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Error modelling of quantum Hall array resistance standards

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Introduction

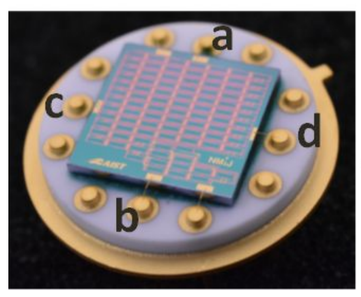
Quantum Hall array resistance standards (QHARS) are integrated devices composed of interconnected quantum Hall effect elements that allow the realization of arbitrary resistance values. The evaluation of the accuracy of a QHARS is an open problem, because of the effect of the contact and wire resistances.

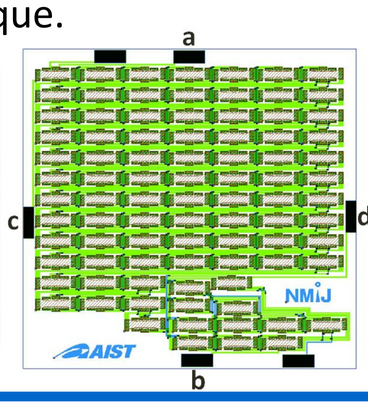
We present here a general and systematic procedure for the error modelling of QHARSs, based on modern circuit analysis techniques and Monte Carlo evaluation of the uncertainty.

This method of analysis is applied, as example, to the characterization of a 1 MΩ QHARS fabbricated by the National Metrology Institute of Japan.

1 MΩ QHARS

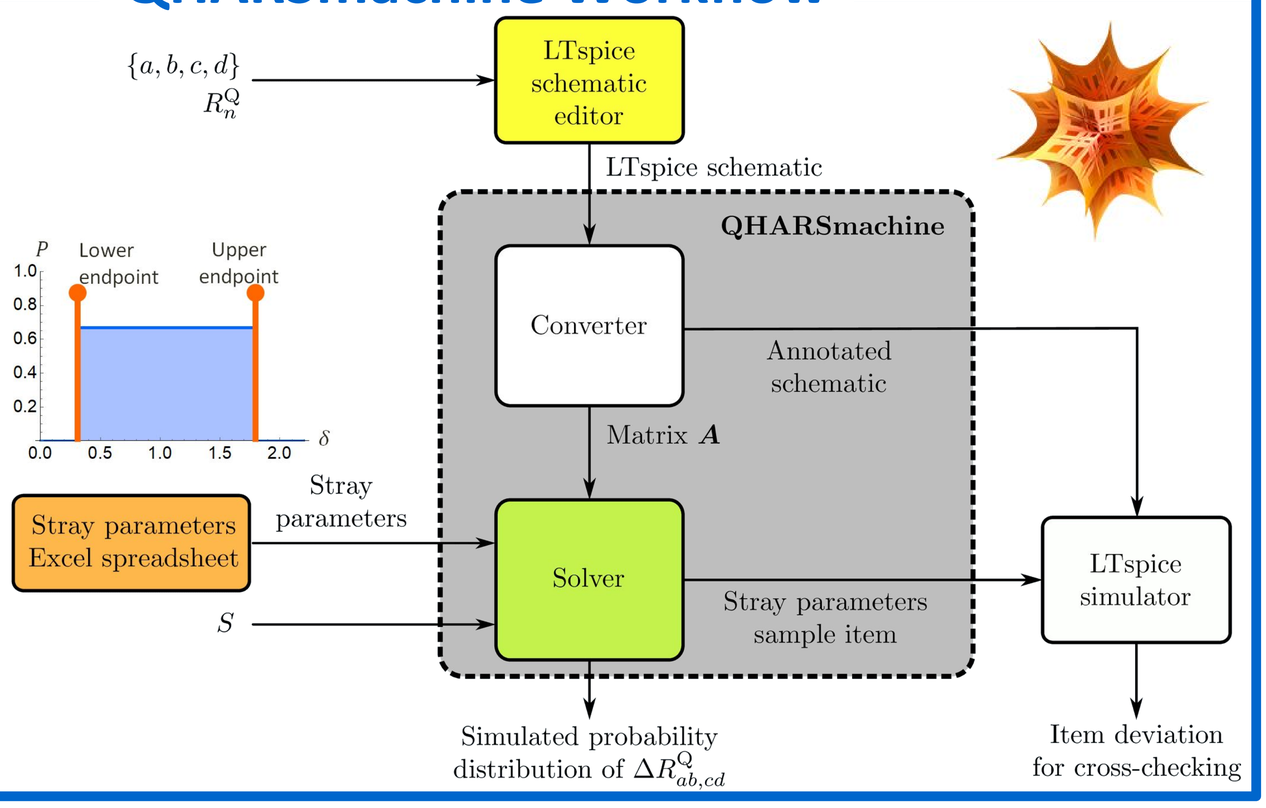
The 88 Hall bars were fabricated on a 8mm-GaAs/AlGaAs square chip using triple connection technique.



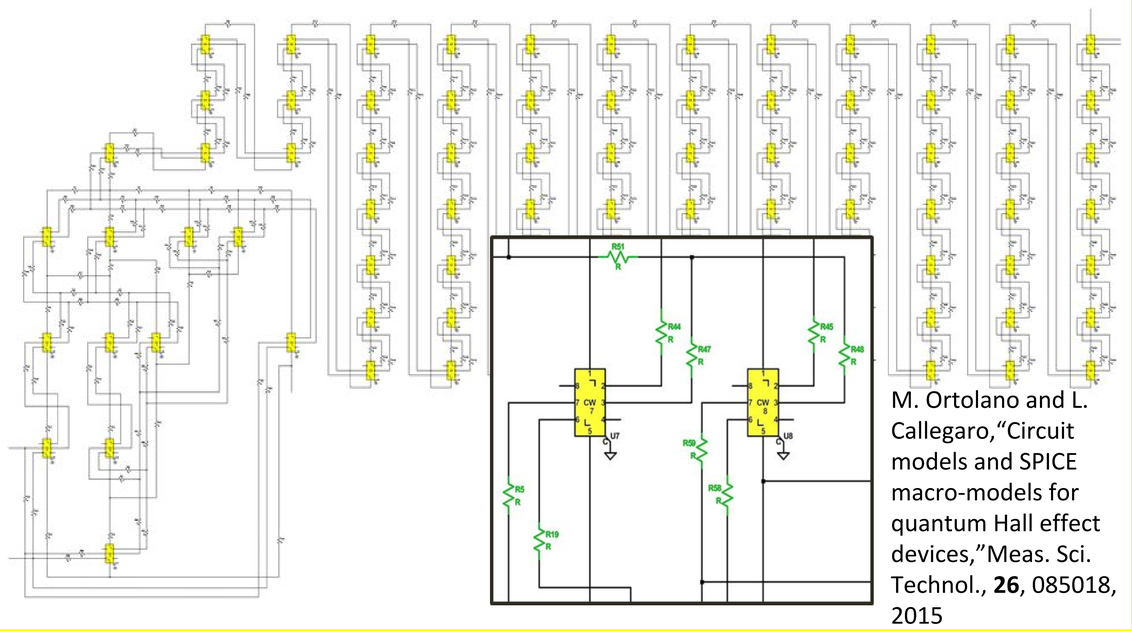


T. Oe et al., "Development of 1 MΩ Quantum Hall Array Resistance Standards", IEEE Trans. Instrum. Meas., **66**, 1475, 2017.

QHARSmachine Workflow

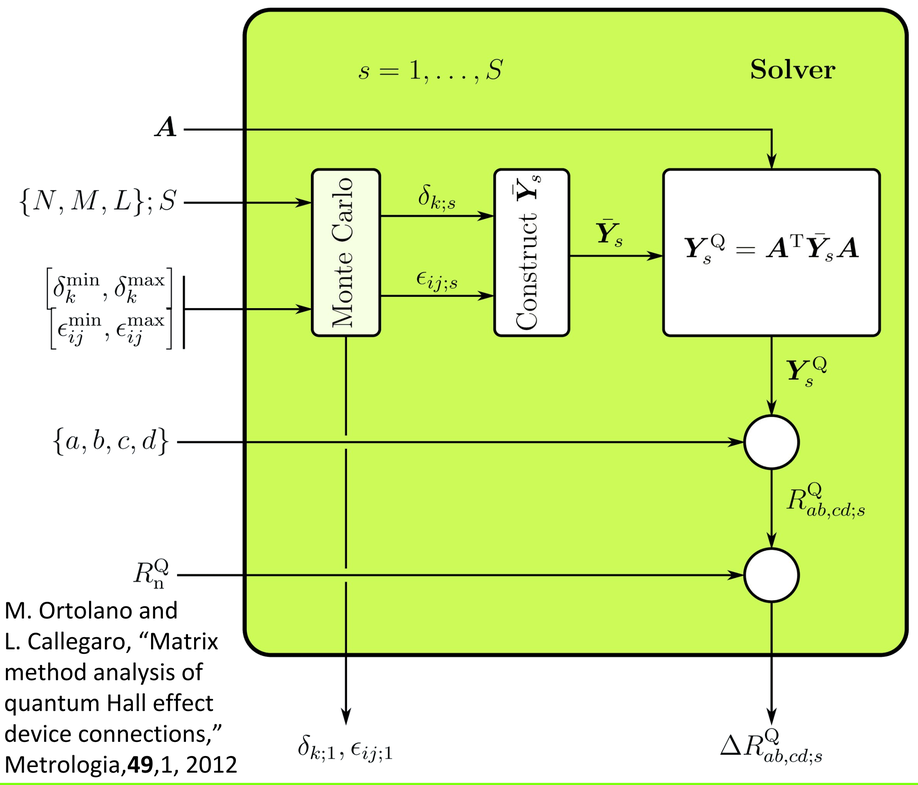


LTspice schematic 1 MΩ QHARS



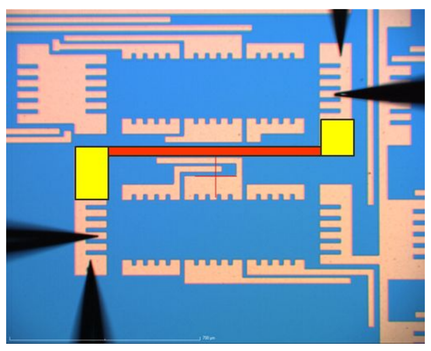
M. Ortolano and L. Callegaro,"Circuit models and SPICE macro-models for quantum Hall effect devices,"Meas. Sci. Technol., **26**, 085018, 2015

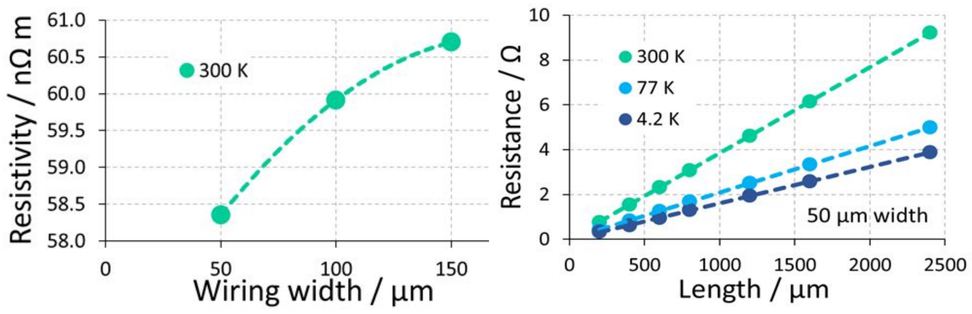
Solver



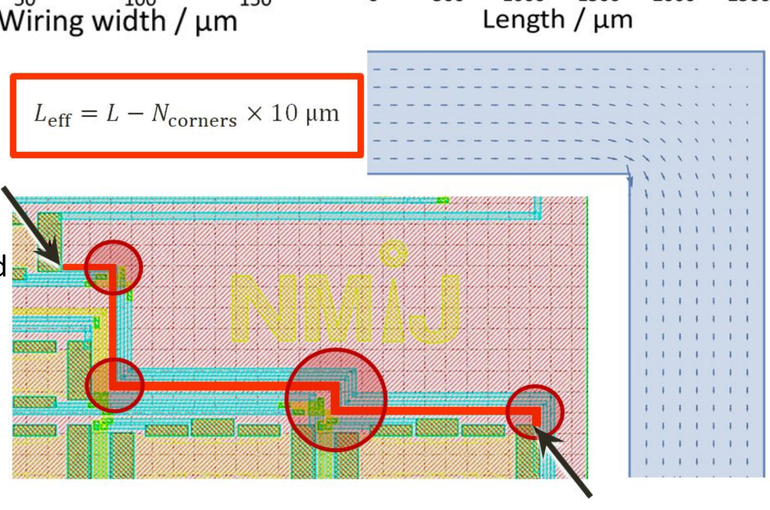
M. Ortolano and L. Callegaro, "Matrix method analysis of quantum Hall effect device connections," Metrologia,**49**,1, 2012

Wire resistances evaluation



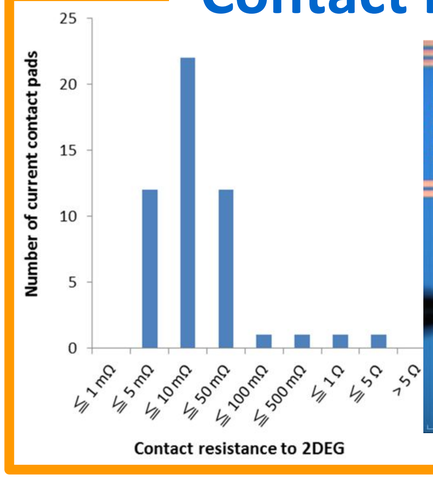


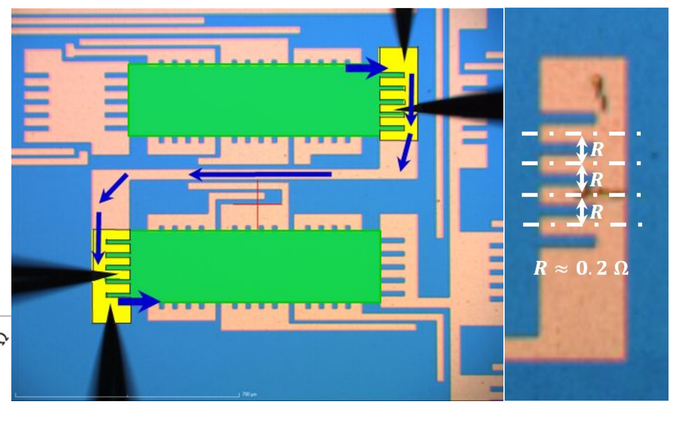
$L_{\mathrm{eff}} = L - N_{\mathrm{corners}} \times 10\ \mu\mathrm{m}$



- The resistivity at 4K of 50 μm wide wires is measured by using a test pattern. Then by fitting the resistivity obtained at RT, we scaled the resistivity at 4K for each segment width.
- We introduced a correction factor to account for the reduced resistance due to elbows along the current wires. This factor has been obtained by a finite elements simulation.

Contact resistance evaluation





The contact resistance distribution is obtained from:

- The contact resistance to the 2DEG of 25 Hall bars in the QHE regime.
- The resistance of the pad from edge to edge.

The contact resistances are negligible with respect to the wire resistances.

Result