# OpenFHE – Open-Source Fully Homomorphic Encryption Library

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## Key Facts

OpenFHE, a new open-source C++17 FHE software library that incorporates selected design ideas from prior FHE projects, such as PALISADE, HElib, HEAAN, and FHEW, and includes several new design concepts and ideas [1].

The main new design features can be summarized as follows:

- We assume from the very beginning that all implemented FHE schemes will support bootstrapping and scheme switching;
- OpenFHE supports multiple hardware acceleration backends using a standard Hardware Abstraction Layer (HAL);
- OpenFHE includes both user-friendly modes, where all maintenance operations, such as modulus switching, key switching, and bootstrapping, are automatically invoked by the library, and compiler-friendly modes, where an external compiler makes these decisions.

OpenFHE includes efficient implementations of all common FHE schemes:

- ✓ Brakerski/Fan-Vercauteren (BFV) scheme for integer arithmetic
- ✓ Brakerski-Gentry-Vaikuntanathan (BGV) scheme for integer arithmetic
- ✓ Cheon-Kim-Kim-Song (CKKS) scheme for real-number arithmetic (includes approximate bootstrapping)
- ✓ Ducas-Micciancio (DM) and Chillotti-Gama-Georgieva-Izabachene (CGGI) schemes for Boolean circuit evaluation

OpenFHE also includes the following multiparty extensions of FHE:

- ✓ Threshold FHE for BGV, BFV, and CKKS schemes
- ✓ Proxy Re-Encryption for BGV, BFV, and CKKS schemes

OpenFHE complies with the HomomorphicEncryption.org post-quantum security standards for homomorphic encryption. We offer OpenFHE under the 2-clause BSD open-source license, making it easier to wrap and redistribute OpenFHE in products.

OpenFHE is generously supported by DARPA. OpenFHE is a community-driven open-source project developed by a diverse group of contributors from both industry and academia, including Duality, Samsung, Intel, MIT, UCSD, and others. Google Transpiler [2] uses OpenFHE as an FHE backend. OpenFHE is formally affiliated with the NumFocus stable of open-source software projects.

## New Features as Compared to PALISADE

Includes all prior FHE functionality of PALISADE.

Also includes the following new features:

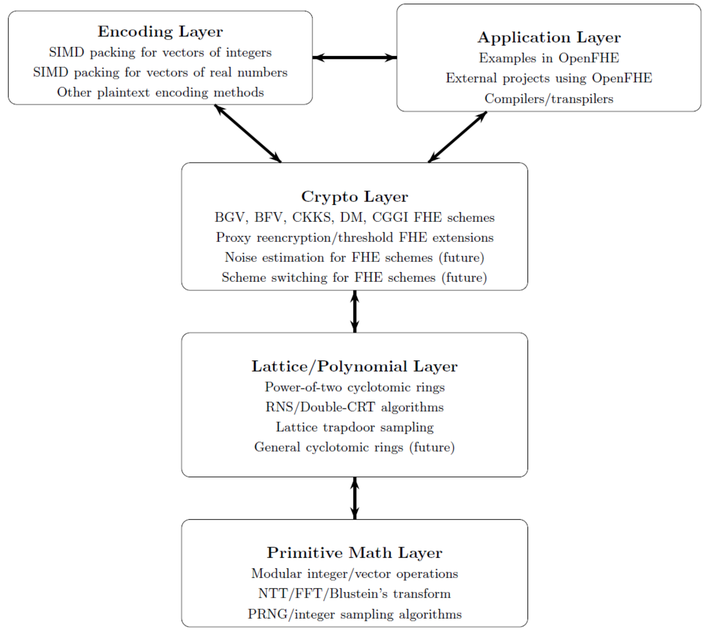
- ✓ Adds support for multiple hardware acceleration backends using a Hardware Abstraction Layer feature; includes a backend for Intel HEXL library [3]
- ✓ New BGV and BFV RNS variants proposed in [4]
- ✓ A new CKKS RNS variant proposed in [5]
- ✓ A full RNS implementation of CKKS bootstrapping
- ✓ Large-precision comparison and other algorithms proposed in [6]

## OpenFHE Scheme Support Matrix

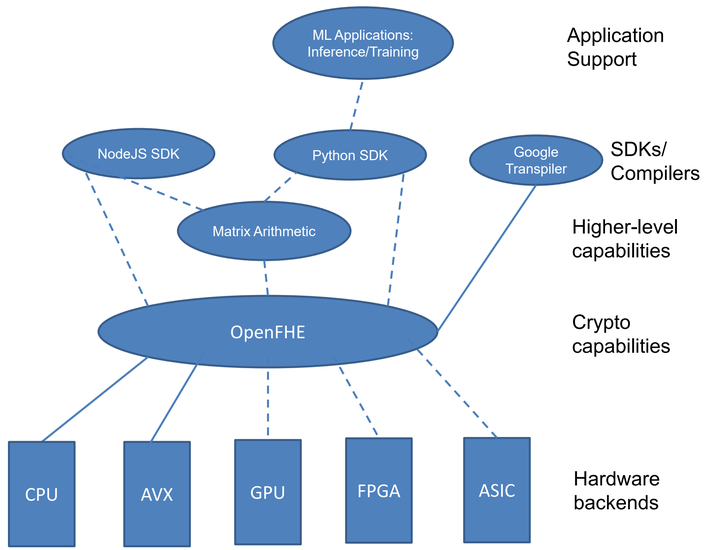
| Library/ Scheme or Extension | BGV | BGV Bootstr. | BFV | CKKS | CKKS Bootstr. | DM | CGGI | Threshold FHE (MP) | PRE (MP) |
|---|---|---|---|---|---|---|---|---|---|
| Concrete | | | | | | | ✓ | | |
| **FHEW** | | | | | | ✓ | | | |
| **HEAAN** | | | | ✓ | ✓ | | | | |
| **HELib** | ✓ | ✓ | | ✓ | | | | | |
| Lattigo | | | ✓ | ✓ | ✓ | | | ✓ | |
| **OpenFHE** | ✓ | * | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **PALISADE** | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| SEAL | ✓ | | ✓ | ✓ | | | | | |
| TFHE | | | | | | | ✓ | | |

* - prototype exists, but not part of release

## Layers in OpenFHE (Contributor View)




## Broader OpenFHE Community (User View)




## Further Information

Main resources and links for OpenFHE:

- ✓ OpenFHE design paper: https://eprint.iacr.org/2022/915
- ✓ OpenFHE website: https://openfhe.org
- ✓ ReadTheDocs documentation for OpenFHE: https://openfhe-development.readthedocs.io/en/latest/
- ✓ OpenFHE development repository: https://github.com/openfheorg/openfhe-development
- ✓ OpenFHE github organization where various OpenFHE-dependent projects are housed: https://github.com/openfheorg
- ✓ Community Forum for OpenFHE: https://openfhe.discourse.group/

## Contact

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## References

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