Visit at SNS Pisa in September 2003

We visited the SQUBIT-funded group at the Scuola Normale Superiore in Pisa, headed by Rosario Fazio, with which we share common interest in qubits coupled to resonators and in coupled qubits (Michele Governale). The visit was timed to coincide with the SQUBIT meeting. On both days of that meeting experimental and theoretical work was presented and reviewed. The workshop updated our view on experiments, gave us the opportunity to present and discuss our own work and to establish collaborations with workshop participants.

- Talks on experiments

General summary

The different experimental groups that participate in SQUBIT/SQUBIT 2 gave updates on experiments regarding both flux and charge qubits. Moreover, readout schemes and design issues were discussed intensively and different techniques to manufacture Josephson junctions were proposed. In the following the major topics will be mentioned in more detail.

Main topics

Tim Duty/Per Delsing (Chalmers U) presented their current progress with superconducting charge qubits. They are not able to perform single shot readout yet but performed spectroscopy of the energy levels of the Cooper pair box. The decoherence is mostly due to 1/f-noise in these systems. Decoherence times are estimated from experiments to be $T_1 \approx 250$ns and $T_2 \approx 150$ps.
The pulse lengths for fast DC pulses are around 100ps in their case.

Eddy Collin/Gregoire Ithier/Denis Vion (CEA Saclay) presented modifications to the Quantronium experiment where they modified the E_J/E_C ratio from around 1.3 in the first experiments to 4.0 and observed many spurious resonances so that they again choose the former design for further experiments. Moreover, the readout scheme was improved by clever biasing methods that increase the visibility from 22% to 32% and a design to couple two Quantronium Cooper pair boxes capacitively to perform two qubit gates at the "double" magic point was envisaged.

Irinel Chioréscu (TU Delft) explained their latest flux qubit design that now includes quasiparticle traps and heat sinks to decrease the high frequency noise. The main improvement is to increase the kinetic coupling and use larger SQUID junctions so that the measurements give clearly separated histograms corresponding to the |0> and |1> states.
Evidence for local two-level fluctuators, e.g. a two-level fluctuator in the barrier was shown.

Alexander Zorin/Martin Goetz (PTB Braunschweig) showed their design of single electron transistors with Al/AlOx/Nb and Nb/AlOx/Nb junctions as devices to read out qubits. The design of the charge-phase qubit that is coupled to a tank circuit was described in detail and analyzed theoretically.

- Talks on theory

General summary

The interaction of Josephson qubits with cavity QED modes, where the resonator is a quantum bath, was investigated. Here, the decoherence and possible topological protection from decoherence is shown.
Decoherence due to coupling of a qubit to a bistable impurity can be described with Spin-Boson theory and is modeled by a qubit that is coupled to a spin, which is coupled to a bath of harmonic oscillators.

A controllable coupling of phase interacting charge qubits that leads to a $\sigma_x^1 \otimes \sigma_x^2$-type of interaction was introduced.
Ground state quantum computation that is closely connected to the geometrical Berry phase was presented.
Dynamic decoupling of structured environments, i.e. a bang-bang scheme, averages out noise at frequencies $\omega << 1/\Delta t$. It was shown that the system can still be described by master equation techniques and an analytic expression that describes the evolution of the system density matrix was given.

Discussions/Collaborations

We discussed with Göran Johansson (U Karlsruhe) who talked about "A qubit coupled to a damped harmonic oscillator at intermediate temperatures". This work is motivated by recent work that studies cavity QED in superconducting devices. For weak dissipation this problem is treated with Bloch-Redfield formalism. Especially the validity of the secular approximation in the Redfield approach was illuminative. We have extensively elaborated on our own work on the same problem at zero temperature, which uses the noninteracting blip approximation and the flow equation renormalization method.

Antti Niskanen (Helsinki UT) presented work that determines optimized gate sequences to perform quantum algorithms. These simulations were done without taking decoherence into account. Thus, we established a collaboration to utilize our own work (see below) on coupled qubit systems to find optimized quantum algorithms incorporating the effects of decoherence.

Giuseppe Falci (U Cataina) presented an analytical study of decoupling a qubit from telegraph noise at the pure dephasing working point, which was directly inspired by our own previous work. We discussed the mutual benefit and a possible collaboration on comparing both approaches.

We have discussed the scenario of initial slippage (see below) with Tim Duty and came to the conclusion, that the Chalmers experiments probably observe the slippage regime.

- Presentation of our own work

Frank Wilhelm: "*Refocusing qubits exposed to telegraph noise using quantum bang-bang*"

Frank Wilhelm: "*Reasons for the lack of visibility in current qubit experiments*"
Here, different reasons for the lack of signal were discussed. Namely,

- non Markovian behaviour,
- short time behaviour/initial slippage,
- the initial condition that $\rho_S \otimes \rho_B$ holds.

Markus Storcz: "*Optimizing the gate performance of coupled solid-state qubit systems*"
Here, we discussed the importance of symmetries to improve the gate performance of systems of serveral coupled qubits. We presented simulations of two coupled qubits where the coupling of the bath commutes with the Hamiltonian of the controlled phase-shift operation and thus leads to an improved gate performance and decoherence free subspace encoding schemes to overcome decoherence effects.
During the ensuing discussion zero-temperature fluctuations and flipless dephasing were further discussed.

Markus Storcz: "*Design of realistic switches for coupling superconducting solid-state qubits*"
We presented a scheme to couple two superconducting flux qubits inductively via a superconducting flux transformer with different switches for the coupling. The noise properties of different switches were estimated quantitatively. There was some discussion regarding technical implementations of these switches.

Overall the presentations gave us the opportunity to present, discuss and furhter develop our work on superconducting qubit devices.