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Novel ion trap with fibre cavity integration

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The ion trap serves as a quantum platform with the potential to facilitate the realization of a scalable, fault-tolerant quantum computer, coupled with a straightforward photonic interface for connection to the so-called quantum network. In this system, multiple ions can be trapped within a single trap and individually controlled via laser manipulation. However, practical implementation faces several challenges, including low photon collection efficiency. Addressing this issue, integrating an optical cavity and establishing strong coupling with the ions in the trap emerges as a potent solution[1], aligning with our ultimate objective.

In this study, we have designed a prototype of a monolithic trap, characterized as a linear Paul trap. Notably, the trap can be monolithically fabricated, with the blades supplying distinct electric signals being insulated from one another through a trench structure.

The first trap has been fabricated using the selective laser etching method (SLE). Subsequently, we successfully endeavoured to trap both individual ions and ion chains within the trap and are currently engaged in the process of acquiring ion spectroscopy data.

However, during the implementation, several potential improvements are spotted, thus, the second generation has started to be designed.

In the second-generation trap, a significant modification involves the central section, where the endcap transitions into a spherical shape to enhance DC trapping efficiency. Additionally, four DC compensation blades have been incorporated to counterbalance the effects stemming from the cavity substrate. Comsol simulations on the trapping potential have been conducted to determine optimal compensation voltage and the distance between the blade and ion axis.

Furthermore, due to the reduction in the number of cavity modes resulting from the decreased mode volume, the size of the trap has been scaled down to approximately 1cm x 1cm, allowing for closer placement of the cavity mirrors. Another benefit of this reduction in size is the ability to shrink the cavity substrate accordingly, thereby enhancing the mechanical stability of the cavity system.

Moreover, the intricate wiring required to transmit electric signals via the feedthrough from outside of the chamber will be replaced by a neat printed circuit board (PCB) positioned beneath the trap itself. This PCB comprises two copper layers insulated by a dielectric layer, and the trap will be wirebonded to the PCB using gold wires. To create additional space for optical access, we intend to implement a type of PCB known as a rigid-flex PCB. In this configuration, the rigid part mirrors a standard PCB, while the flexible part, composed of polyimide, is foldable.[2] Leveraging this foldable feature, multiple dimensions within the chamber can be utilized to construct the most suitable configuration for laser beam alignment.

As of the conference date, the fabrication of the prototype for the second-generation trap is anticipated to be completed, as well as the final assembly with the new PCB.

[1]Takahashi, Hiroki, et al. "Strong coupling of a single ion to an optical cavity." Physical review letters 124.1 (2020): 013602.
[2]Sterman, Yoav. PCB Origami: Folding circuit boards into electronic products. Diss. Massachusetts Institute of Technology, 2013.

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