Supersingular Isogeny Key Encapsulation

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`https://sike.org`

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SIKE

Supersingular **I**sogeny **K**ey **E**ncapsulation (SIKE)

- IND-CCA2 KEM
- Based on **S**upersingular **I**sogeny **D**iffie-**H**ellman (SIDH)
- Uses Hofheinz et al. transformation (TCC 2017) on SIDH to achieve CCA security

The SIKE protocol specifies:

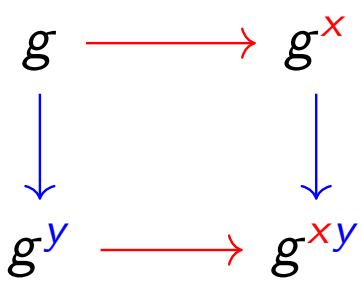
- Parameter sets
- Key/ciphertext formats
- Encapsulation/decapsulation mechanisms
- Choice of symmetric primitives (hash functions, etc.)

Overview of SIDH

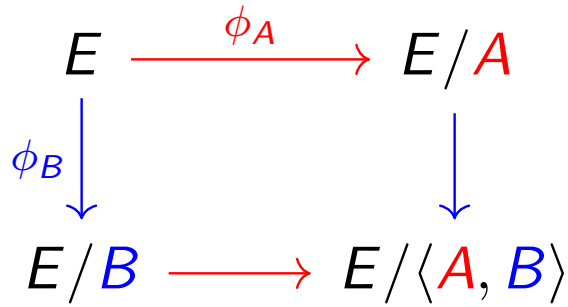
1. Public parameters: Supersingular elliptic curve E over $\mathbb{F}_{p^2}$.
2. Alice chooses a kernel $A \subset E(\mathbb{F}_{p^2})$ and sends E/A to Bob.
3. Bob chooses a kernel $B \subset E(\mathbb{F}_{p^2})$ and sends E/B to Alice.
4. The shared secret is

$$E/\langle A, B\rangle = (E/A)/\phi_A(B) = (E/B)/\phi_B(A).$$

Diffie-Hellman (DH)



SIDH



Changes for SIKE in second round

- New parameter sets: SIKEp434, SIKEp503, SIKEp610, SIKEp751, ~~SIKEp964~~
- New starting curve $E : y^2 = x^3 + 6x^2 + x$
- Key compression: $\approx 40\%$ smaller public keys and ciphertexts
- Updated security analysis

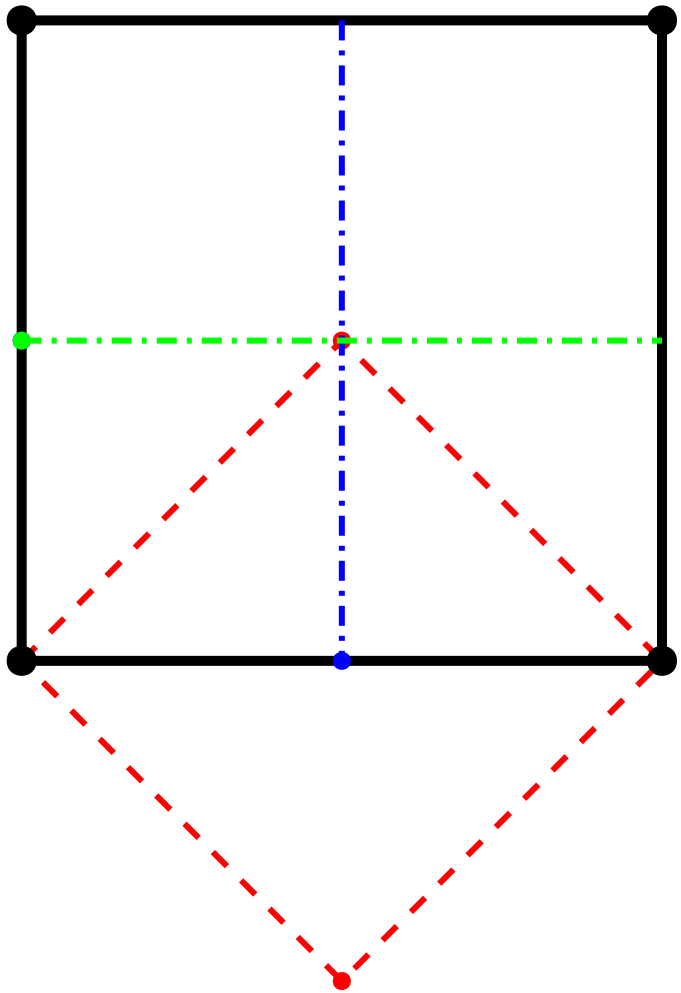
Parameter sets

Scheme	prime p	$\log_2 p$	Security level
SIKEp434	$2^{216}3^{137} - 1$	433.14	NIST 1
SIKEp503	$2^{250}3^{159} - 1$	502.01	NIST 2
SIKEp610	$2^{305}3^{192} - 1$	609.31	NIST 3
SIKEp751	$2^{372}3^{239} - 1$	750.81	NIST 5

New starting curve

The previous starting curve $y^2 = x^3 + x$ has complex multiplication symmetries, reducing key entropy.

- Red kernel point yields curve isomorphic to starting curve.
- Blue and green kernel points yield curves isomorphic to each other.



Key compression

Scheme	Public key	Decaps (x86_64)
SIKEp434	330 bytes	11.3 $\times 10^6$ cc
SIKEp434_compressed	196 bytes	18.9 $\times 10^6$ cc
SIKEp503	378 bytes	15.6 $\times 10^6$ cc
SIKEp503_compressed	224 bytes	25.5 $\times 10^6$ cc
SIKEp610	462 bytes	28.6 $\times 10^6$ cc
SIKEp610_compressed	273 bytes	45.5 $\times 10^6$ cc
SIKEp751	564 bytes	45.4 $\times 10^6$ cc
SIKEp751_compressed	331 bytes	72.8 $\times 10^6$ cc

Security analysis

Attack cost	SIKEp434			SIKEp610		
	G	D	W	G	D	W
Grover [1]	126	116	10	171	160	10
Tani (optimal $\#G$) [2]	124	114	25	169	159	25
Tani (optimal $D \times W$) [2]	131	122	10	177	166	10
Van Oorschot-Wiener [2]	132	14	128	177	14	173

1. *A framework for reducing the overhead of the quantum oracle for use with Grover's algorithm with applications to cryptanalysis of SIKE*, Benjamin I. Pring and Jean-François Biasse, MathCrypt 2019
2. *Quantum cryptanalysis in the RAM model: Claw-finding attacks on SIKE*, Sam Jaques and John Schanck, CRYPTO 2019

Recent implementations

Decapsulation times, cc $\times 10^6$	SIKEp503	SIKEp751
ARM64 (NIST 2nd round)	47.4	159.5
ARM64 [1]	39.7	138.4
Cortex M4 [2]	183	491

1. *ARMv8 SIKE: Optimized Supersingular Isogeny Key Encapsulation on ARMv8 Processors*, Amir Jalali, Reza Azarderakhsh, Mehran Mozaffari Kermani, Matthew Campagna, and David Jao, IEEE TCAS, `10.1109/TCSI.2019.2920869`. Code available at `https://github.com/amirjalali65/armv8-sike`
2. *SIKE Round 2 Speed Record on ARM Cortex-M4*, Hwajeong Seo, Amir Jalali, and Reza Azarderakhsh, 2019/535.

Summary

SIKE advantages:

- Smallest public key size
- Straightforward parameter selection
- No decryption error, Gaussians, rejection sampling, etc.
- Generic attacks are well understood
- Only KEM proposal not based on lattices / codes / LW[ER]

SIKE disadvantages:

- Slow
- Future analysis may uncover non-generic attacks against SIKE (though none are known so far)

Future work:

- Cryptanalysis and side-channel attacks