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WaveCarrier

Electro-Optical Chip-Carrier for Ion-Traps in Ultra High Vacuum Environment

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1 Electro-optical Chip-Carrier

Ion traps are a promising technology for quantum computing due to the long coherence time of spin qubits and the ability to manipulate and control individual qubits with high precision by means of laser radiation. However, ion-trap quantum computing processors require numerous **electrical connections and access for multiple optical channels**.

- Scaling up quantum processors to higher number of qubits increases space requirements for beam guidance.
- Integrated optics solutions for laser access reduce size and increase robustness of the processor.
- Integrating the optical waveguides into the electrical chip-carrier allows further miniaturizing and scaling of ion-trap quantum processors.
- Current research on optical waveguides focuses on fabrication independent of the electrical chip-carrier with various material combinations for different wavelengths.
- Especially UV and visible light (e.g. 532nm) experience high optical losses on current waveguide platforms.

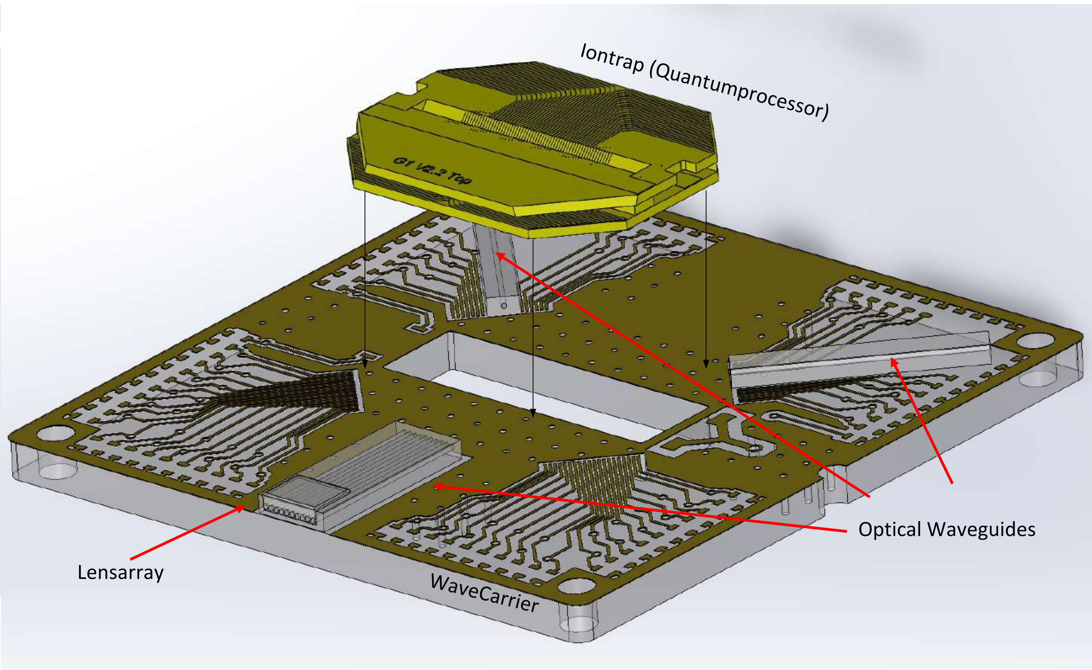
2 Innovation

With **glass as the chip-carrier material**, electrical and optical connections can be integrated onto one monolithic platform.

- Through glass vias (TGV) enable electrical connection and heat dissipation through the glass. The surfaces of the **metallized glass substrates** allow soldering and wirebonding of the ion trap.

- **Ion-exchange (IoX) waveguides** can be buried under the glass surface but need to be developed for single mode operation at 532nm wavelength. The light out of the waveguide will be **collimated with lenses** made by selective laser assisted etching (SLE) followed by fine-polishing with a CO_2 laser.

- Dependence of the waveguide on **temperature cycling to 150°C** for several days during vacuum bakeout will be studied. Also, the risk of failures due to different thermal expansion of ion trap and electro-optical chip-carrier will be investigated and mitigated by the choice of glass.



3 Future performance profile & skills of the project partners

Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration (IZM)
The core competence of the Fraunhofer IZM is the development of innovative packages for components and systems in microelectronics, photonics and microsystems technology. IZM is a development partner for customers from the communications technology, sensor technology, consumer industry, medical technology and laser technology sectors for hybrid integrated prototypes and small series based on various materials (polymer, glass, ceramic, glass fiber and silicon) in panel and wafer-level manufacturing processes, which are operated and further developed on the latest systems with maximum precision. The automated systems used ensure cost-effective scalability and transferability to industrial production.

Johannes Gutenberg-Universität Mainz
The group of Ferdinand Schmidt-Kaler at JGU Mainz is involved in the development and operation of ion-based quantum computers. This also includes a fully equipped clean room for glass-based 3D ion trap production using laser structuring, metallization and assembly. With more than 30 years of experience in the field of quantum technologies and within the framework of various publicly funded projects, the group is already researching the integration of compact addressing units and optical elements into the ion trap for future scaling of the qubit number, yet requires individual components for assembly.

4 Prospects

- Further development on the chip-carrier design may allow additional wavelengths and beam geometries.
- Thermal cycling in an extended temperature regime might be possible by additional investigation of substrate material for waveguides and ion trap.

- The electro-optical chip-carrier could set new standards with innovative chip-carrier technologies.
- A combination of electrical and optical connections on a glass substrate could significantly contribute to developments in quantum technologies, e.g. photonics systems for computer-, sensor- and communication applications.
- Integrated optical circuits for green laser light offers an alternative for beam guiding in e.g. NV-colorcenters.

- Fabrication of glass substrates provide a cost effective solution compared to silicon for prototypes to small series production

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