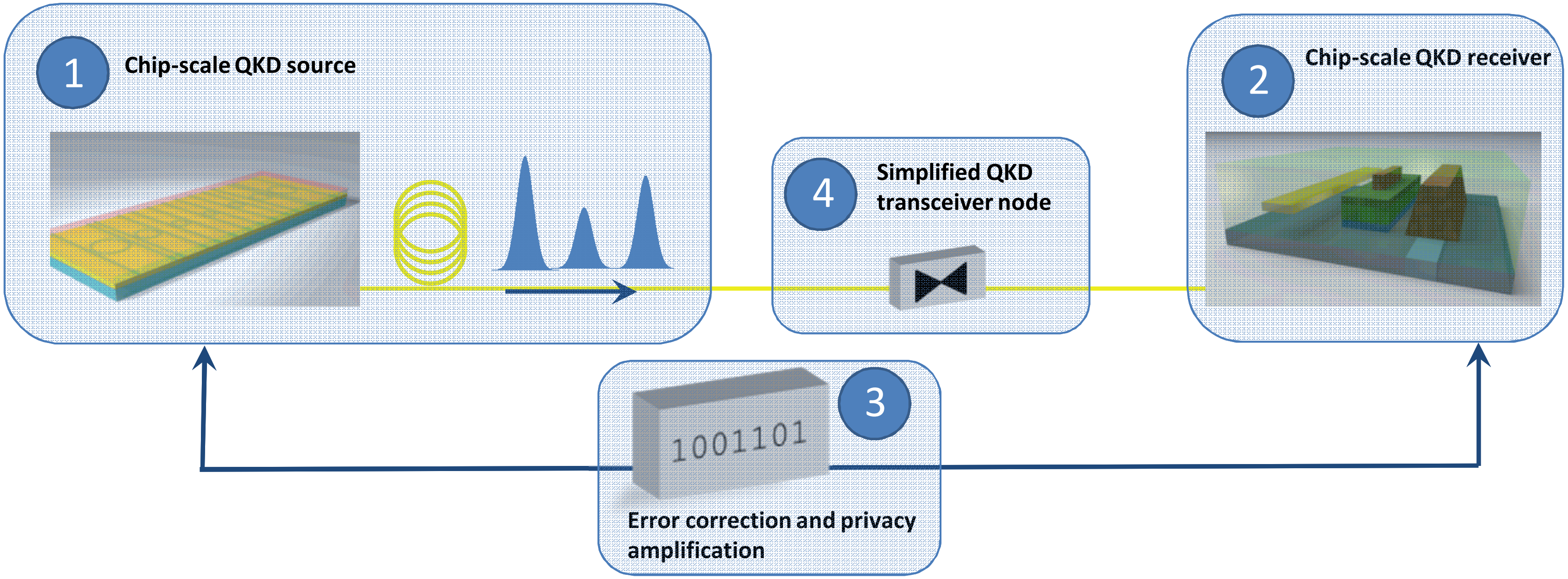
Sandia National Laboratories

With the components we are developing, we should also be able to implement on chip:

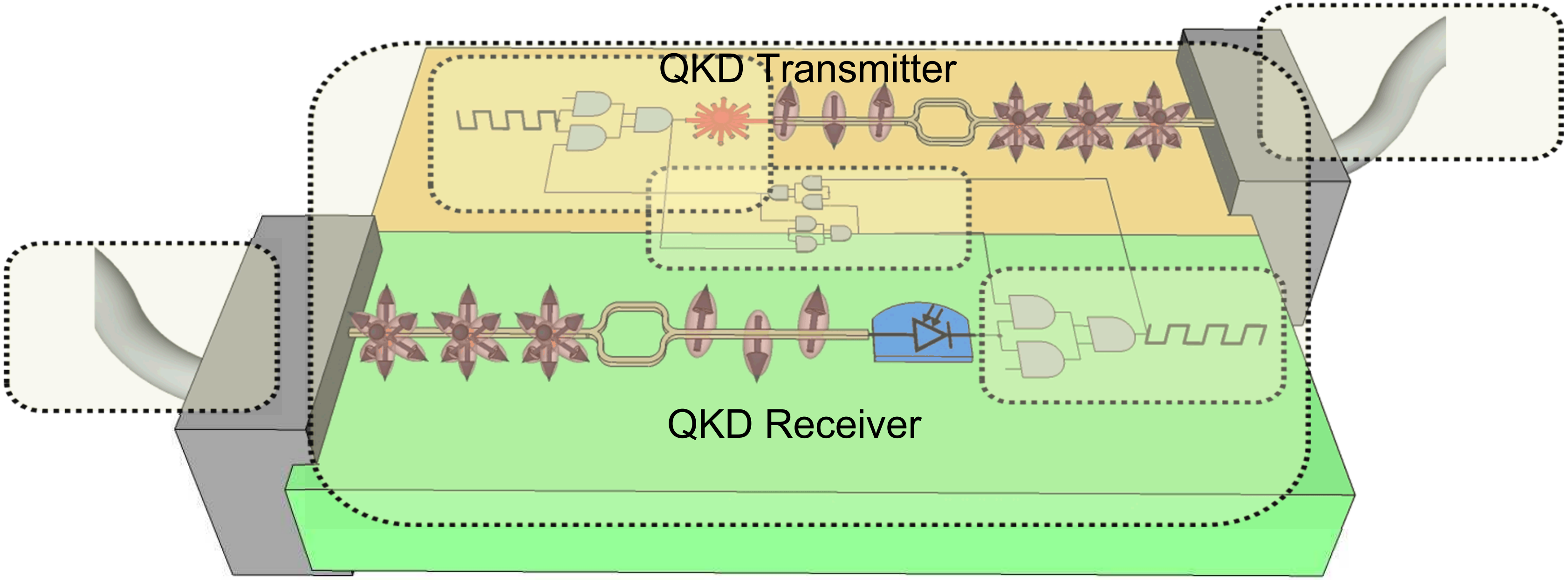
1. *Quantum Photonics Primitives* (sources, detectors, nonlinearities, memories, etc.)
2. *Quantum Photonic Measurement* (quantum radar, green machine, state discrimination, imaging, quantum metrology)
3. *Logic Operations / Computing Primitives* (logic gates, compiled Shor's algorithm, coherent quantum feedback)
4. *Quantum Photonic Simulations* (quantum walks, boson sampling, chemistry, condensed matter, anderson localization, relativistic particle physics)
5. *Foundations/Tests of Quantum Mechanics* (Examples here…)
6. *Communications Primitives* (entanglement distribution, teleportation, QRNG's, synchronization etc.)
7. Other Communications tasks (bit commitment, distributed measurement, etc.)

Collaborations underway for non-QKD applications…

What is needed to make a complete chip-scale QKD system on a chip?



The Vision



Five Program Thrusts:

1. Network QKD
2. Chipscale Integration / Single Photon Detectors
3. Quantum Transmission Link
4. Continuous Variable Sources
5. Single Photon Sources

The Team

PM: **Dan Barton**
PI: **Ryan Camacho**

Consultant: **Mark Huey**

Business Development: **Alyssa Christy**

Chipscale Integration / Single Photon Detectors: **Paul Davids**

Network QKD: **Norbert Lütkenhaus**

Quantum Transmission Link: **Junji Urayama**

Continuous Variable Sources: **Mohan Sarovar**

Single Photon Sources: **Art Fischer**

Deployment Analysis:
Saikat Guha