Dependence of the disorder prediction quality on scan area size

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Since SGM data are available for a part of the sample area only, the question appears whether the disorder in the scan area can be reliably predicted from that transport information. As it seems obvious that an accurate prediction of disorder becomes impossible in the limit of vanishing size of the scan area, we investigated the locality of the relation between the SGM response and the disorder potential, and more precisely the effect of the SGM scan size on the precision of the disorder prediction.

While quantum transport is in general non-local such that disorder features in all parts of the sample can in principle influence the conductance of the sample that is measured by SGM, such effects are expected to be of reduced importance in our case, where the scan area is larger than the correlation length of the potential $l_c = 65\,\mathrm{nm}$ which itself is larger than the Fermi wavelength $\lambda_F = 49.8\,\mathrm{nm}$. Moreover, the fact that the potential is relatively smooth on the scale of λ_F, and much smaller than the Fermi energy, places us close to the semiclassical regime where the scattering mean free path $l = 168\,\mathrm{nm}$ and the transport mean free path $l_T = 18\,\mu\mathrm{m}$ are much larger than λ_F, and where a more local behavior can be expected. This is confirmed in an SGM experiment on a QPC structure with an additional reflector gate [2], where the SGM response has been measured outside the zone of the reflector gate. It has been found that the potential change that is generated when a voltage is applied to the reflector gate modifies mainly the visibility of interference fringes in the SGM response, but only very weakly the branch structure, indicating that the main structures of the SGM-response indeed depend on local properties of the sample.

The correlation length of the SGM conductance features was investigated in detail in Ref. [1] for a system containing a QPC and a reflecting circular mirror gate. It was found experimentally and theoretically that the structure of the SGM-response strongly depends on the tip strength. For strong tips, in the regime of the present paper, the SGM-response has a correlation length of the order of λ_F. A condition for a good quality of the potential prediction is therefore that the size of the scan area is well beyond the Fermi wavelength.

We have investigated the locality of the relation between the disorder potential and the SGM-response, and its impact on the precision of the potential prediction by a neural network, using simulated data where the exact disorder potential is known. Starting from the initial rectangular scan area $a \times b = 384 \times 240\,\mathrm{nm}$, we have reduced the size of the scan zone inside the full area, keeping the aspect ratio at $a/b \approx 1.7$. For each size, we have trained a neural network to determine the disorder potential inside the reduced area from the transport data in that same zone. As in the study of the experimental sample, we applied a Gaussian filter of width $\sigma = 6\,\mathrm{nm}$ on the SGM images of the test set. The training procedure is the same as the one described in Sec. 3, with a reduced pre-training set of PLDOS-potential pairs containing 60.000 samples. The precision of the obtained predictions, *i.e.* the correlation of the predicted potential with the exact disorder potential c_{ep}, averaged over the 400 samples of the test set, is depicted by the green dots in Fig. 1 as a function of the lateral size b of the scan area. $\bar{c}_{\mathrm{ep}}$ is plotted in units of $\bar{c}_{\mathrm{e_0p_0}}$ which

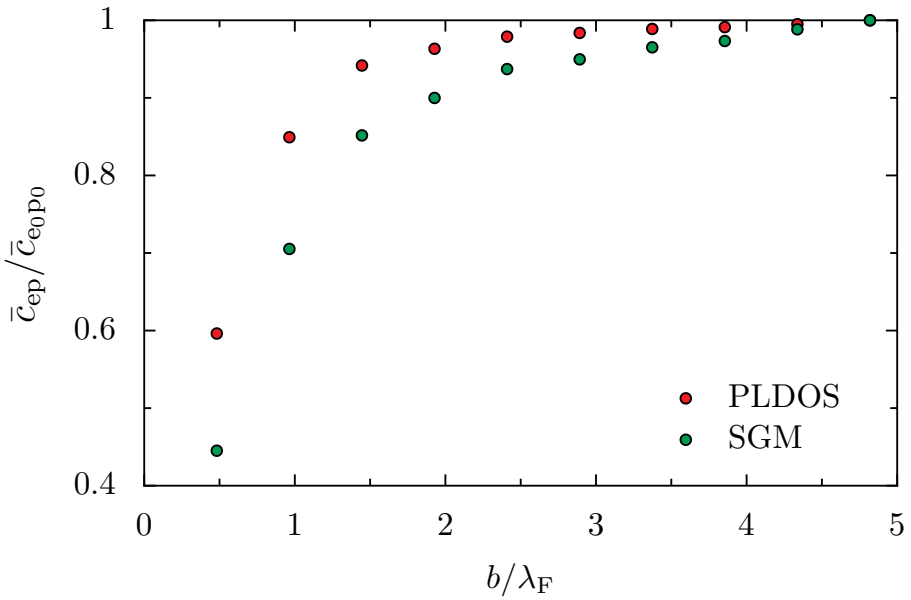

Figure 1: Correlation of the predicted potential with the exact potential as a function of the width b of the scan area.

corresponds to the performance of the neural network trained on the initial scanning zone but evaluated on the corresponding reduced area, and b is given in units of $\lambda_{\rm F}$. The quality of the potential prediction is stable and decreases only slowly with decreasing scan area while its size remains larger than a few times $\lambda_{\rm F}$. As expected, the prediction becomes unreliable for very small scan sizes and the sharpest drop of the prediction quality appears when b decreases below $\lambda_{\rm F}$.

For completeness, we performed the same study with the PLDOS images of the pre-training set. The red dots in Fig. 1 show the effects of reduced area on the accuracy of the potential prediction on the test set of 1000 samples when the PLDOS is used as input. The behavior of the accuracy evolution is similar to the prediction from SGM data, except that the loss of accuracy at smaller area is somewhat weaker when the PLDOS is used as input. This can be explained by the more local character of the PLDOS as compared to the SGM-response. The structures on the PLDOS are independent of the SGM tip and do not suffer from the invasive perturbation of the system by the tip potential nor the limitation by the finite size of the features in the SGM-response.

References

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