Post-Quantum

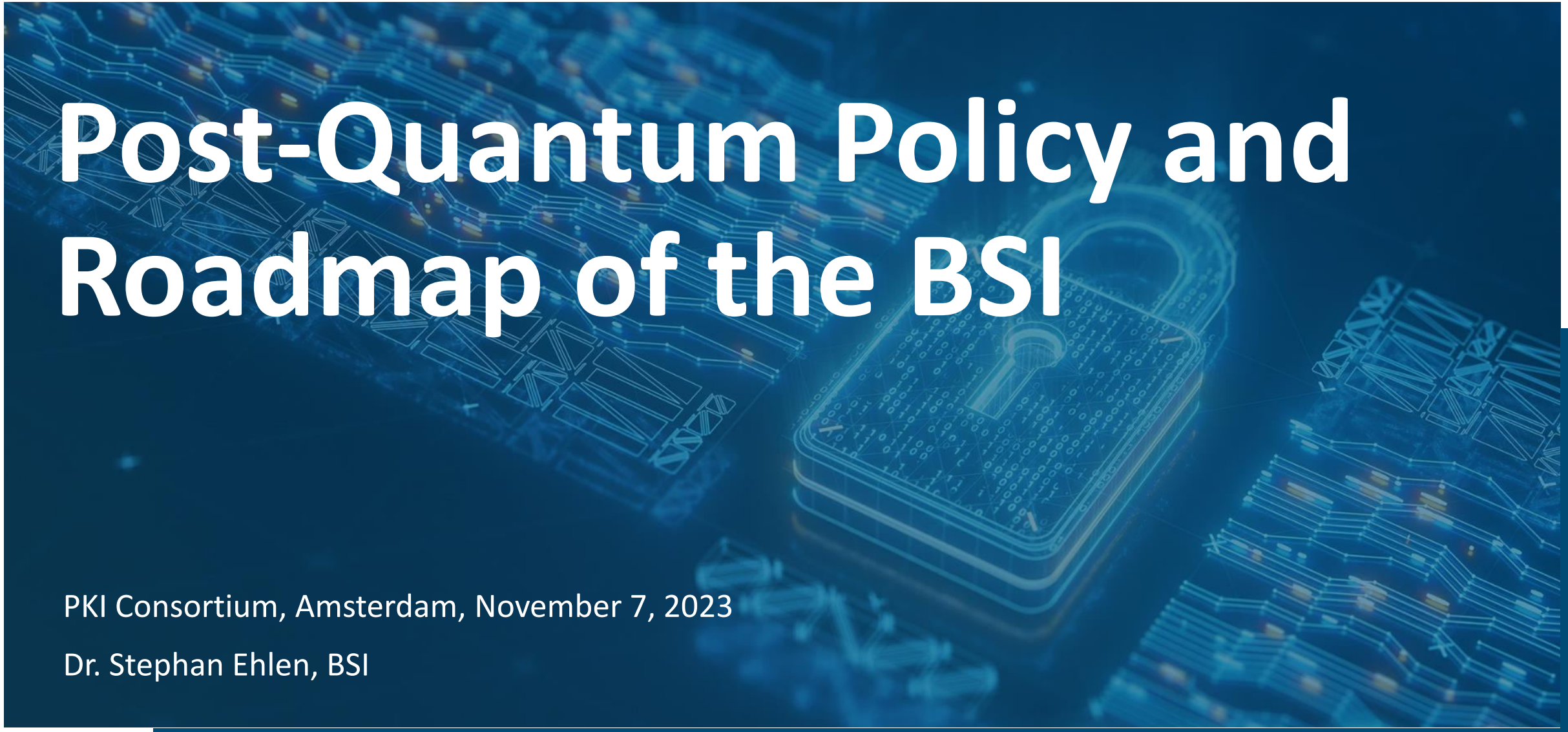
Cryptography Conference

Post-Quantum Policy & Roadmap of the BSI

Stephan Ehlen
The Federal Office for Information Security (BSI)

Federal Office
for Information Security

Post-Quantum Policy and Roadmap of the BSI



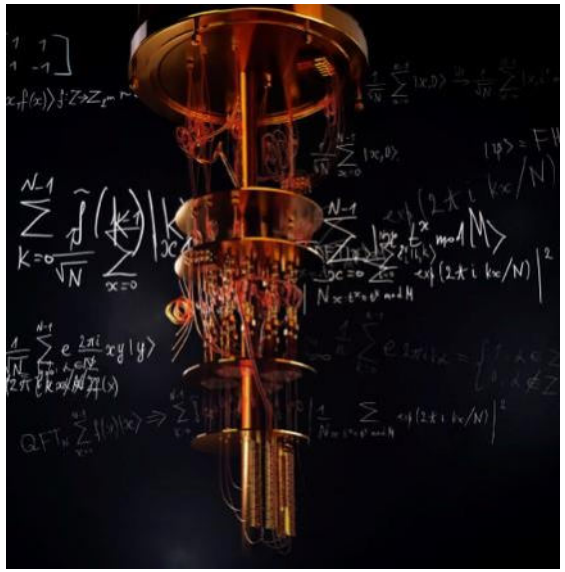
PKI Consortium, Amsterdam, November 7, 2023

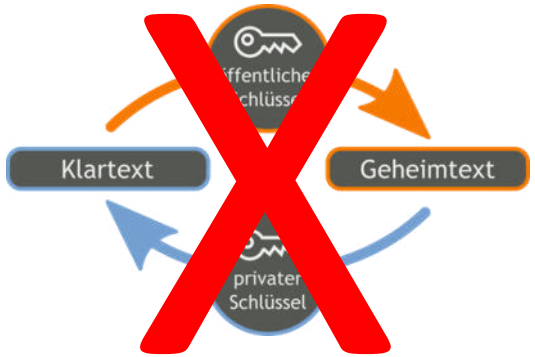
Dr. Stephan Ehlen, BSI

About me

- PhD in pure Mathematics (number theory)
  - Main interest: Modular forms and their arithmetic and geometric applications
- Since 2021 at the Federal Office for Information Security (BSI)
  - Main interest: Post-quantum cryptography, in particular lattice-based
- Associate professor (Privatdozent) in Mathematics at University of Cologne, Germany

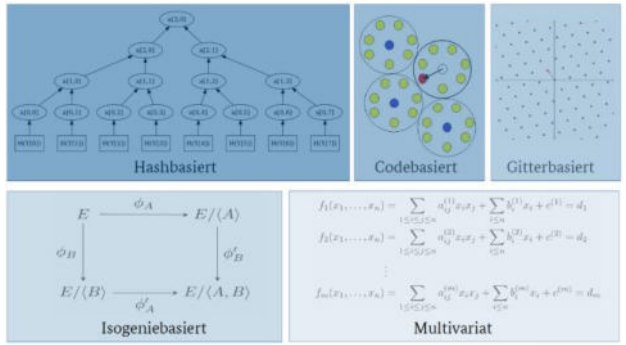
Why Quantum-safe Cryptography?



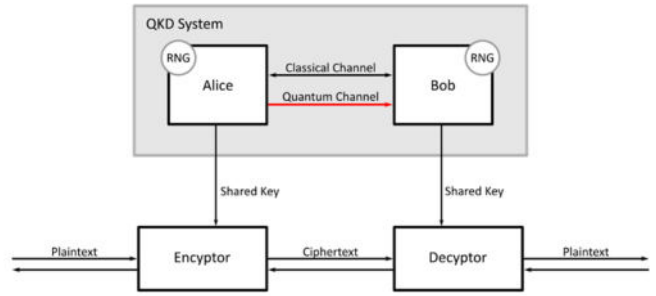


Current Public Key Cryptography
(RSA, (EC)DH, (EC)DSA)

Post Quantum Cryptography



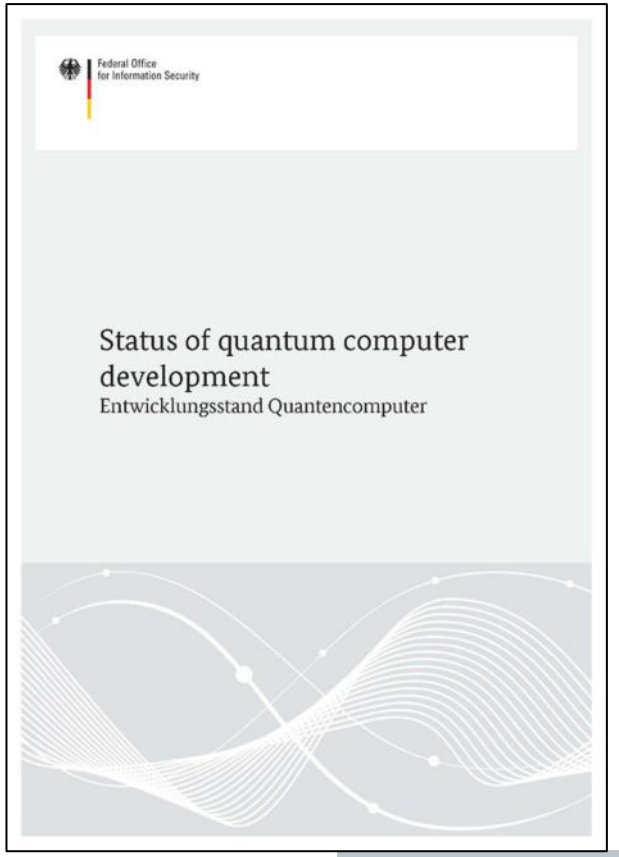
Quantum-safe Cryptography



Quantum Key Distribution

BSI Study „Status of quantum computer development“

- First published 2018, updated 2019 and 2020
- Available at www.bsi.bund.de/qcstudie
- Project lead: Prof. Frank Wilhelm-Mauch (FZ Jülich)
- 2023 update (available soon):
  - New developments in
    - Algorithms in the NISQ-era
    - Error correction and –mitigation
    - Hardware
  - No fundamental breakthrough
  - However, major leaps forward are possible if heuristic results are confirmed.



Working Hypothesis and Scenarios

„Cryptographically relevant quantum computers will be available early in the 2030s.“
(This is **not** a prediction but rather a guideline for conservative risk assessment.)

(BT-Drs. 19/26340)

Scenarios:

- *Store now, decrypt later*
  → quantum-safe encryption
- *Complex migration* (e.g. PKI)
  → quantum-safe authentication

Political Guidelines

MAY 04, 2022

National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems

BRIEFING ROOM › STATEMENTS AND RELEASES

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

THE DIRECTOR

November 18, 2022

M-23-02

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: Shalanda D. Young
Director

SUBJECT: Migrating to Post-Quantum Cryptography

Deutscher Bundestag — Drucksache 20/6610

20. Wahlperiode — 28.04.2023

Unterrichtung

durch die Bundesregierung

Handlungskonzept Quantentechnologien der Bundes

Inhaltsverzeichnis

Zugeleitet mit Schreiben des Bundesministeriums für Bildung und Forschung vom 26. April 2023.

Die Bundesregierung

Quantenkommunikation und Post-Quanten-Kryptografie

In der Quantenkommunikation und der Post-Quanten-Kryptografie will die Bundesregierung bis 2026 folgende Meilensteine erreichen:

- Etablierung von ersten abhörsicheren, d.h. quantenverschlüsselten, Kommunikationsteststrecken zwischen ausgewählten Behördenstandorten.
- Weitere Start-ups/Firmen sind im Bereich der Quantenkommunikation in Deutschland gegründet.
- Realisierung eines bundesweiten Glasfaser-Backbones für die Quantenkommunikation und die Zeit- und Frequenzverteilung.
- Demonstration erster Quantenrepeatertestrecken.
- Start erster Testsatelliten zur Quantenschlüsselverteilung.
- Erstellung einer Strategie der Bundesregierung für die Migration zu Post-Quanten-Kryptografie in Deutschland.
- Weiterführung der Migration zu Post-Quanten-Kryptografie für den Hochsicherheitsbereich.

- Einleiten der Migration zu Post-Quanten-Kryptografie in weiteren sicherheitskritischen Bereichen.
- Integration von Post-Quanten-Kryptografie-Verfahren in praxistaugliche IT-Sicherheitslösungen.

Für eine spätere Überführung in Produktivsysteme sind im Anschluss weitere Schritte im Bereich der Prüfung, Zulassung und technischen Ertüchtigung der beteiligten Komponenten und Infrastrukturen erforderlich.

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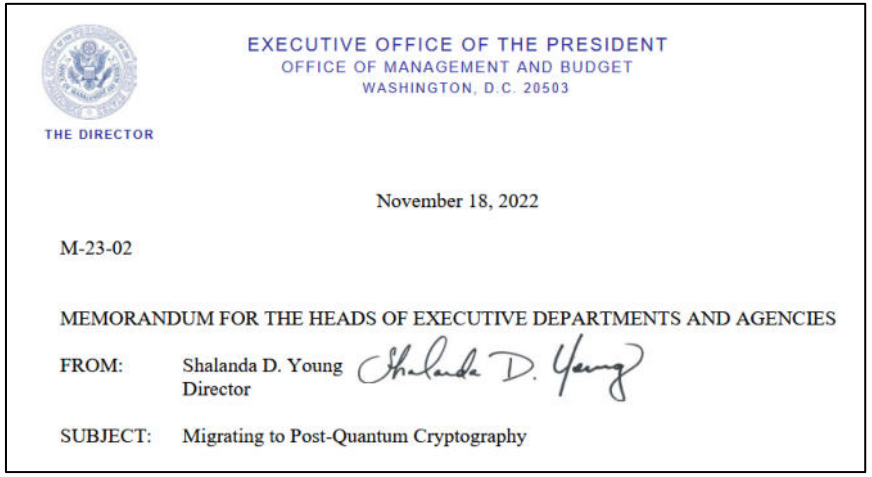

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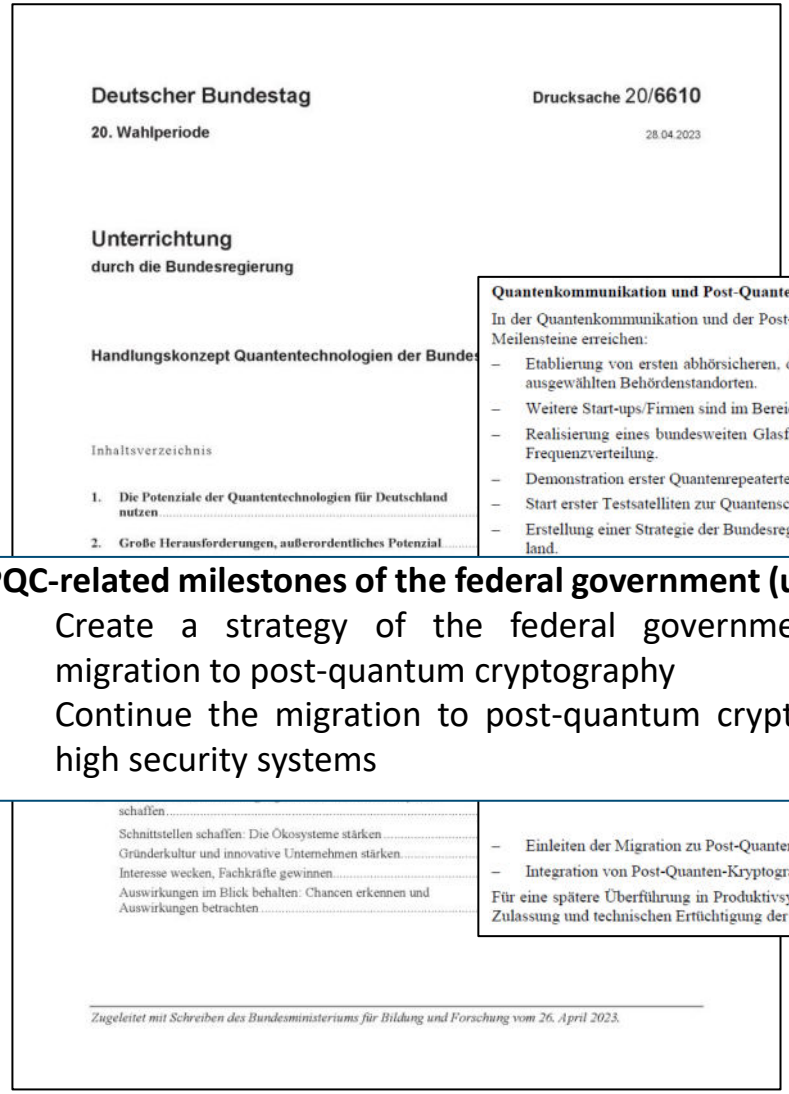

Deutscher Bundestag — Drucksache 20/6610

20. Wahlperiode — 28.04.2023

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Handlungskonzept Quantentechnologien der Bundes

Inhaltsverzeichnis

1. Die Potenziale der Quantentechnologien für Deutschland nutzen
2. Große Herausforderungen, außerordentliches Potenzial

schaffen
Schnittstellen schaffen: Die Ökosysteme stärken
Gründerkultur und innovative Unternehmen stärken
Interesse wecken, Fachkräfte gewinnen
Auswirkungen im Blick behalten: Chancen erkennen und Auswirkungen betrachten

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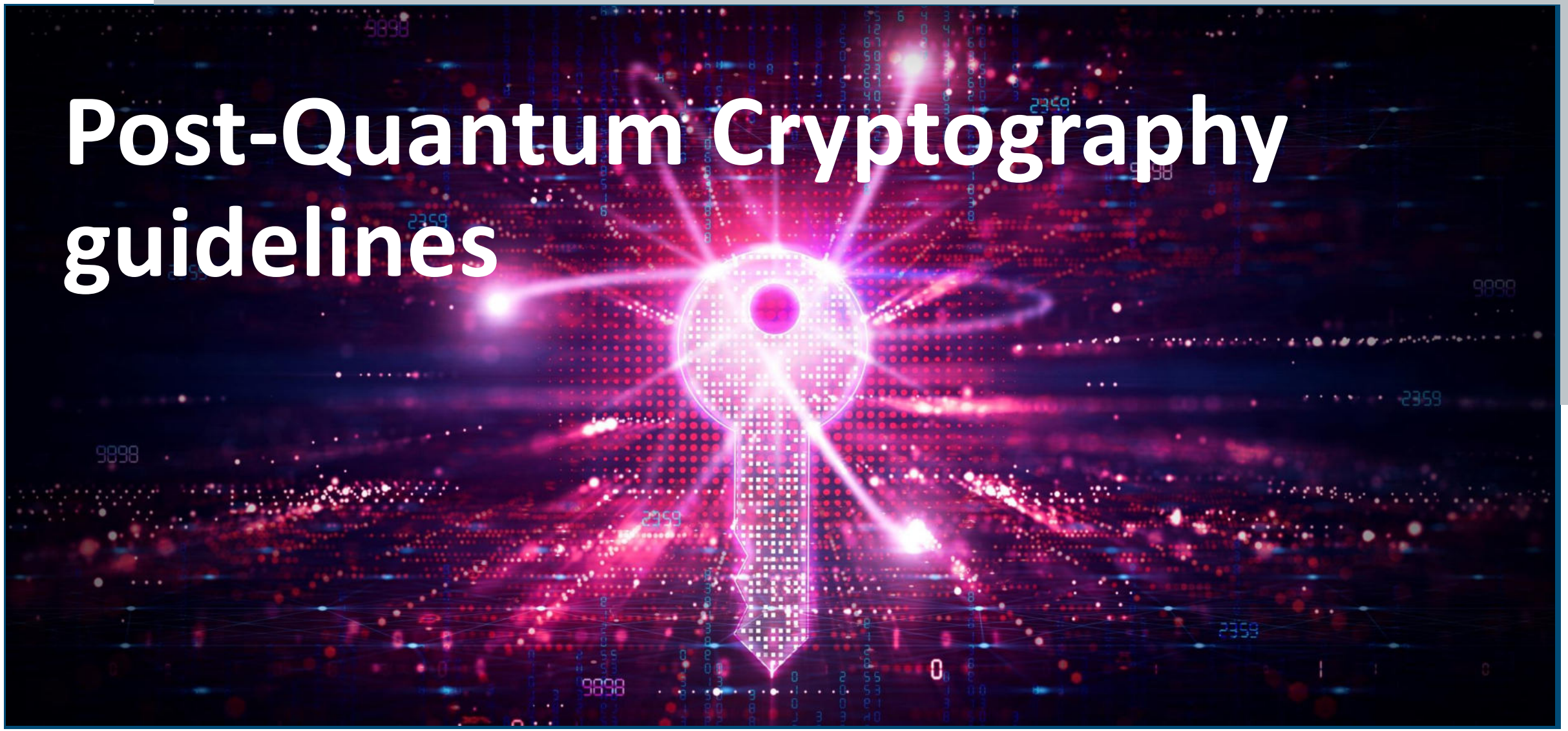
PQC-related milestones of the federal government (until 2026):

- Create a strategy of the federal government for the migration to post-quantum cryptography
- Continue the migration to post-quantum cryptography for high security systems

Post-Quantum Cryptography guidelines

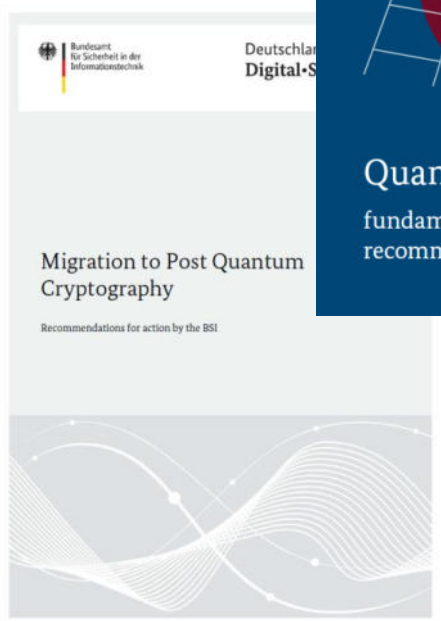


Federal Office
for Information Security

BSI Guide „Quantum-safe cryptography“

In 2021 BSI published the guideline
Quantum-safe cryptography – fundamentals, current developments and recommendations:

- Background on *quantum computers*, *PQC*, *protocols*, *QKD*
- Developments in politics, research and industry
- Recommendations for actions (excerpt):
  - Preparation: cryptographic inventory!
  - Hybrid solutions for KEMs and signature schemes
  - Cryptographic agility

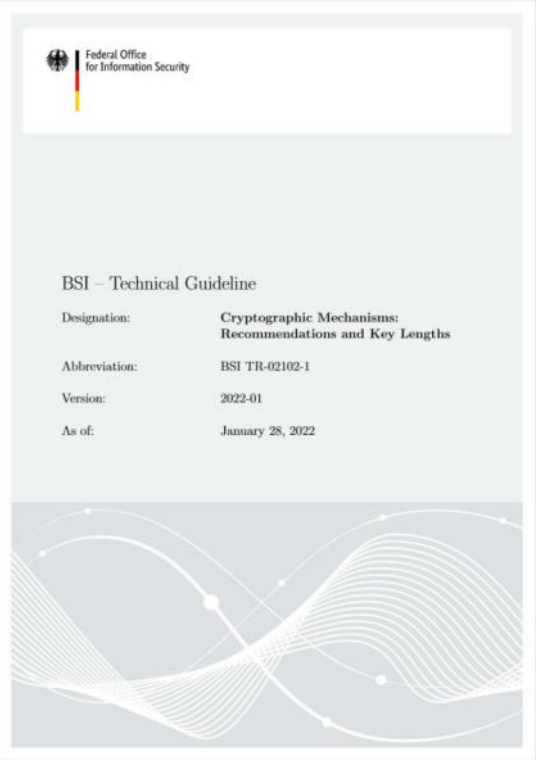


Reference: www.bsi.bund.de/dok/pqmigration-en

BSI Technical Guideline TR-02102-1

„Cryptographic Mechanisms: Recommendations and Key Lengths“

- Key Encapsulation Mechanisms:
  - *FrodoKEM* and *Classic McEliece*
- PQC only in *hybrid solutions*, i.e. PQC + “Classical”, except for HBS
- Stateful hash-based signatures
  - *LMS/HSS*
  - *XMSS/XMSS^MT*

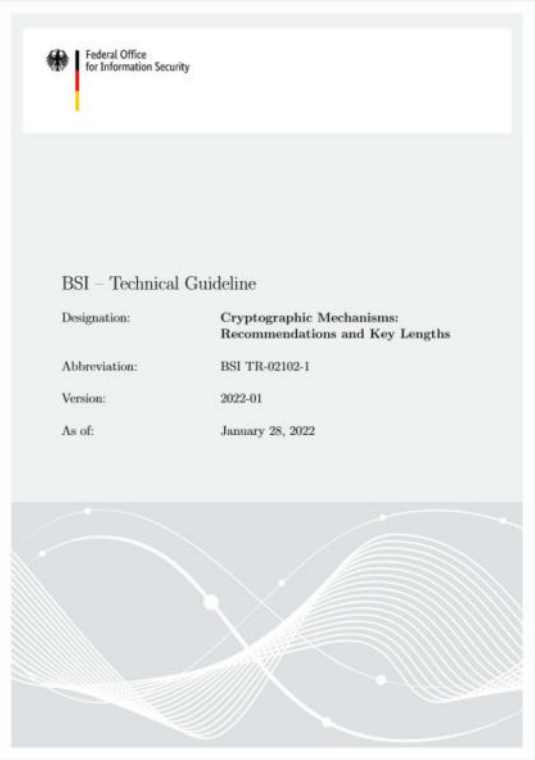


Reference: www.bsi.bund.de/TR-02102

BSI Technical Guideline TR-02102-1

Outlook (2024/2025):

- Key Encapsulation Mechanisms:
  - *FrodoKEM* and *Classic McEliece*
  - *ML-KEM (after standard becomes available)*
- Digital Signature Schemes:
  - *ML-DSA (after standard becomes available)*
  - *SLH-DSA (after standard becomes available)*
  - *LMS/HSS* and *XMSS/XMSS^MT*
- *Parameters: NIST security categories 3 and 5*
- PQC only in *hybrid solutions*, i.e. PQC + “Classical”, except for HBS

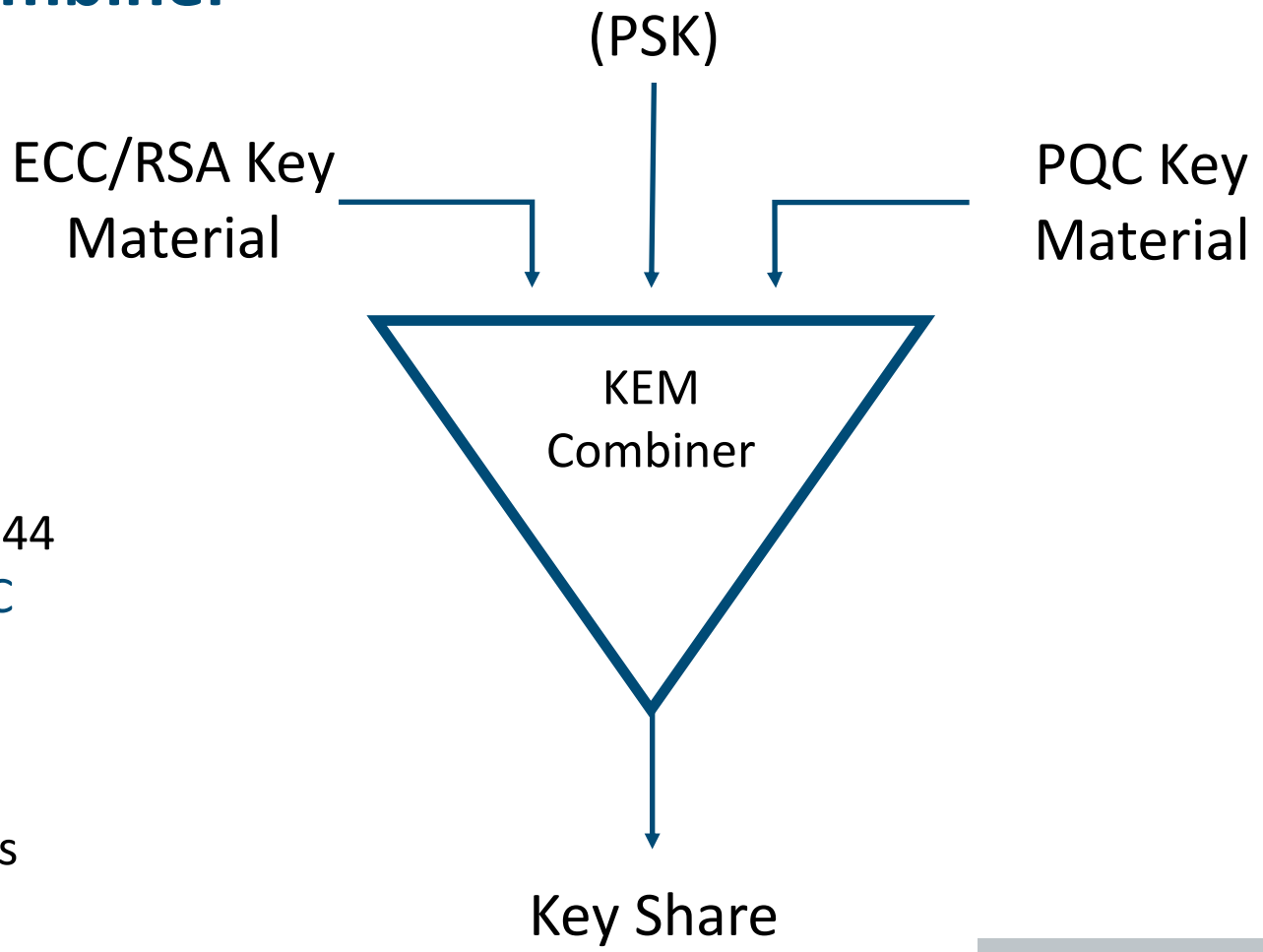


Hybrid Key Exchange: KEM Combiner

- Goal:
  Construction is secure as long as
  at least one component KEM is secure.

- Recommendations:
  - CatKDF & CasKDF from ETSI TS 103 744
  - The Keccac (SHA3, KMAC) and HMAC
    based KDFs in NIST SP 800-56Cr2

- Some relevant IETF drafts/RFCs:
  - draft-ounsworth-cfrg-kem-combiners
  - draft-ietf-tls-hybrid-design
  - RFC9370: Multiple Key Exchanges IKEv2



BSI‘s current PQC projects

- PQC in the cryptographic library Botan:
  - FrodoKEM*, Classic McEliece*, Kyber (* coming soon)
  - Dilithium, SPHINCS+, XMSS, LMS/HSS
  - TLS 1.3 hybrid key exchange
- PQC in OpenPGP and Thunderbird
  - IETF I-D “PQC for OpenPGP” (coming soon)
  - Implementation in Thunderbird and RNP/Botan
  - Implementation in GnuPG/libgcrypt
- Quantum-safe PKI for Germany’s federal administration (“Verwaltungs-PKI”)
  → Tomorrow!

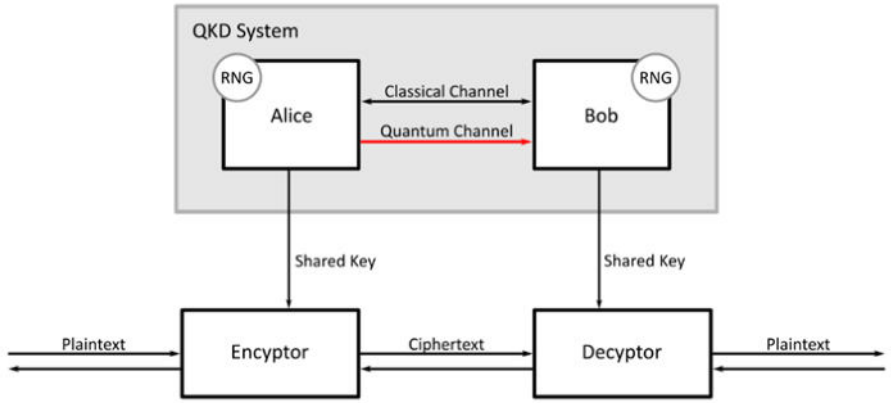
What about Quantum Key Distribution?

Quantum Key Distribution (QKD)

Some facts:

- Theoretical security is based on quantum-physical principles
- Only works for key agreement
- Requires specialized (and expensive) hardware
- Implementation security also has to be considered

  (in addition to theoretical security)
- Limitations of QKD make it only applicable for specific use cases



BSI‘s policy:

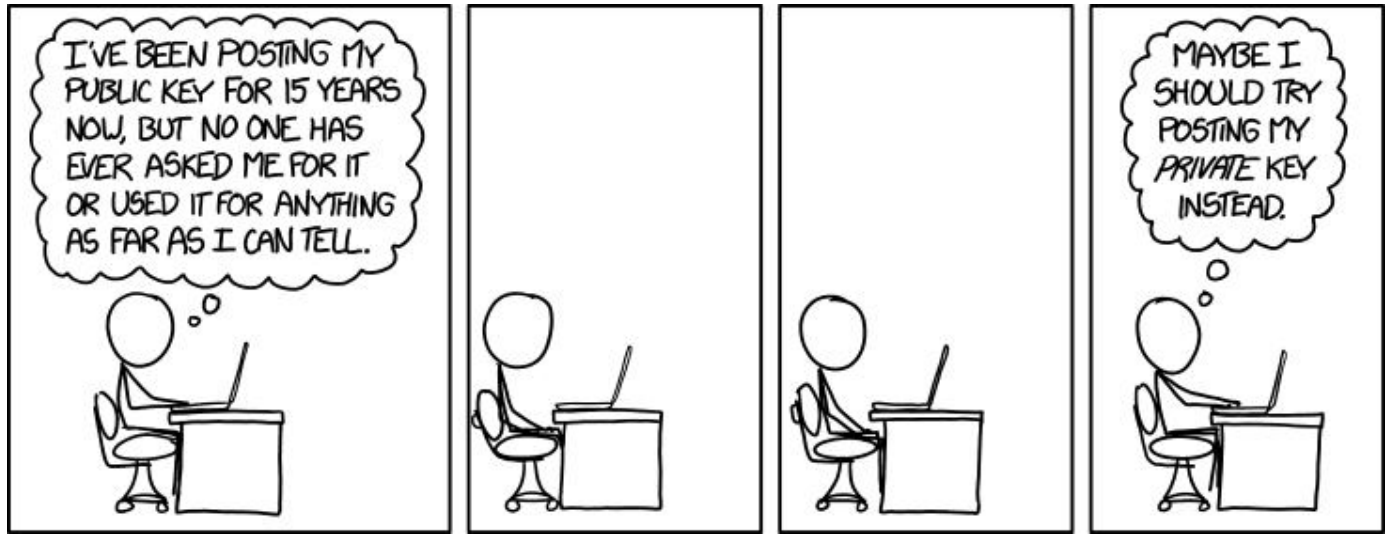
- **Migration to PQC has highest priority**
- QKD could potentially complement or backup PQC in the future

Wrap-up

- The public-key cryptography deployed today will be broken when large-scale quantum computers become available.
- *„Store now, decrypt later“* is a real threat & considerable migration times are to be expected.

  ⟶ PQC-migration has to be initiated **now**!

- In general, PQC should be used in hybrid mode together with RSA or ECC.
- QKD is not sufficiently mature from a security perspective.



Source: https://xkcd.com/1553/

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www.bsi.bund.de/dok/pqmigration-en

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