NTNU | Norwegian University of Science and Technology

Quantum-Safe Electronic Voting: Status and Challenges

Tjerand Silde @ Trustworthy Evidence-Based Elections

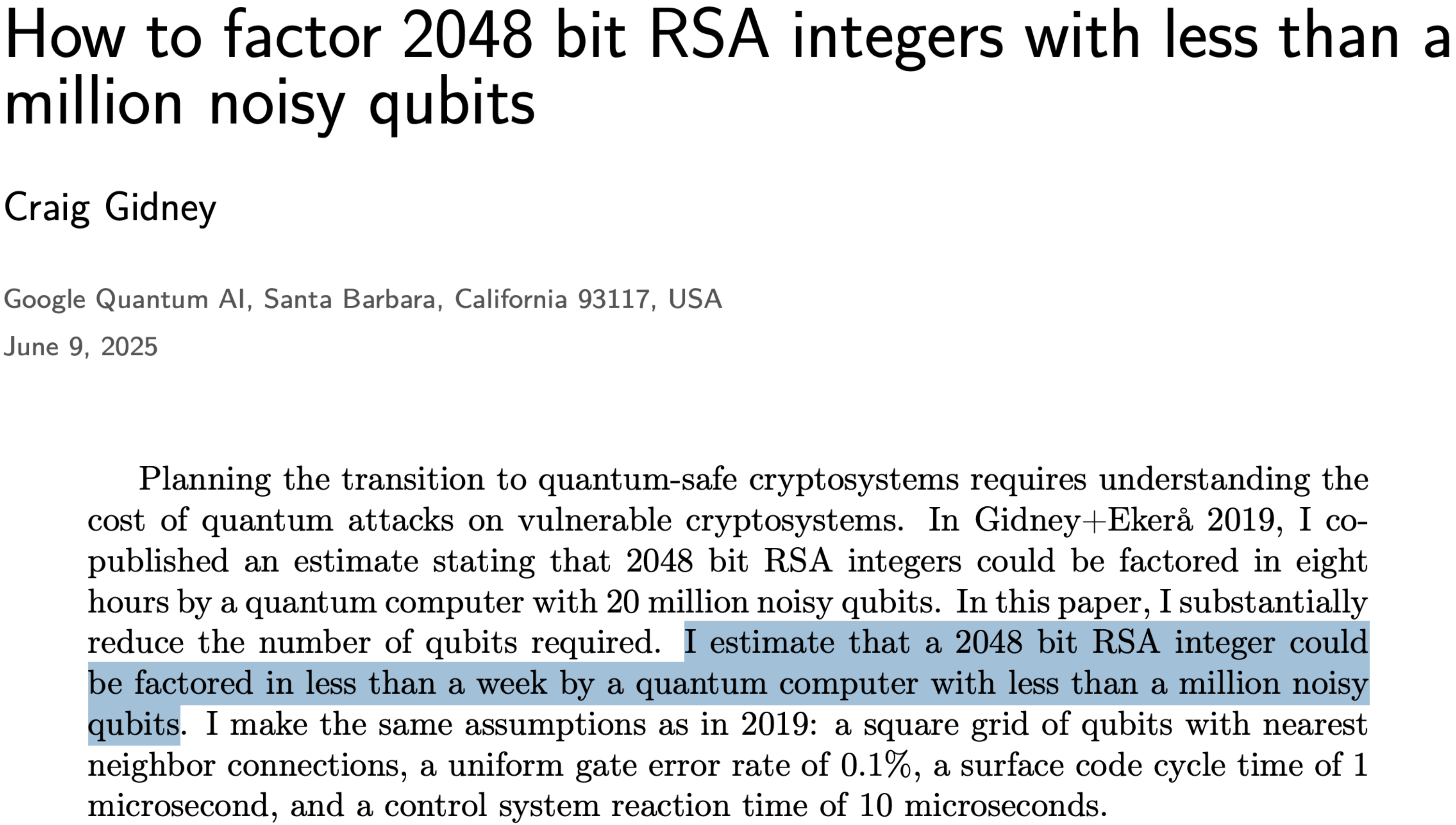
The Quantum Threat

Quantum computers are not better; they are different

They will generally be worse, but do specific things better

In theory, they can break public key encryption and digital signatures based on factoring and discrete log assumptions

There are many recent developments in quantum computing



How to factor 2048 bit RSA integers with less than a million noisy qubits

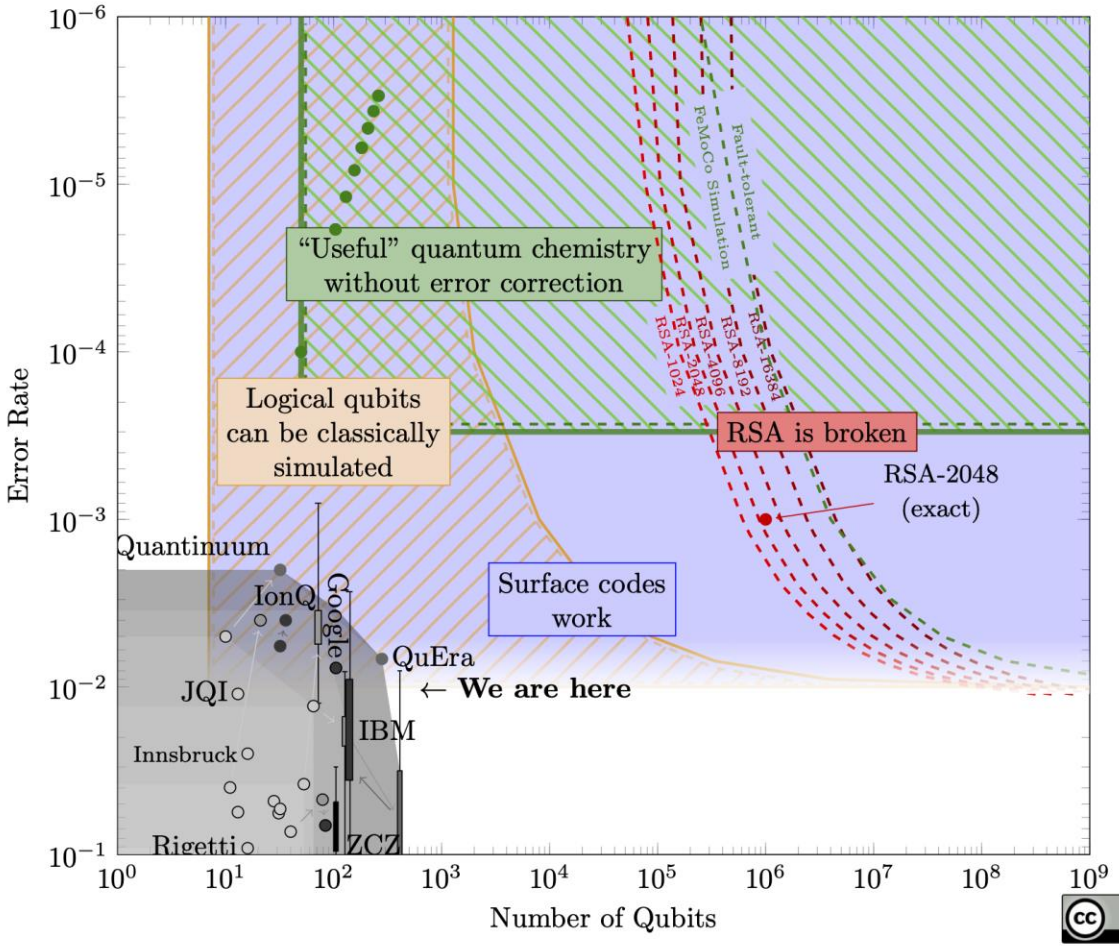
Craig Gidney

Google Quantum AI, Santa Barbara, California 93117, USA

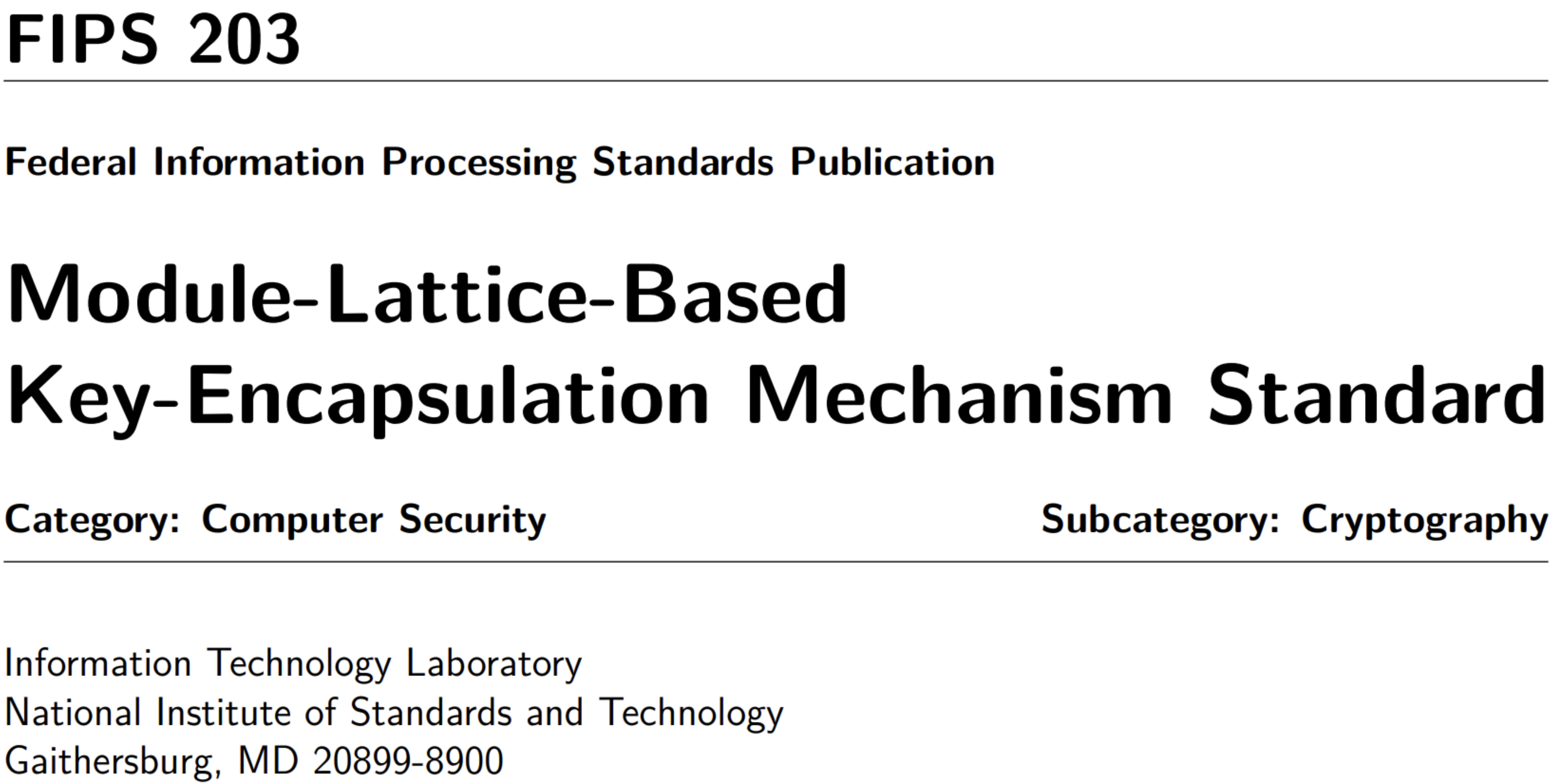
June 9, 2025

Planning the transition to quantum-safe cryptosystems requires understanding the cost of quantum attacks on vulnerable cryptosystems. In Gidney+Ekerå 2019, I co-published an estimate stating that 2048 bit RSA integers could be factored in eight hours by a quantum computer with 20 million noisy qubits. In this paper, I substantially reduce the number of qubits required. I estimate that a 2048 bit RSA integer could be factored in less than a week by a quantum computer with less than a million noisy qubits. I make the same assumptions as in 2019: a square grid of qubits with nearest neighbor connections, a uniform gate error rate of 0.1%, a surface code cycle time of 1 microsecond, and a control system reaction time of 10 microseconds.

Landscape of Quantum Computing in 2025



sam-jaques.appspot.com/quantum_landscape_2025



FIPS 203

Federal Information Processing Standards Publication

Module-Lattice-Based Key-Encapsulation Mechanism Standard

Category: Computer Security **Subcategory: Cryptography**

Information Technology Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899-8900

FIPS 204

Federal Information Processing Standards Publication

Module-Lattice-Based Digital Signature Standard

Category: Computer Security **Subcategory: Cryptography**

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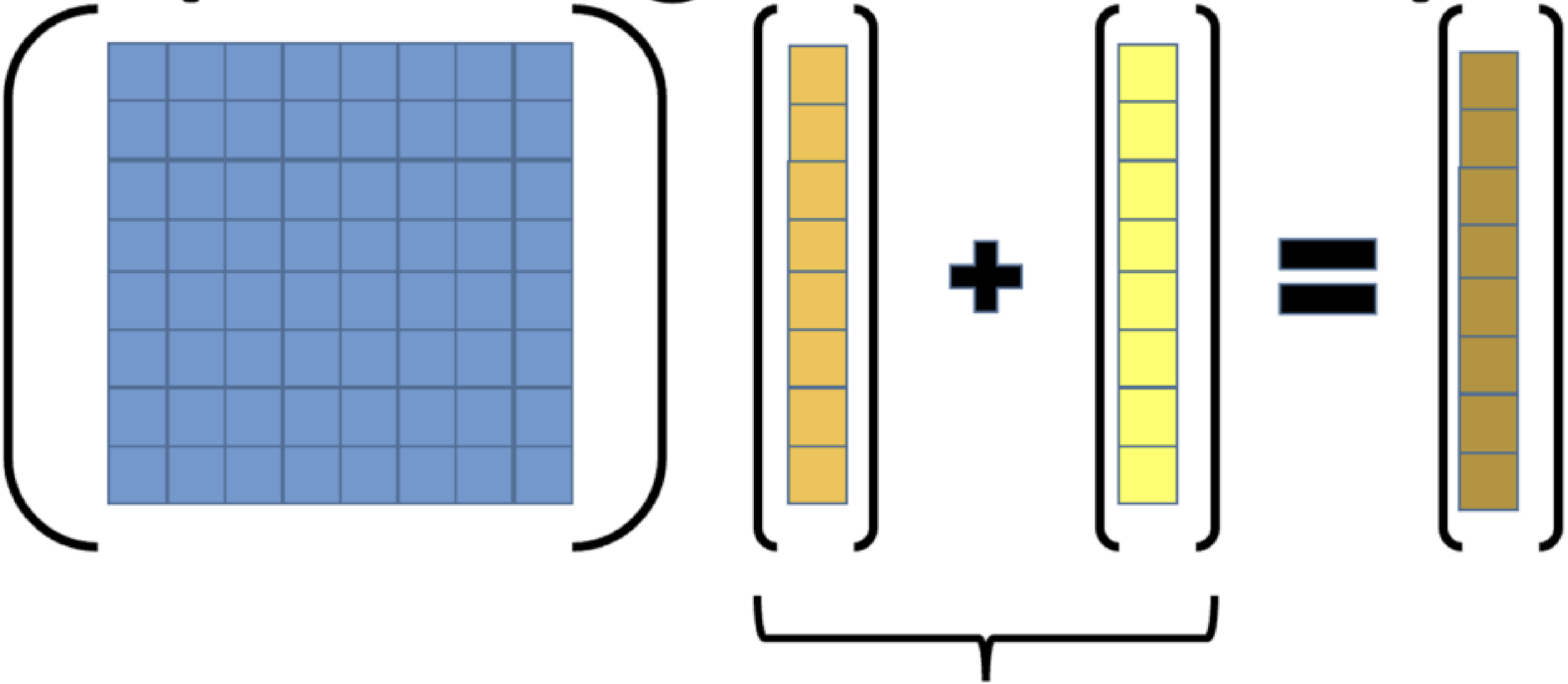
Lattice Assumptions

Three main lattice assumptions: SIS, LWE, and NTRU

Have shown to be very expressive and quantum-secure

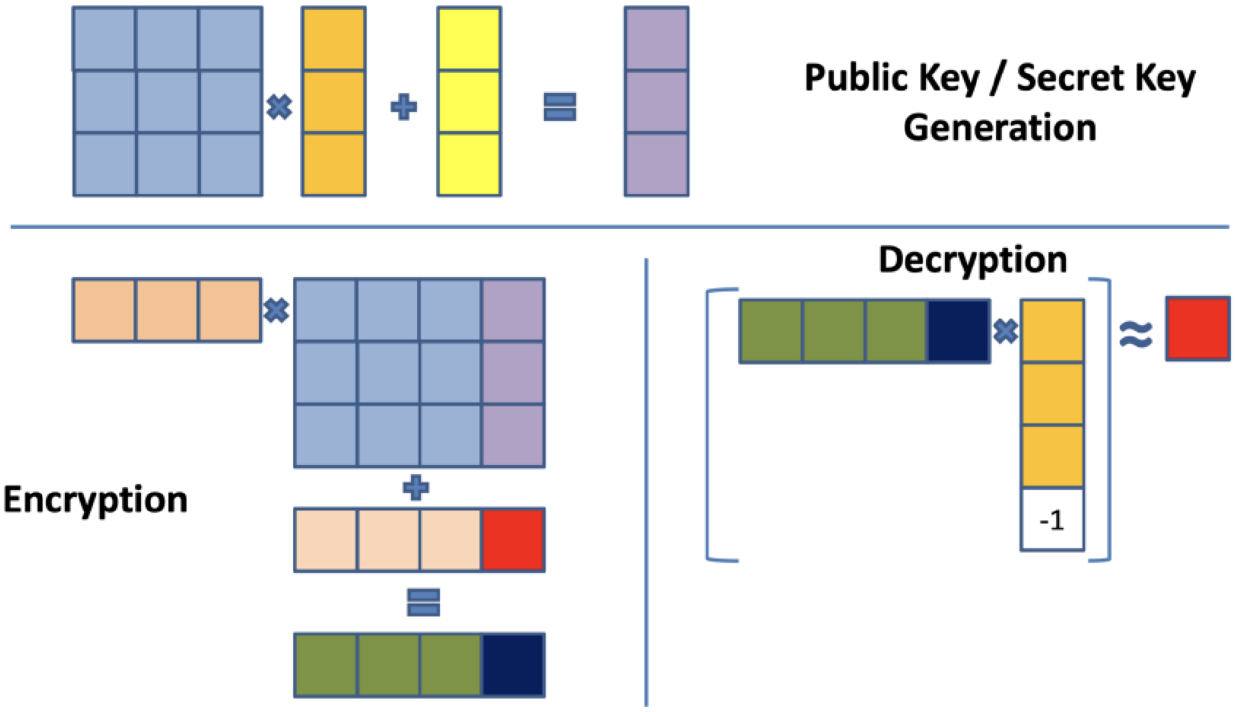
Hard to set parameters for correctness and security

(Learning With Errors)

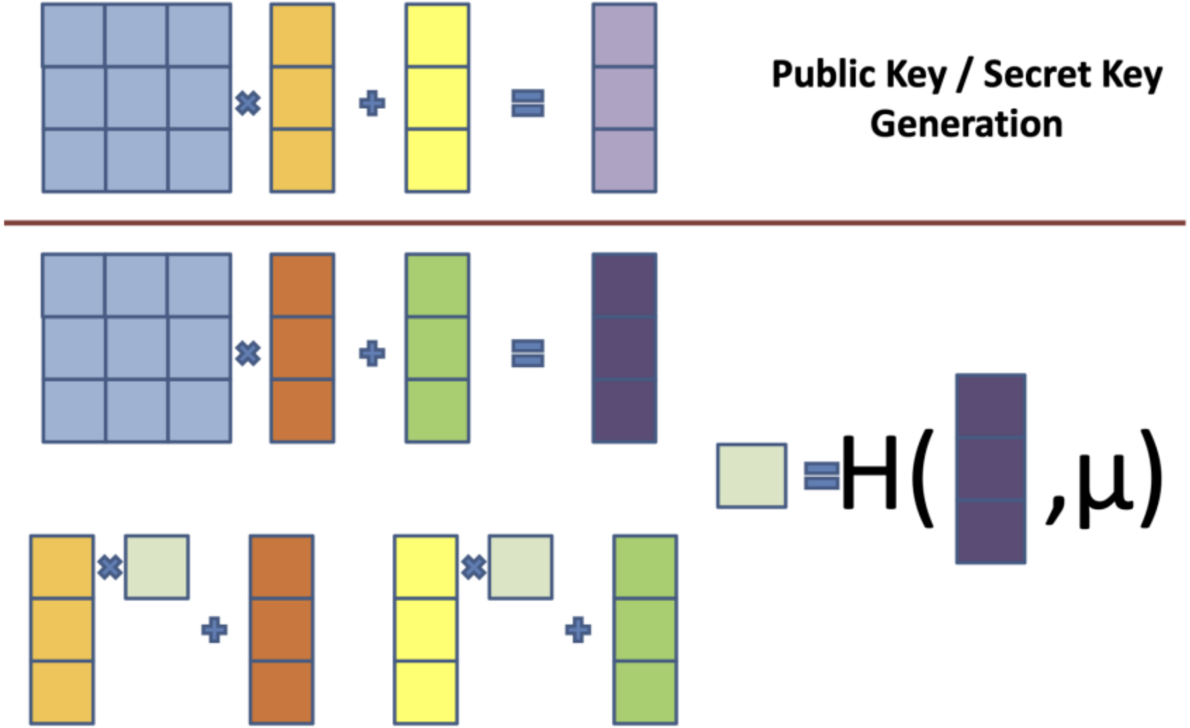


Small coefficients to enforce uniqueness

Encryption



Signatures



Public Key / Secret Key Generation

Basic Lattice Cryptography

The concepts behind Kyber (ML-KEM) and Dilithium (ML-DSA)

Vadim Lyubashevsky

IBM Research Europe, Zurich
vad@zurich.ibm.com

Challenges with Lattices

Masking is complicated since secrets have short norms

- ➢ Must use rejection sampling or noise drowning

There exist efficient trapdoors for lattices

- ➢ Must prove that an instance is generated honestly

Homomorphic operations and challenges impact norms

- ➢ Must use specialized techniques to deal with this

Homomorphic Counting

Practical Quantum-Safe Voting from Lattices

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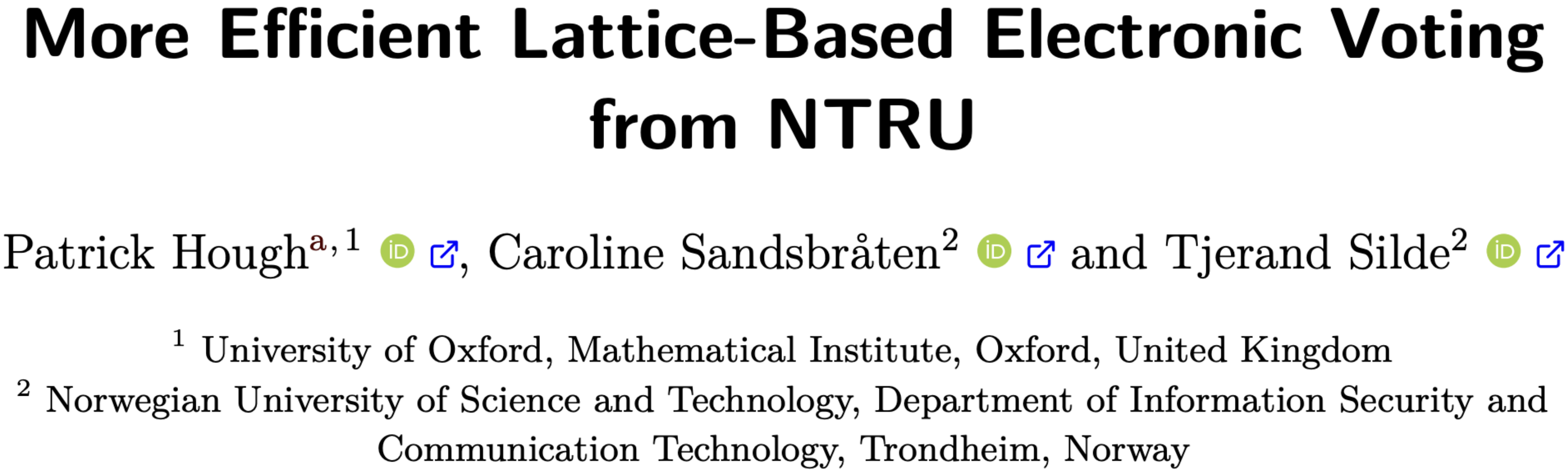
Ciphertexts of 20 KB, decryption 150 KB

Re-Randomization Mix-Net



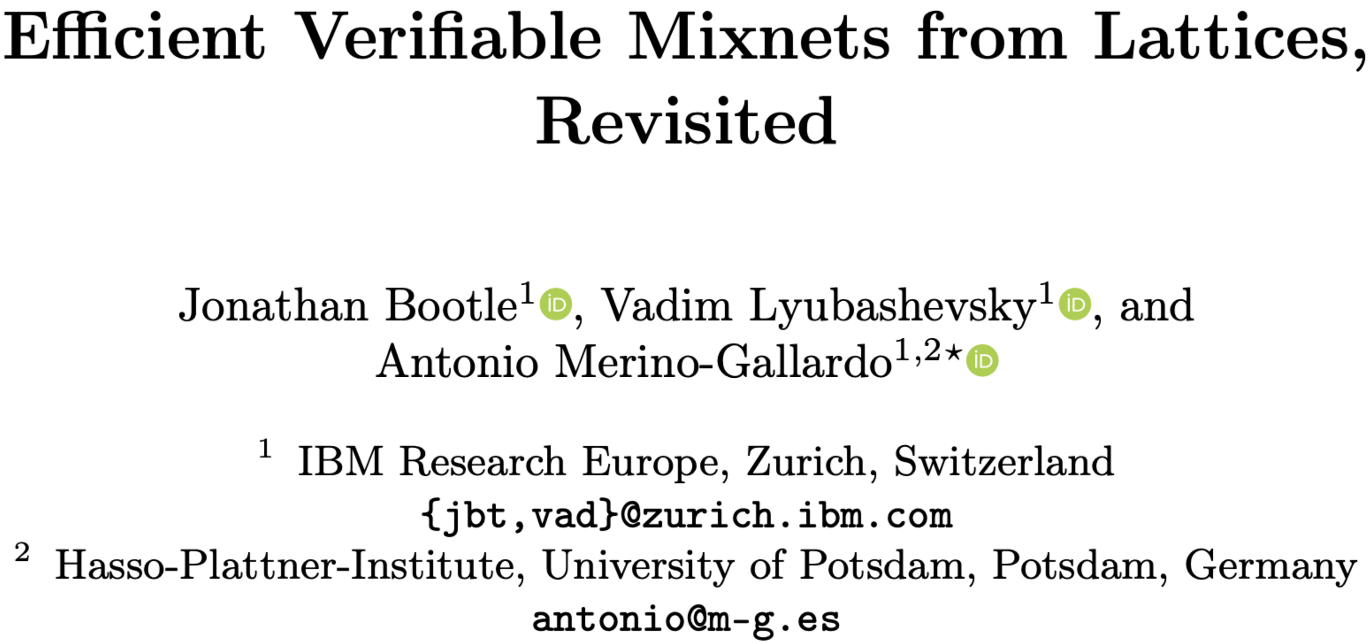
More Efficient Lattice-Based Electronic Voting from NTRU

Patrick Hough[a,1], Caroline Sandsbråten[2] and Tjerand Silde[2]

[1] University of Oxford, Mathematical Institute, Oxford, United Kingdom
[2] Norwegian University of Science and Technology, Department of Information Security and Communication Technology, Trondheim, Norway

Ciphertexts of 15 KB, shuffle 115 KB, decryption 85 KB

Decryption Mix-Net



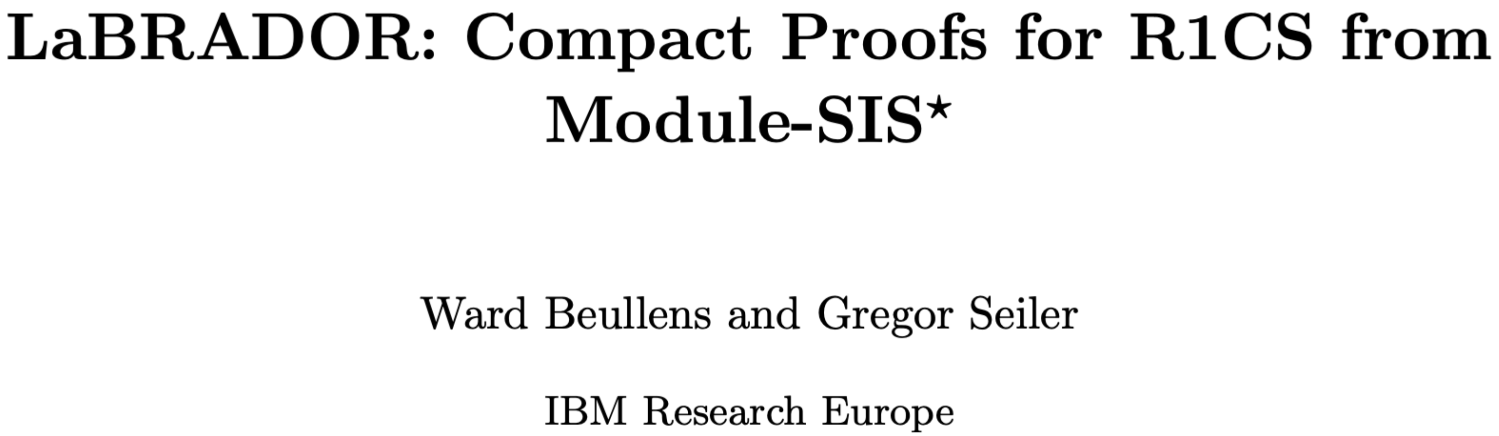
Efficient Verifiable Mixnets from Lattices, Revisited

Jonathan Bootle[1], Vadim Lyubashevsky[1], and
Antonio Merino-Gallardo[1,2⋆]

[1] IBM Research Europe, Zurich, Switzerland
{jbt,vad}@zurich.ibm.com
[2] Hasso-Plattner-Institute, University of Potsdam, Potsdam, Germany
antonio@m-g.es

Ciphertexts of ~6.5 KB, shuffle + decryption of 110 KB

(zk-)SNARKs



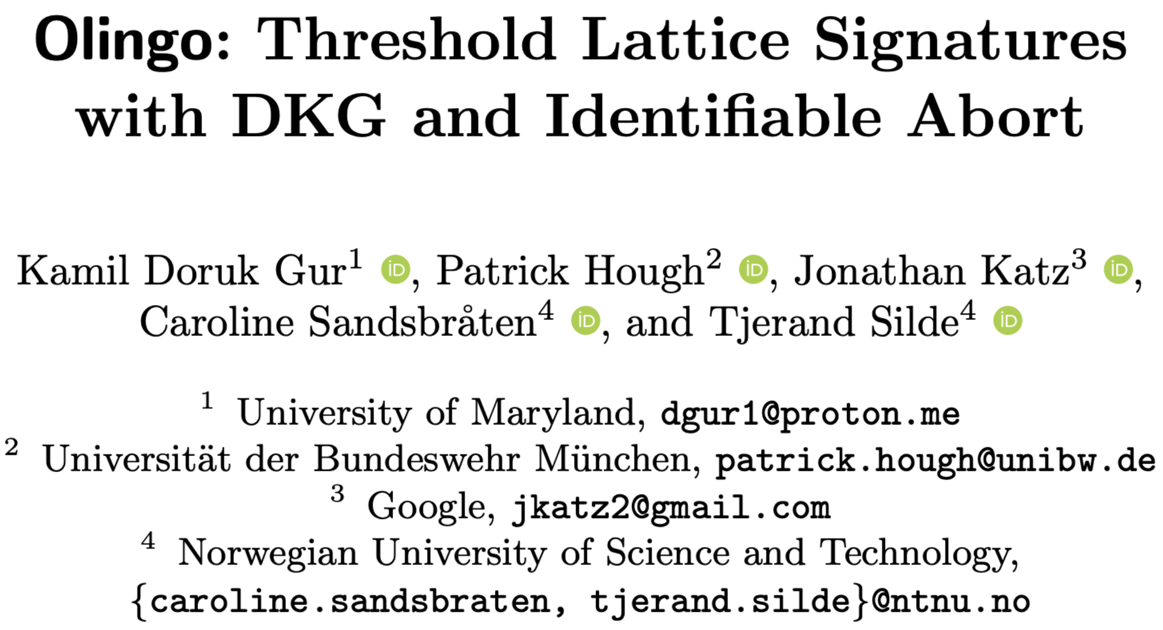
LaBRADOR: Compact Proofs for R1CS from Module-SIS*

Ward Beullens and Gregor Seiler

IBM Research Europe

Proofs of ~60-100 KB for essentially any (lattice) statement

Threshold



Olingo: Threshold Lattice Signatures with DKG and Identifiable Abort

Kamil Doruk Gur[1], Patrick Hough[2], Jonathan Katz[3], Caroline Sandsbråten[4], and Tjerand Silde[4]

[1] University of Maryland, dgur1@proton.me

[2] Universität der Bundeswehr München, patrick.hough@unibw.de

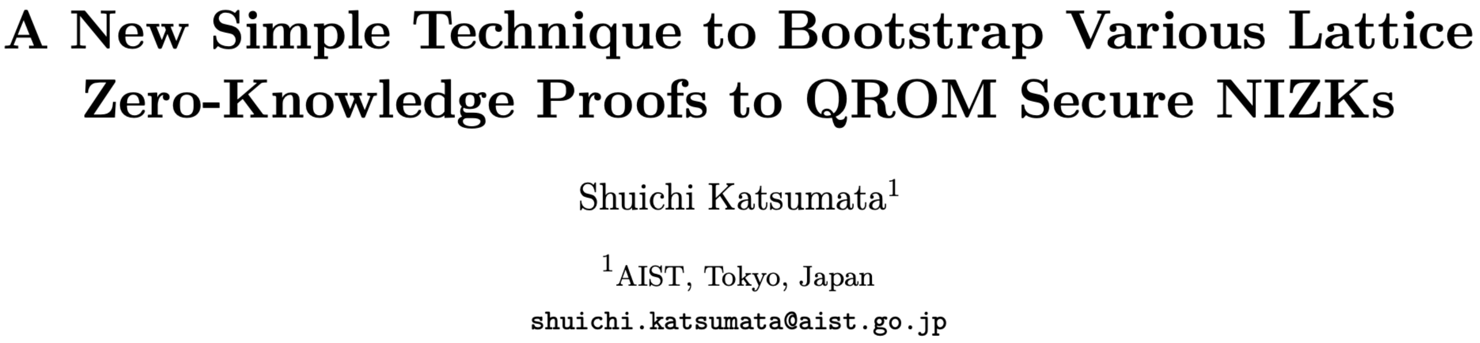
[3] Google, jkatz2@gmail.com

[4] Norwegian University of Science and Technology, {caroline.sandsbraten, tjerand.silde}@ntnu.no

Allows for arbitrary threshold decryption and distributed setup

Improved analysis can also reduce parameters

QROM / Online Extractability



A New Simple Technique to Bootstrap Various Lattice Zero-Knowledge Proofs to QROM Secure NIZKs

Shuichi Katsumata[1]

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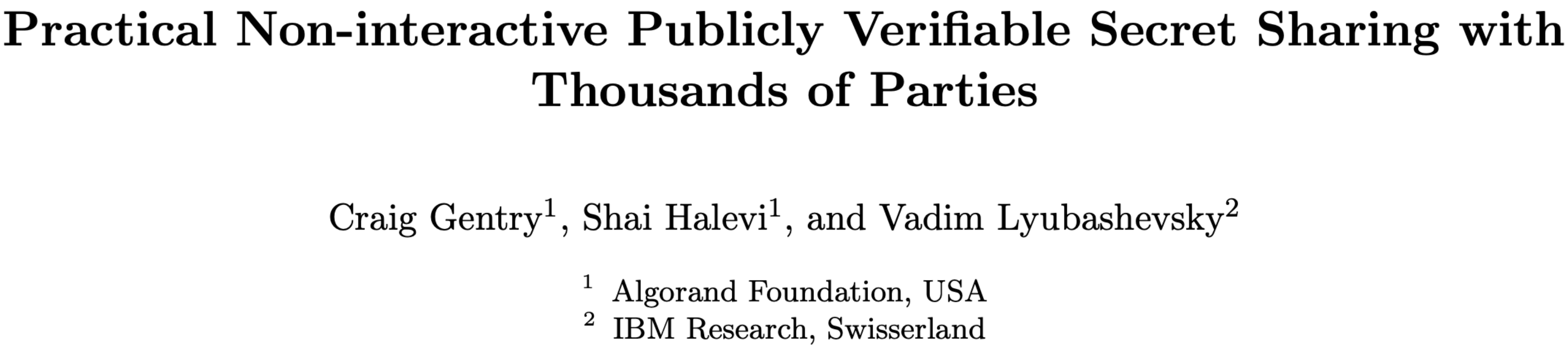
Makes overall security proofs simpler

Post-Quantum Privacy vs Integrity



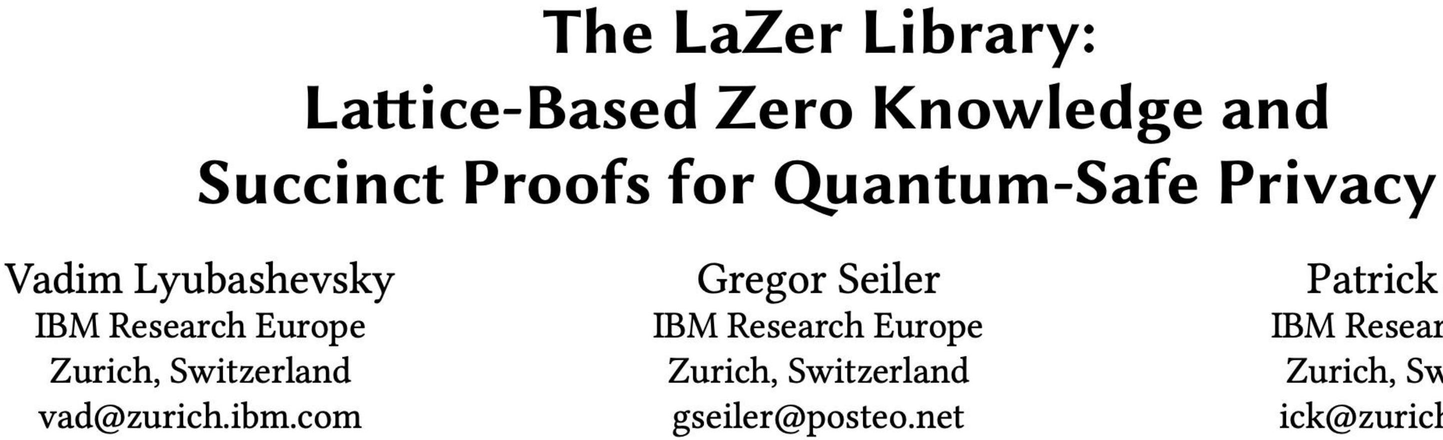
Practical Non-interactive Publicly Verifiable Secret Sharing with Thousands of Parties

Craig Gentry[1], Shai Halevi[1], and Vadim Lyubashevsky[2]

[1] Algorand Foundation, USA
[2] IBM Research, Swisserland

LWE ciphertext + DLOG ZK proofs

Open-Source Implementations



The LaZer Library: Lattice-Based Zero Knowledge and Succinct Proofs for Quantum-Safe Privacy

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Important step towards ZKP implementations

Cryptology and Social Life Workshop

NTNU in Trondheim, on December 11 and 12

Free registration; talks, discussions, dinner

- Phil Rogaway – “Can Ethics Be Taught?”
- Rikke Bjerg Jensen – “Social Foundations of Cryptography: An Ethnography Talk”
- Jean-François Blanchette – “Legislating digital signatures: Lessons from a past cryptographic utopia”