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Ion-Detect

Integrated detection system for ion trap quantum computers

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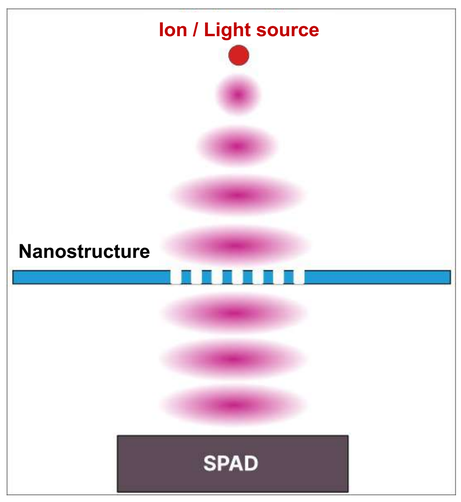
1 Detection systems for ion traps

- Ion trap quantum computers are currently limited to several tens of qubits. For industrial applications, this number needs to be increased further while maintaining high fidelities.
- Requirement for detection systems to support the increasing number of qubits and ensure high read-out fidelities.
- (Ion trap) quantum computers usually rely on bulky detection systems which consist of a set of lenses, slits and a light-sensitive camera.
- However, these camera-based systems are limited in terms of photon collection efficiency, are not scalable and cannot be integrated into chips for ion trap.

→ Innovative approaches required.

2 Innovation

- Miniaturisation of the detection system.
- Single photon avalanche diode (SPAD) as a low-light detector.
- Optical nanostructures for two purposes:
  1st: Collimating light emitted by ions to increase numerical aperture.
  2nd: Filter for other wavelengths than the signal wavelength of the ions.
- Application in cryogenic environment.
- Scalable and chip-integratable approach for an ion trap quantum computer detection system.

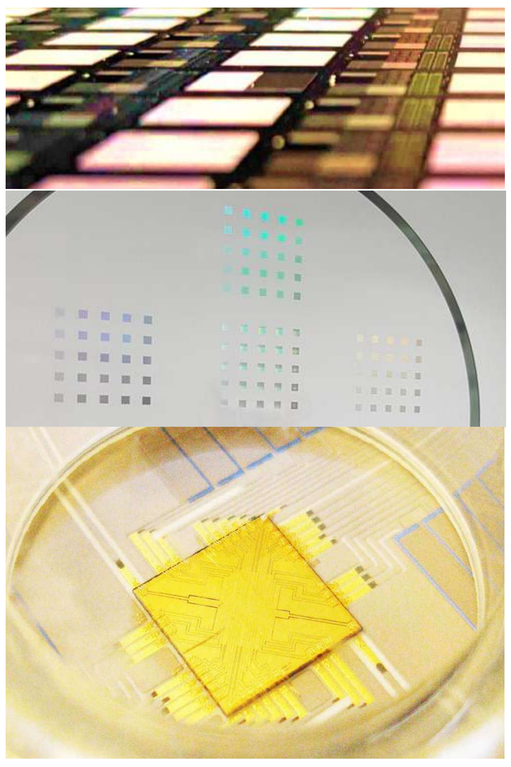


Specification	Value
Wavelength	369.5 nm
Operating temperature	10 K
Photon Detection Probability (SPAD)	70 %
Numerical aperture (Nanostructure)	0.4
Focal length (Nanostructure)	100 - 400 µm

3 Future performance profile & skills of the project partners

Fraunhofer IMS and Fraunhofer ENAS
- IMS: Expanding expertise in SPAD (Single-Photon Avalanche Diodes) at cryogenic temperatures.
- ENAS: Enhancing know-how in the design and fabrication of nanostructures.
- Objective: Joint development of SPAD detectors and integrated optical components.
- Collaboration: Broadening R&D offerings for optimized and innovative detection systems.

eleQtron GmbH
- Focus: Highly integrated and scalable ion traps for quantum computing.
- Scalable Detection System: A key component for compact, high-qubit systems.
- Benefits:
  - Improved overall qubit fidelity.
  - Enhanced product quality through precise detection systems.



4 Prospects

- Scalable detection system will be integrated into future products of eleQtron and further projects with ENAS & IMS are being pursued.
- Advancements in the fields of spectroscopy for, e.g., medical applications or hyperspectral imaging are expected.
- Manufacturing technologies for integrated detection systems with a broad applicative character for low light imaging or other precise measurement tasks using light.

Although the cryogenic environment is very specialized, the demand for a high integrated solution based on silicon technologies is a promising field of microelectronics and demonstrates that added value is created when multiple competencies are combined.

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