D 4.1 Fabrication and operation of a 2-d trap including a resonator for strong microwave coupling

UOS and, in analogy for non-superconducting resonators, USIEG considered the following goals while designing the ion trap chips that include superconducting resonators.

1. Choice of a low loss substrate.
2. The superconducting resonator should fit well within the ion trap architecture without demanding any additional space.
3. The resonator must be a high Q resonator.
4. The line impedance of the resonator across its length must be close to 50 Ω and must match with the impedance at bond pads.
5. The thickness of the electrodes must be higher than the skin depth of MW at 12.6 GHz.

To achieve the above listed points the implementation of a hybrid of strip line type and coplanar waveguide (CPW) type resonator on the ion trap chip was explored. Analytical calculations were made to obtain key parameters for the resonator such as the line impedance, skin depth, resonator length, scattering parameter, resonant frequency and Q factor. Using commercially available finite element simulation software packages such as Microwave Studio (MWS) of Computer Simulation Technology (CST), the key parameters of the resonator were accurately estimated and compared to the results obtained by analytical calculations.

USIEG finalized fabrication and mounting of a planar chip design intended for the creation of a coupling between trapped ions induced via magnetic gradients (MAGIC). A gradient structure leads to a position depending Zeeman splitting of the hyperfine structure of the ^{171}Yb ion. Together with the external trapping potential the combined levels have different equilibrium positions. A change of the internal state of an ion initially at rest leads to an oscillation as the ion is now displaced from the new equilibrium position, mimicking a momentum transfer which can be expressed as an effective Lamb-Dicke-parameter. An effective spin-spin coupling between different ions within a Wigner crystal is mediated via Coulomb repulsion.

CUB have designed, built, and characterize an integrated supererconducting qubit/ion chip. We have found that quality factor of superconducting resonator is considerably influenced by its coupling to rf and dc electrodes of ion trap but the quality factor was increased by one order of magnitude by proper design from $Q{\sim}10^3$ to $Q{\sim}10^{4.}$

The deliverable has nearly been fulfilled by the scheduled time (month 18). The process design is ready since February 2013. Fabrication has been delayed in order to allow for immediate inclusion of microwave resonator in the Niobium ion chip.