Motivation

In a Paul trap, ions are trapped by using a combination of strong alternating and static electric fields. One of the trap designs contains ten electrodes for the static potential and one electrode for the quadrupole RF signal with a frequency of about 100 MHz and an amplitude of up to 100 V [1]. To provide such high voltages without introducing heat into the cryogenic system, a common solution is to amplify the voltage close to the trap using an RF resonator. Such a resonator needs to have a coil with a high Q-factor and its impedance has to be matched to the wave impedance of the feedlines.

Development goals
• Control of the impedance matching from outside the cryostate
• Satisfying matching with varying trap design
• High Q-factor

Electronics

The development of the resonator and the matching network is based on the circuit model shown in Fig. 1. The series resonator contains a coil made from silver wire and the capacitance of the trap itself.

- Impedance matching with a simplified L-network [2] [3]
- Capacitance parallel to the series resonator
- Varactor-diodes (Fig. 2)
- Offset-diodes with fixed value (not visible in Fig. 2)

Components

- Varactor-diodes D1...8 (MA46H204)
  - Controllable capacitance by DC-voltage VBias
  - Dynamic range of 3.7 pF – 23.4 pF at room temperature
  - ‘Back to Back’ connection for the linearization of the voltage–capacitance ratio
- Voltage source VBias
  - DC-voltage 0 V – 20 V
- Coils L1,2,3 and capacitors C1,2
  - Decoupling of the RF and DC-circuit

Measurements

Power reflection

To determine the matching, a VNA was used to record the S11 parameter. Fig. 3 shows the matching at room temperature as a function of the DC voltage. The capacitance of the matching network for VBias = 0 … 20 V is approximately 263.4 … 243.7 pF.

With a process explained in [1], the Q-factor of the resonator can be calculated with the S11 parameter. This resonator has a Q-factor of 173.

Power transmission

- Nonlinearity of the varactor-diodes causes harmonics of the resonance frequency
- Magnetic fields with frequencies of f > 1 GHz could disturb the quantum state of the qubits

The signals were measured by exploiting the crosstalk between the RF electrodes and one of the microwave guides on the trap chip. The calculation of the values was possible with the transmission function, that was also measured with a VNA. The results are shown in Fig. 5.

References