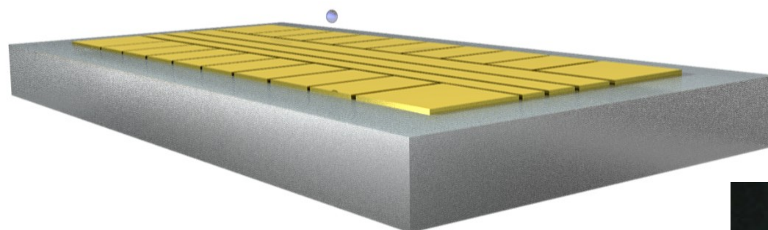
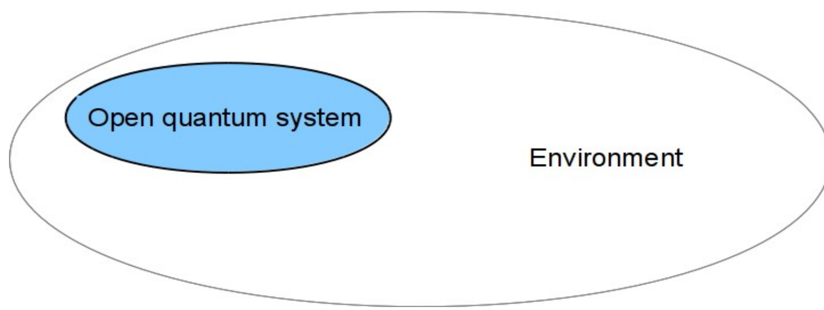
Decoherence and quantum correlations in ion traps

Hartmut Häffner, UC Berkeley

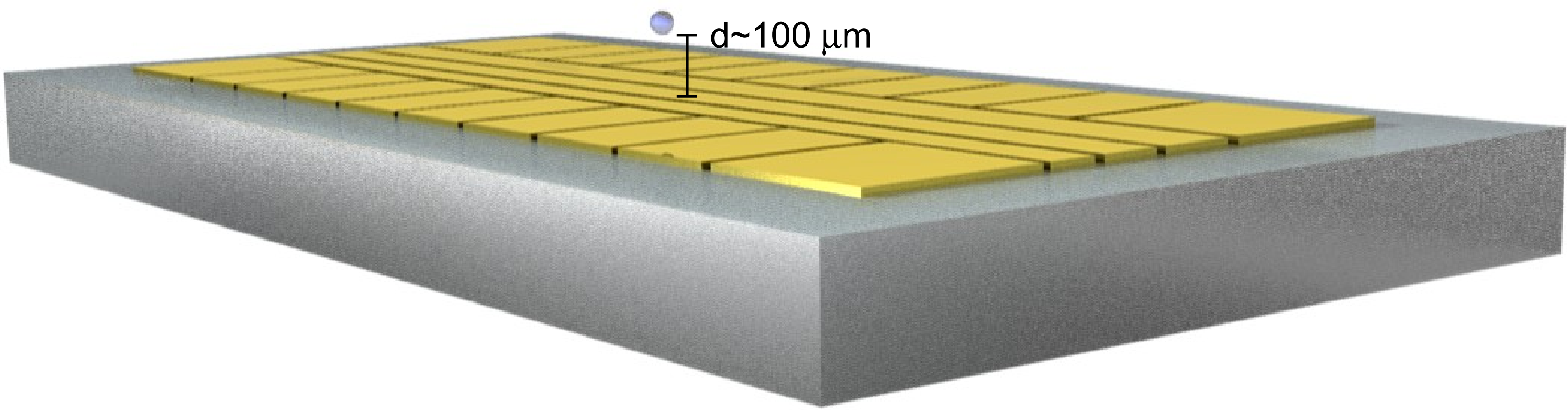
- heating rate studies with surface traps



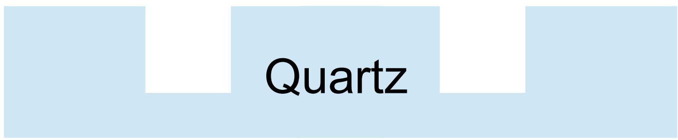
- local detection of quantum correlations



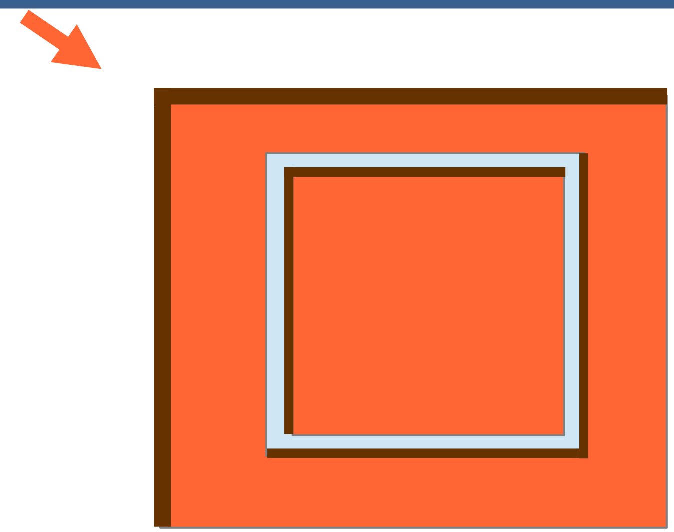
Heating rates



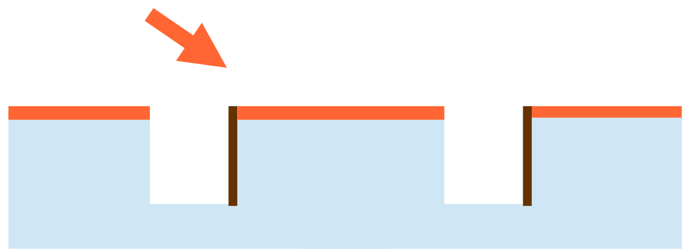
Fabrication of robust traps



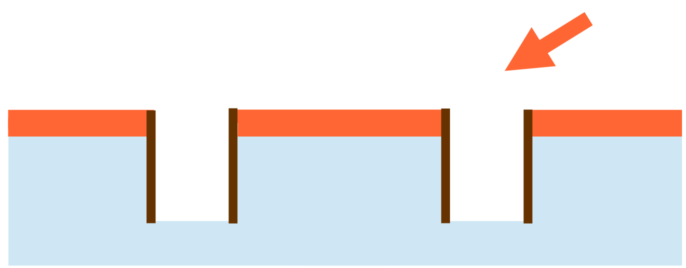
Fabrication of robust traps

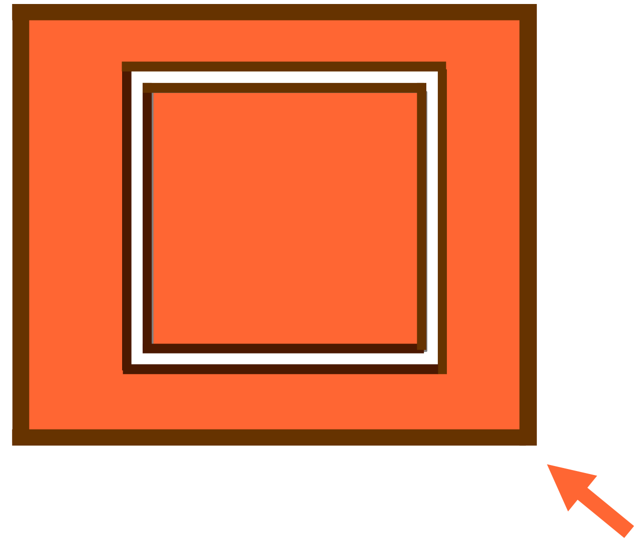


Step 1: evaporate diagonally



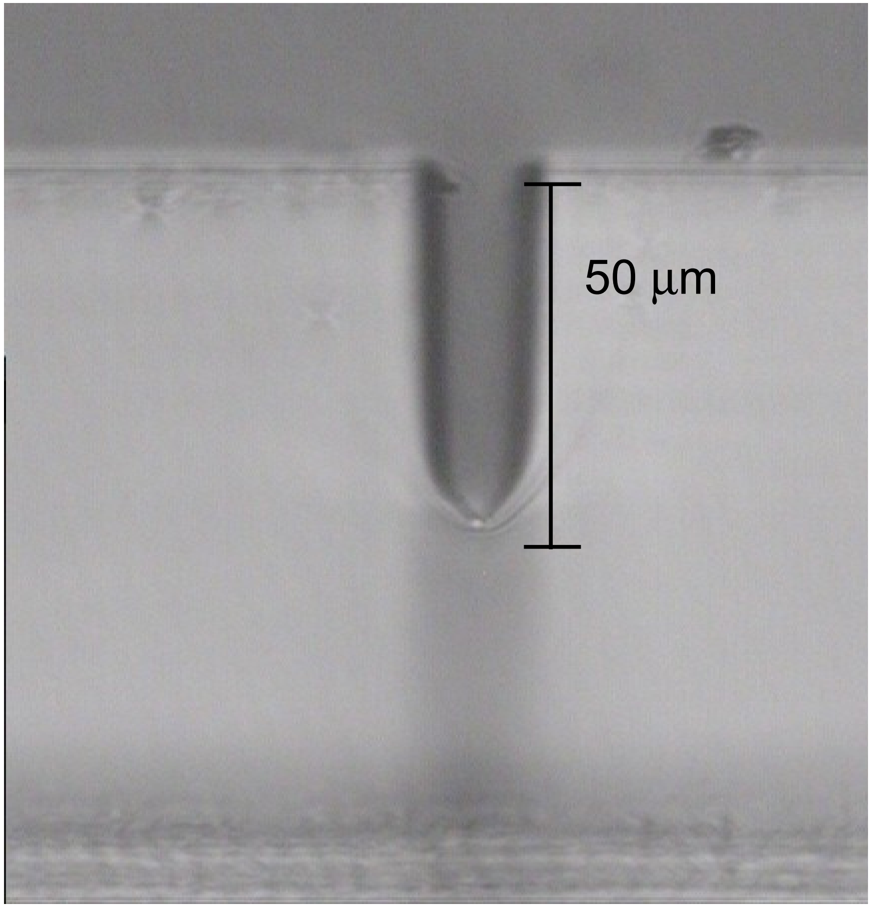
Step 2: evaporate from opposite side

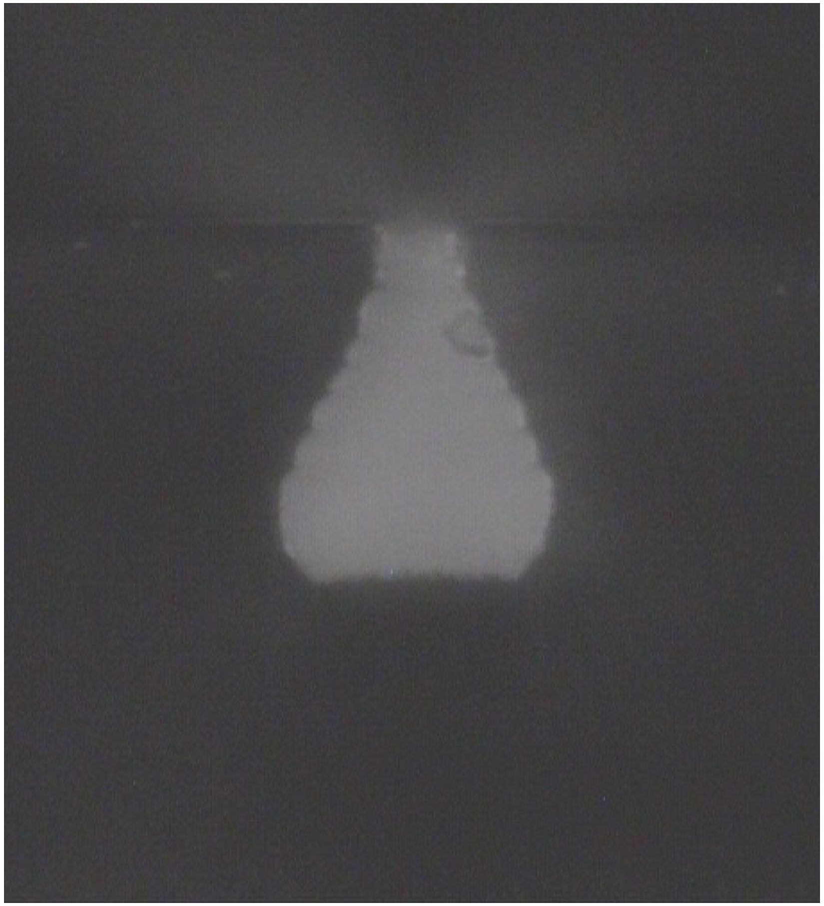




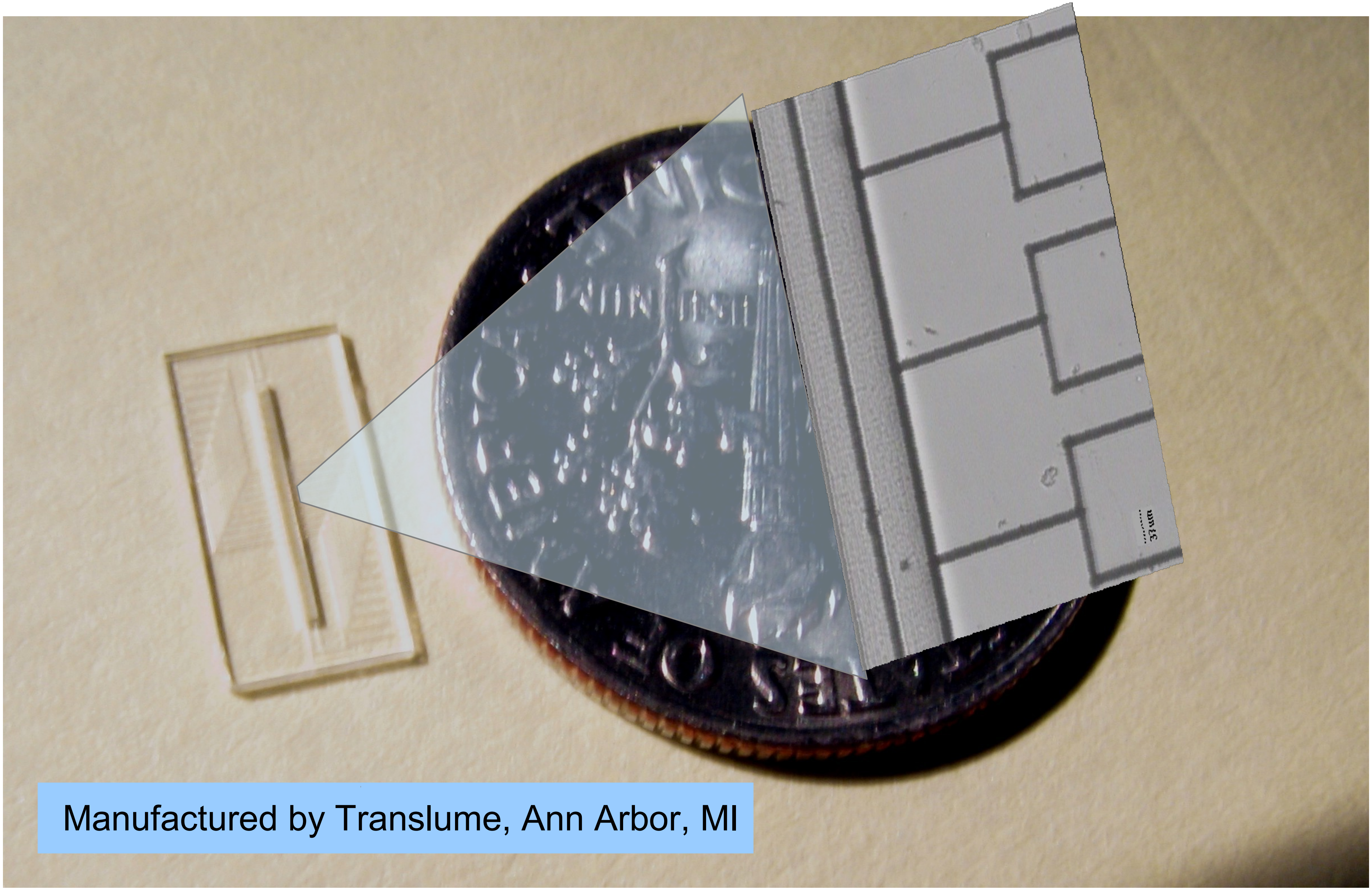
Advantages: robust, flexible materials choice, high quality films, large aspect ratio

Trenches cut/etched in quartz



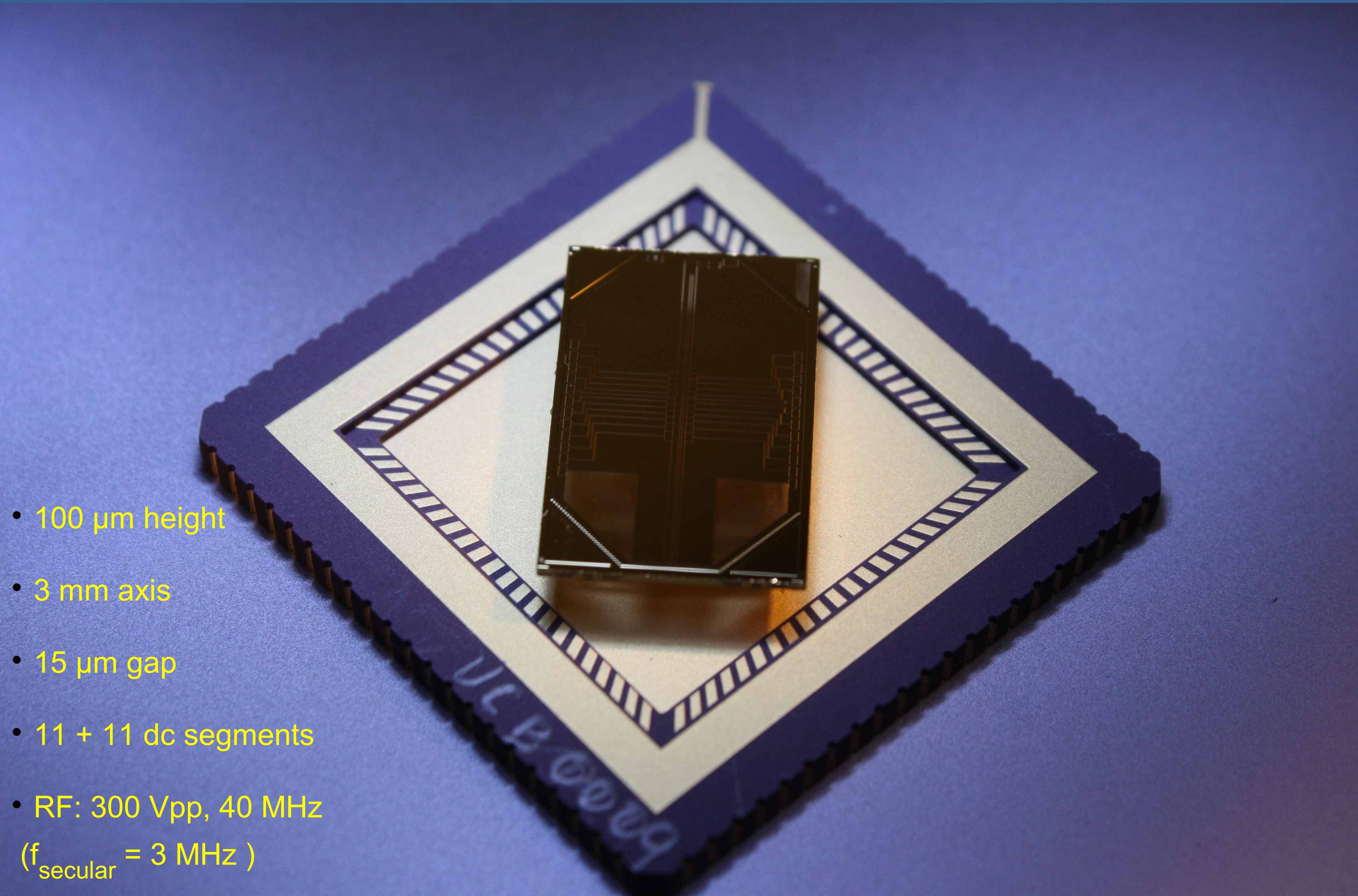


Slit traps



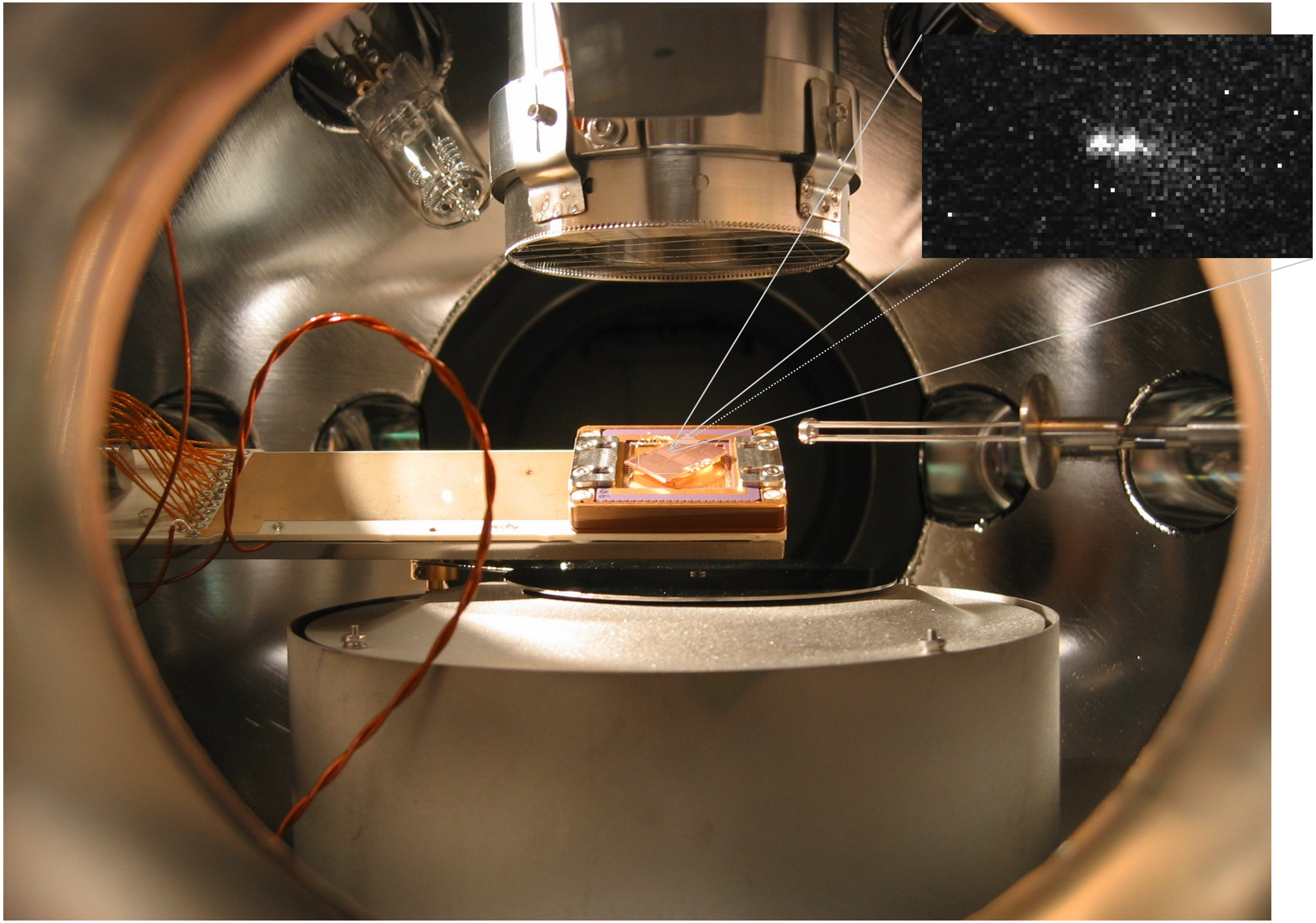
Manufactured by Translume, Ann Arbor, MI

The ion trap

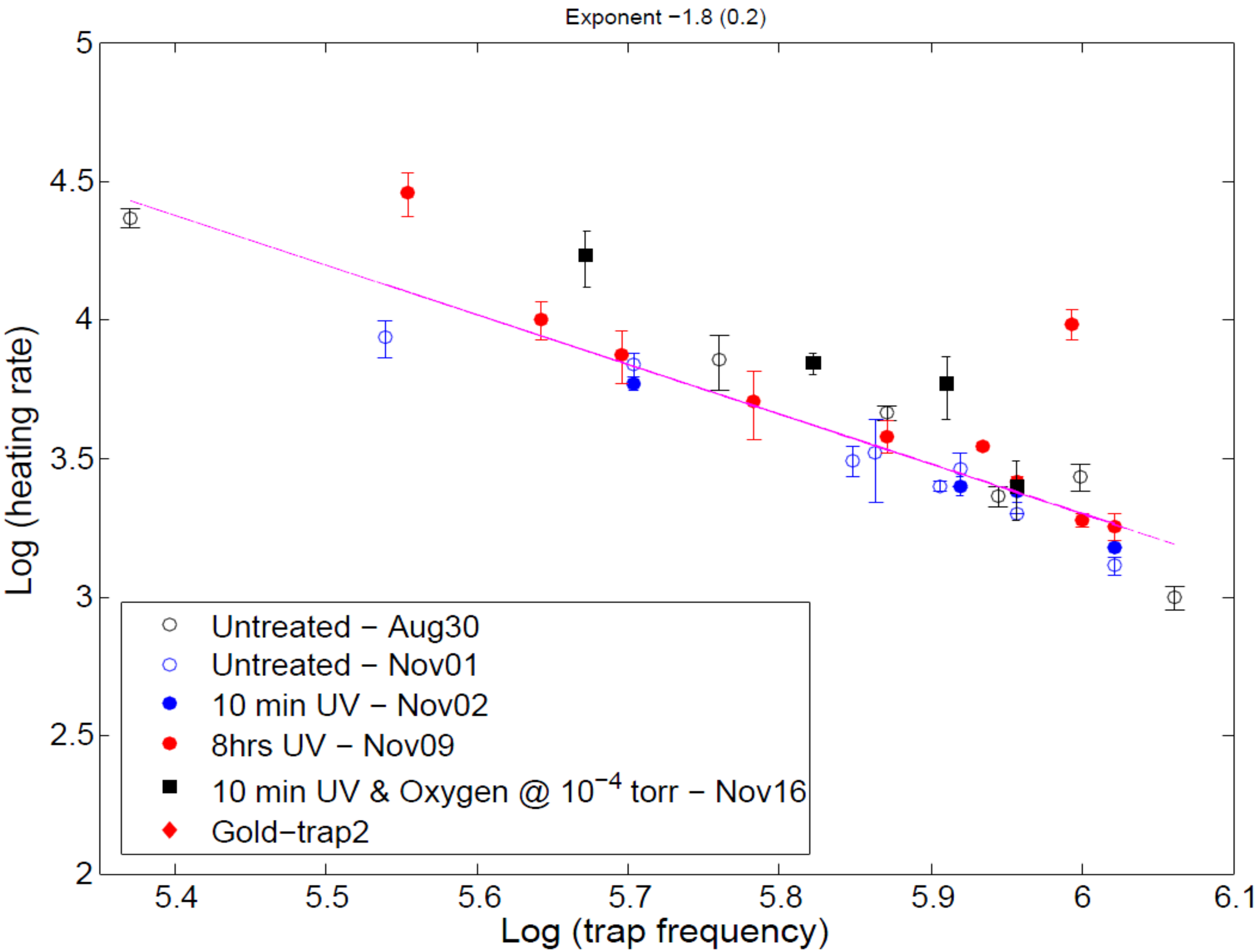


- 100 µm height
- 3 mm axis
- 15 µm gap
- 11 + 11 dc segments
- RF: 300 Vpp, 40 MHz
  ($f_{secular}$ = 3 MHz)

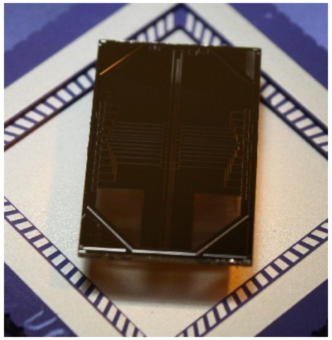
Surface science chamber

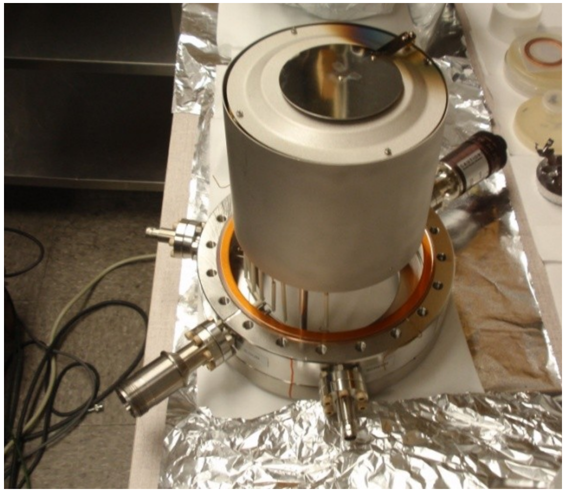


Heating rates

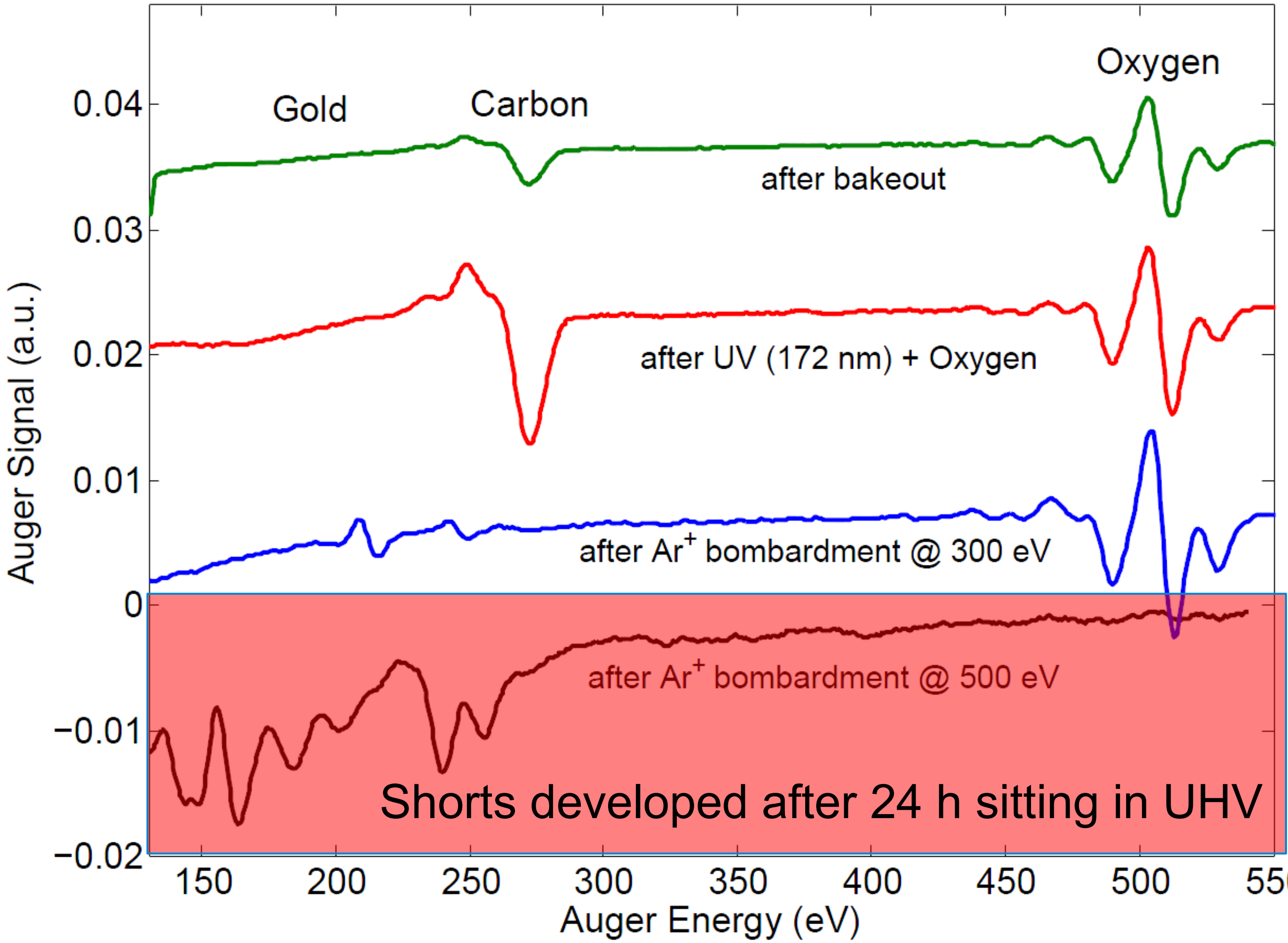


Cleaning the Gold





Auger-LEED unit



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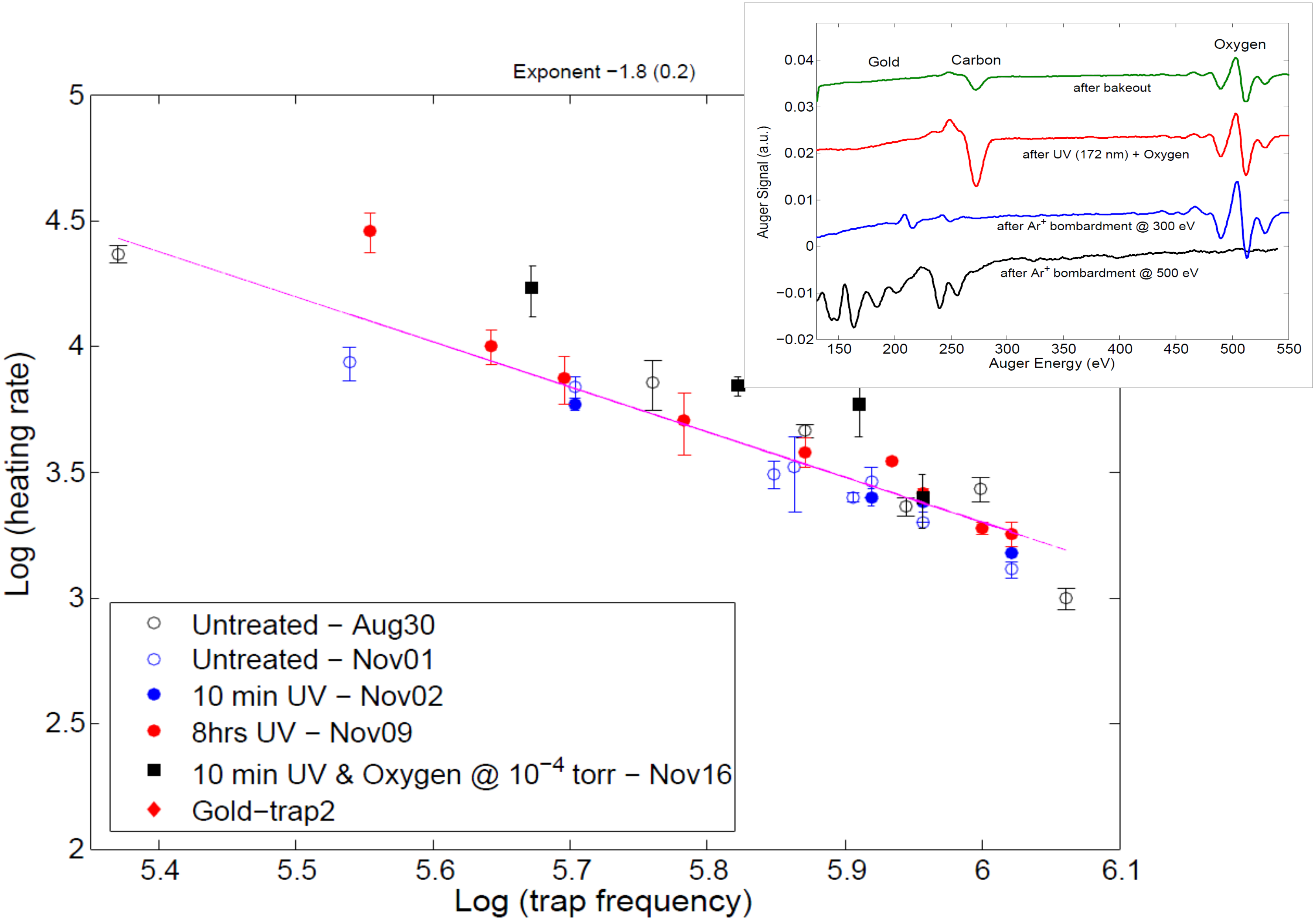
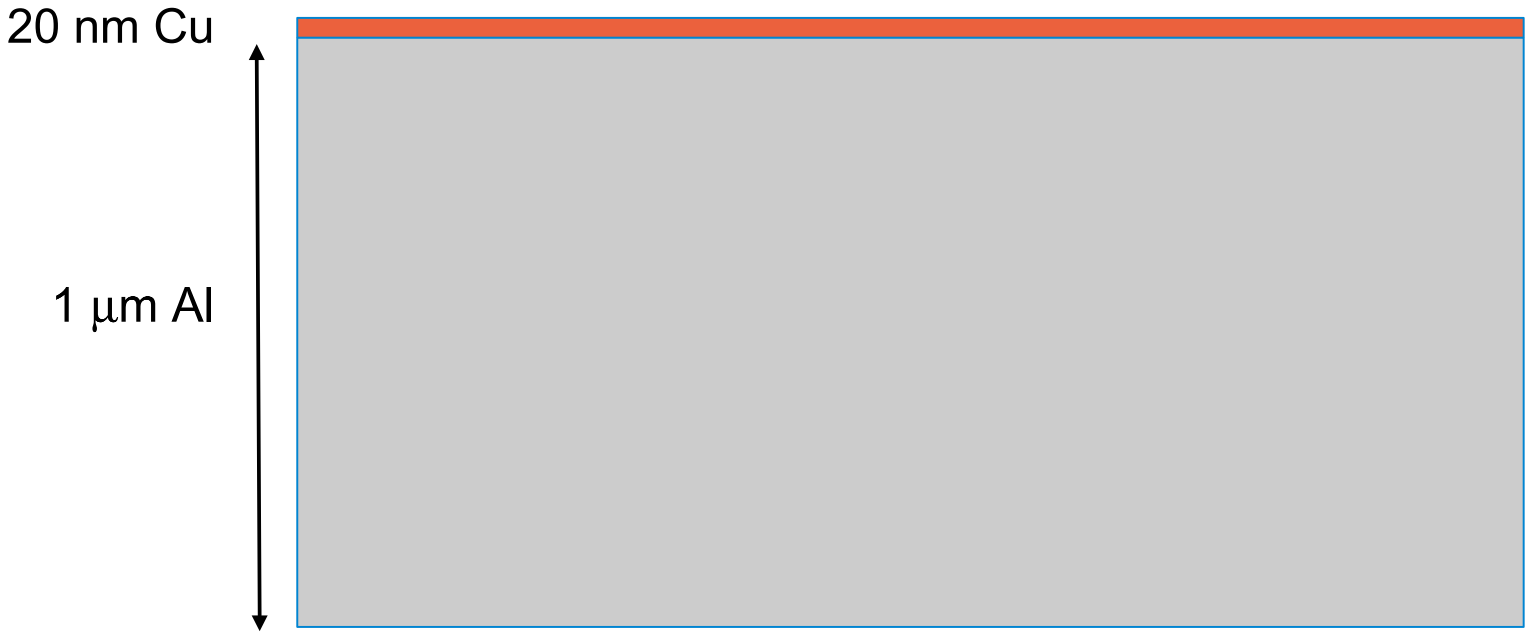
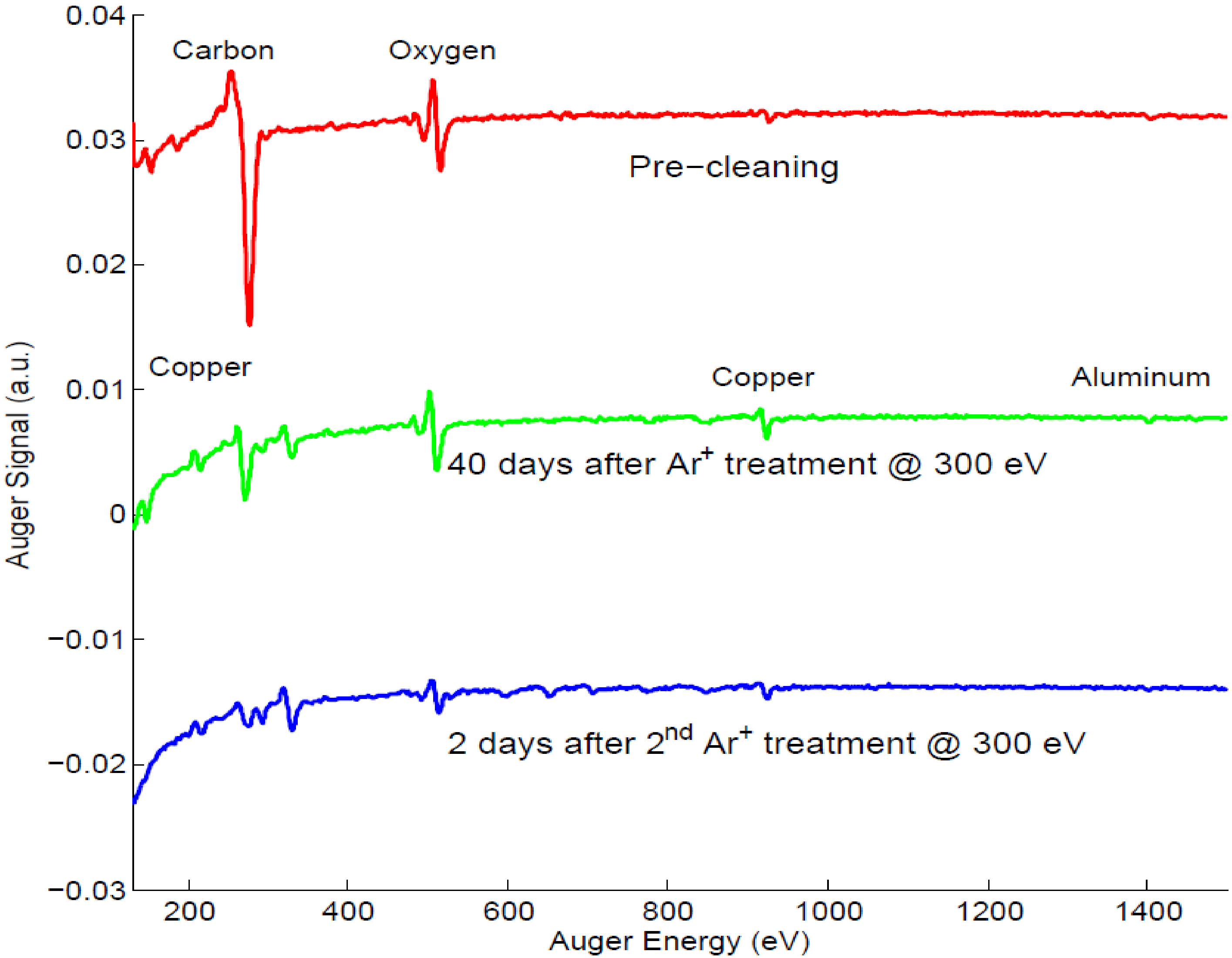


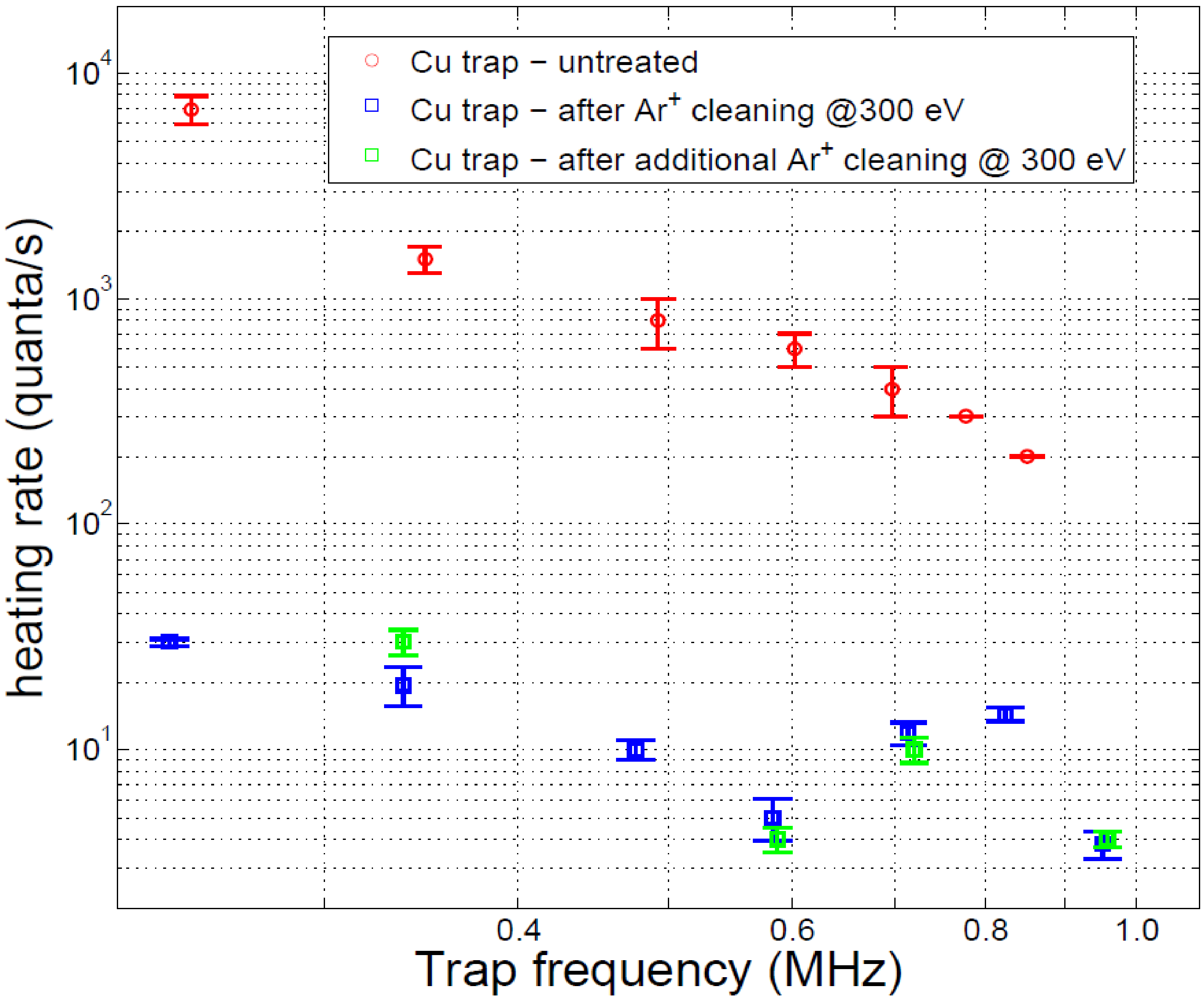
Copper on Aluminum trap



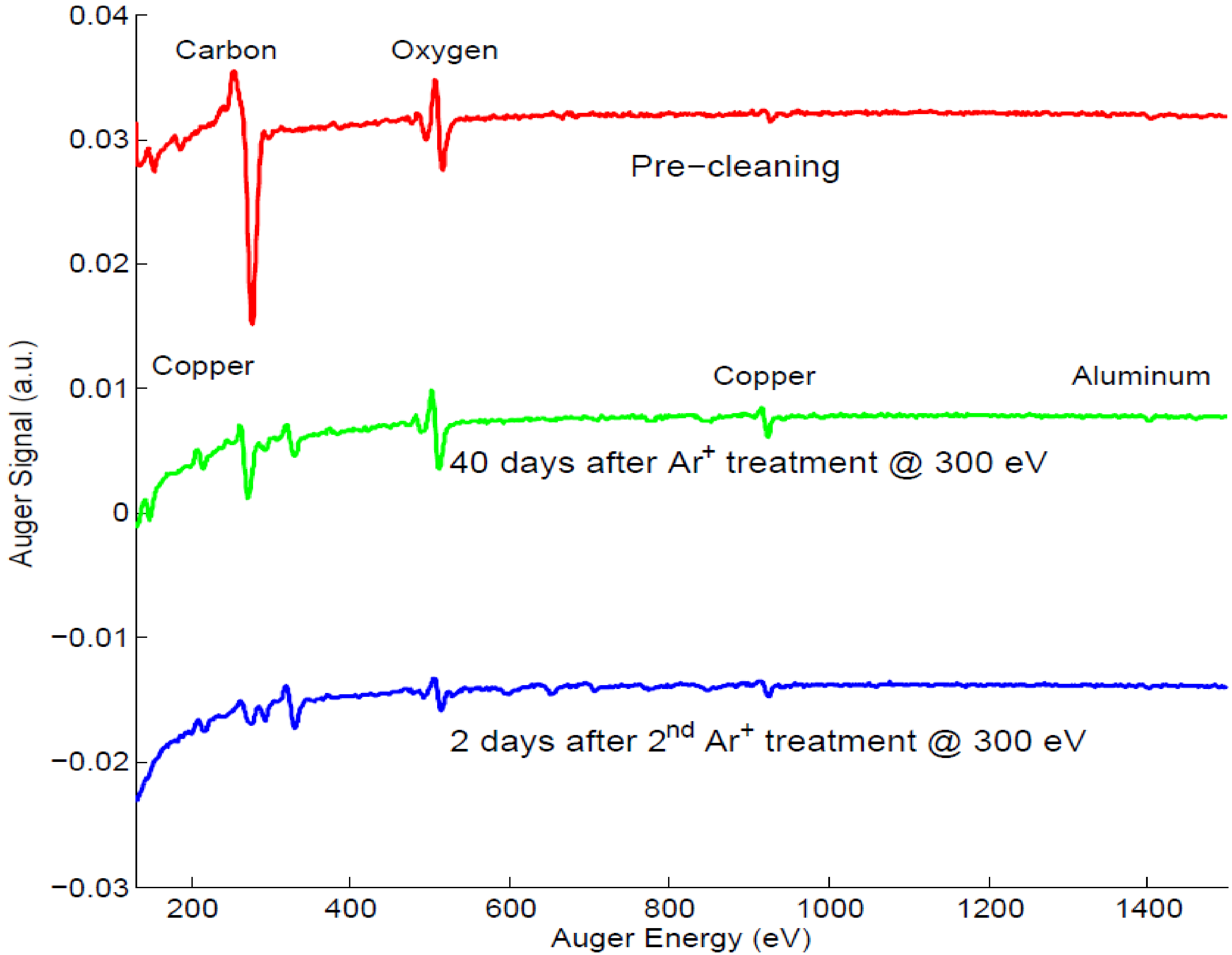
Monitoring the cleaning



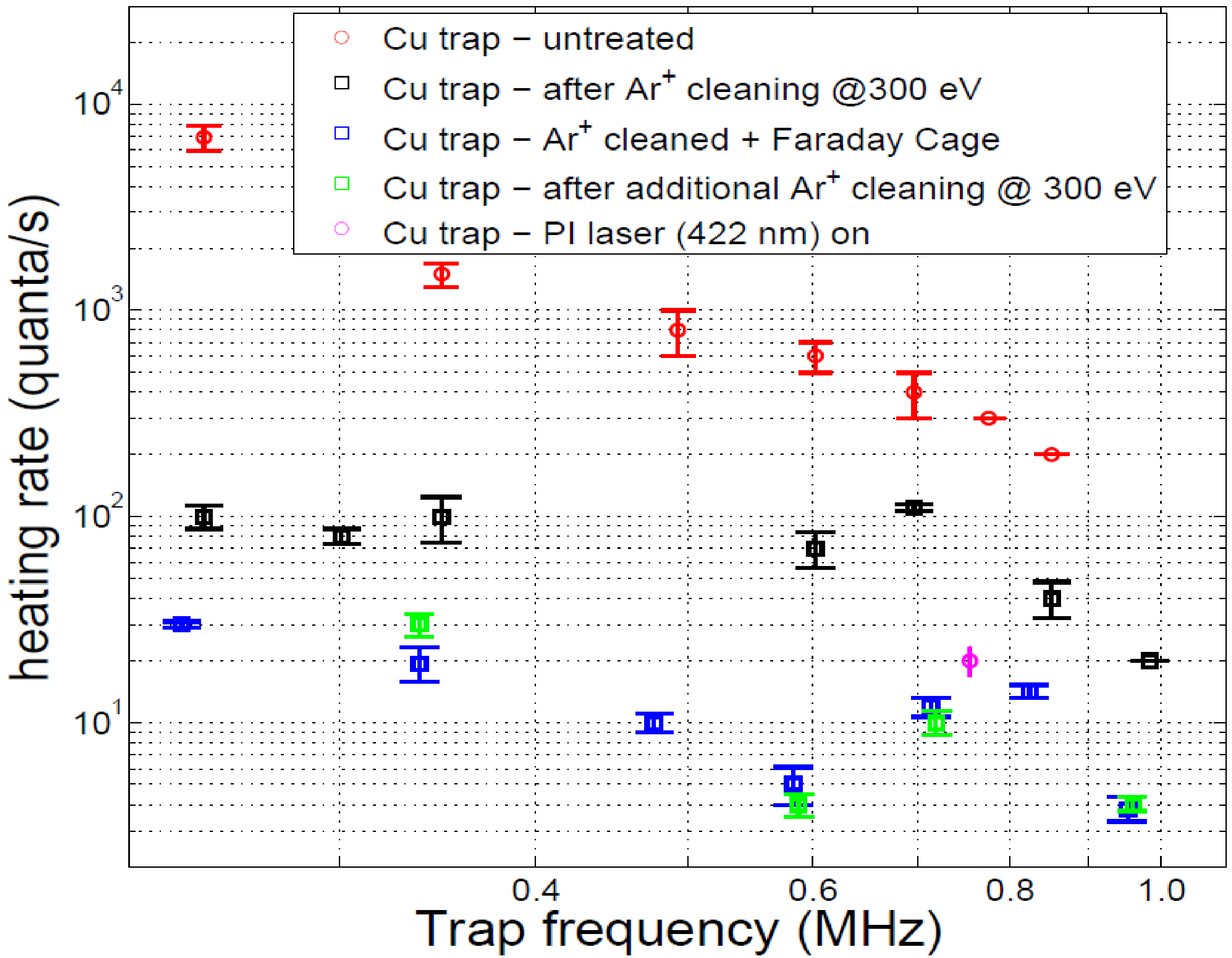
Heating rate



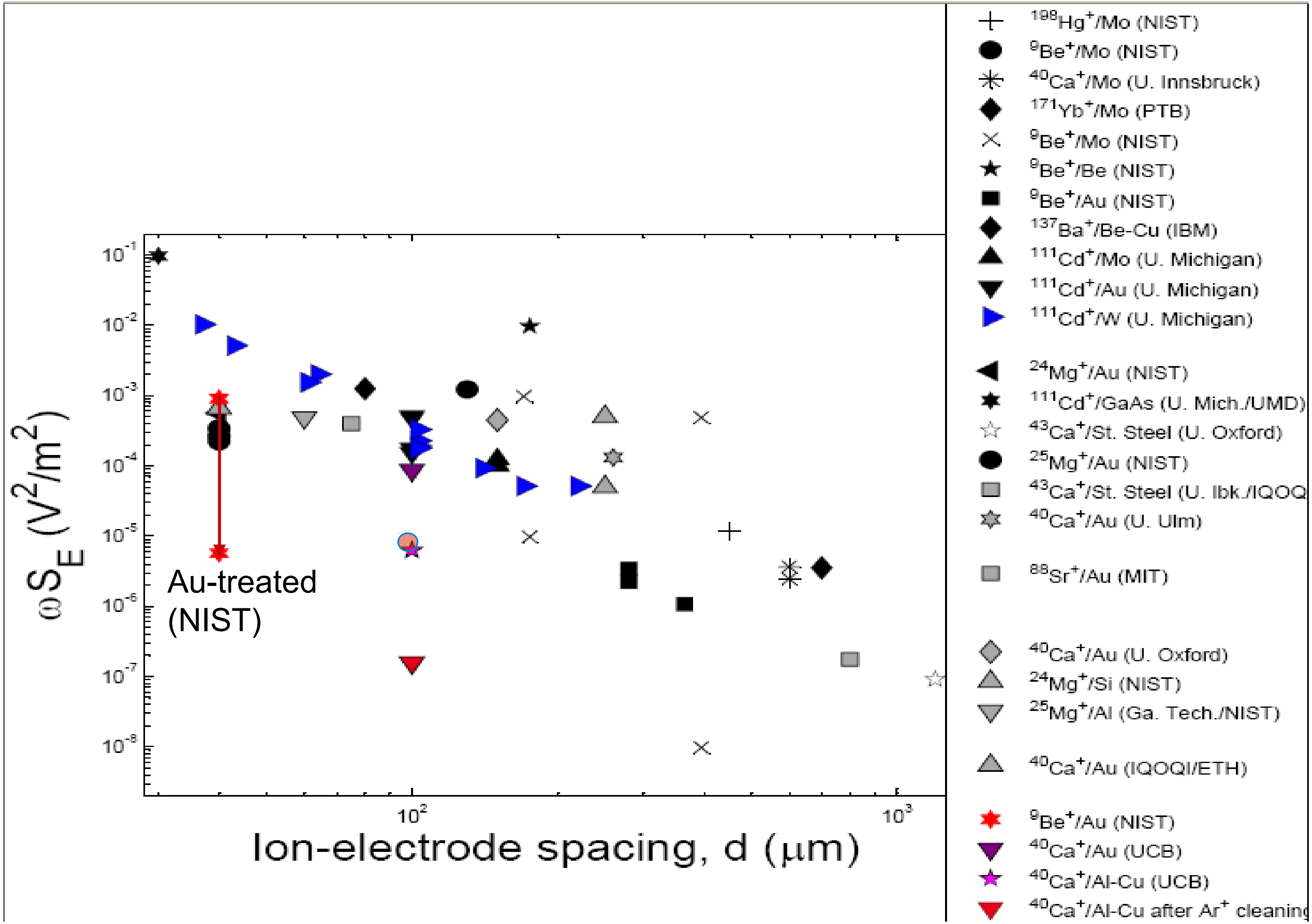
Monitoring the cleaning



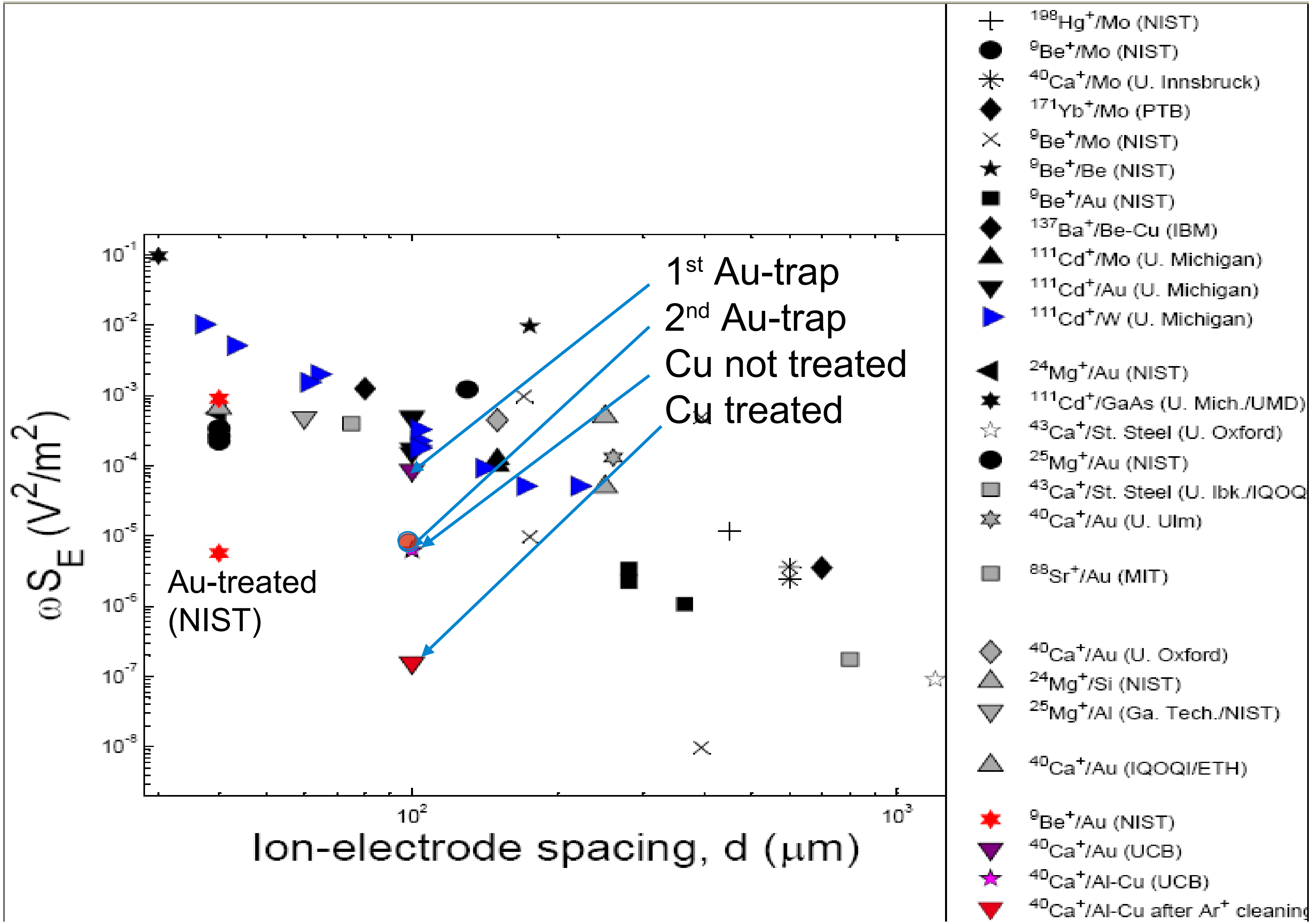
Heating rates



Heating rate summary



Heating rate summary



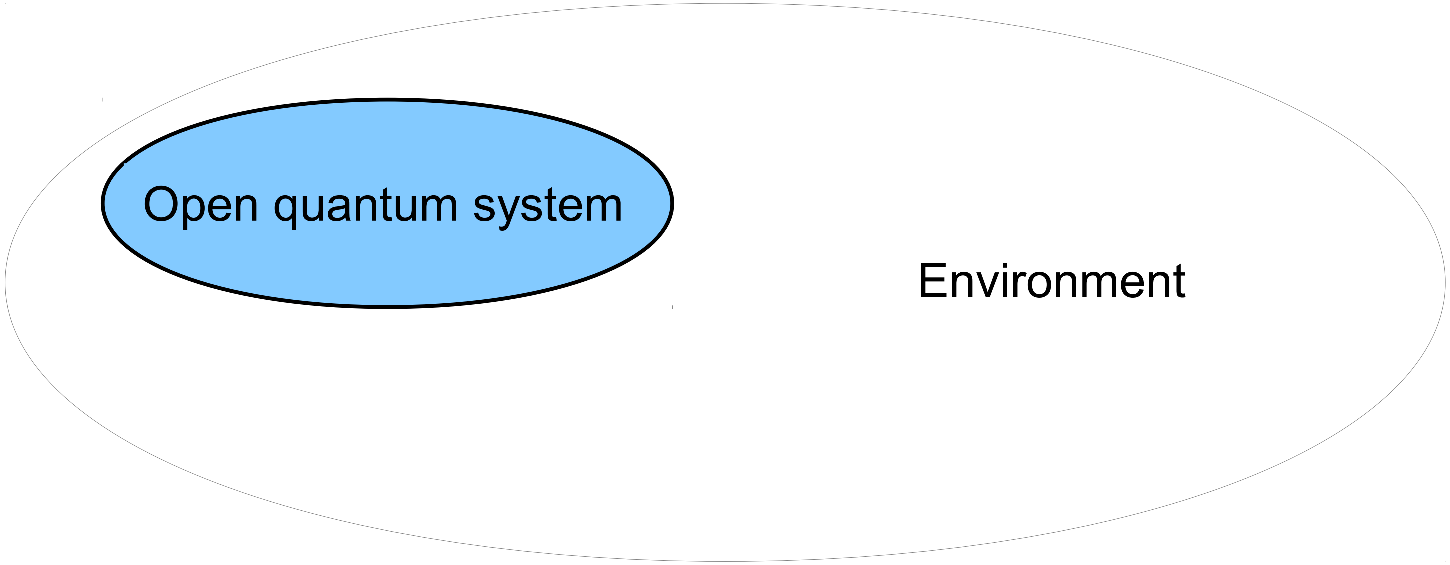
Local detection of quantum correlations

Local detection of quantum correlations

Local detection of quantum correlations

Given a quantum system, can you figure out whether it has quantum correlations with its environment?

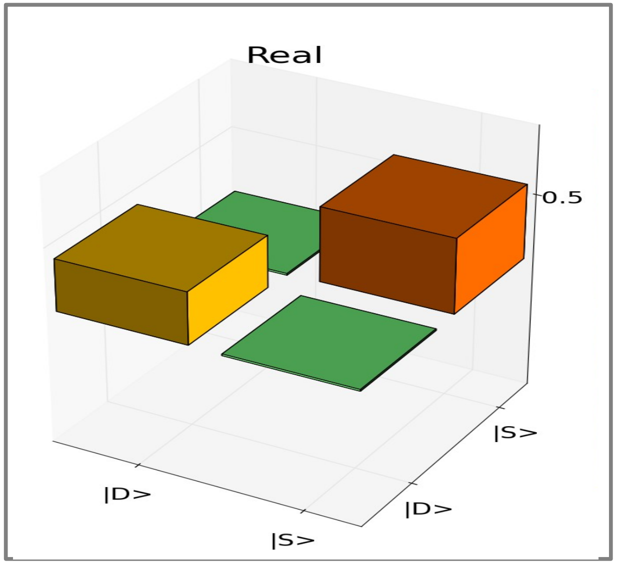
➡ Applications in quantum communication



➡ you can only control the open quantum system

Local detection of quantum correlations

What does the density matrix tell you?



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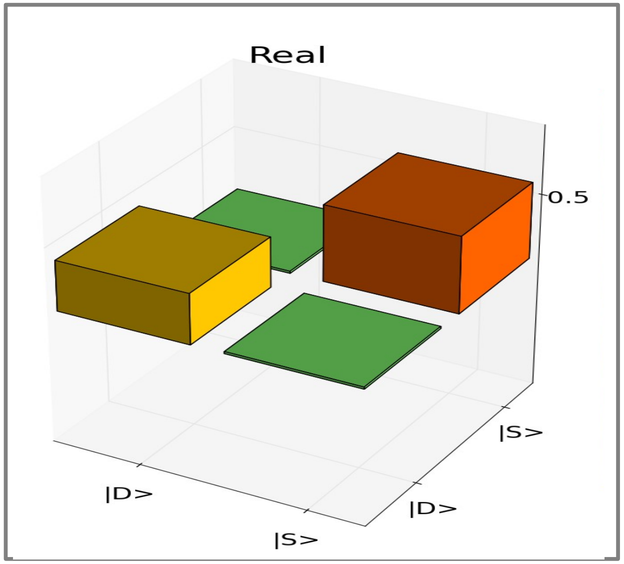
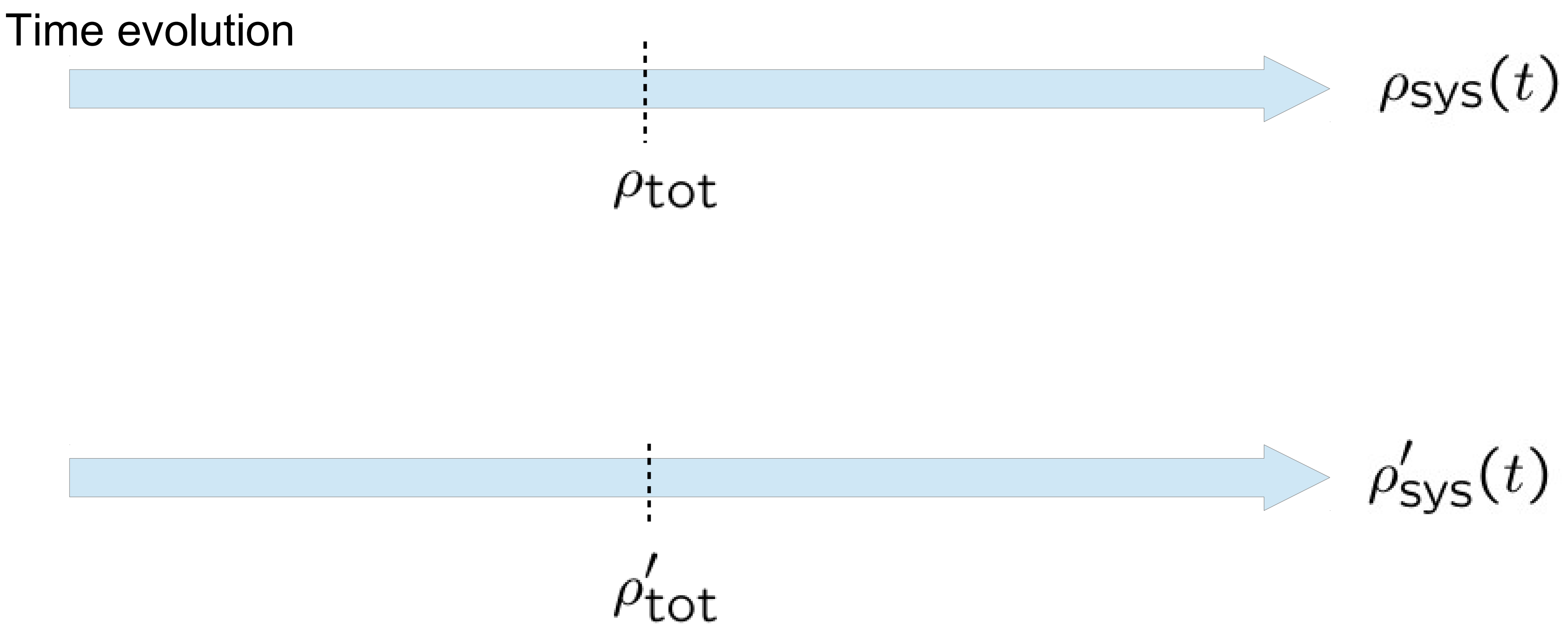
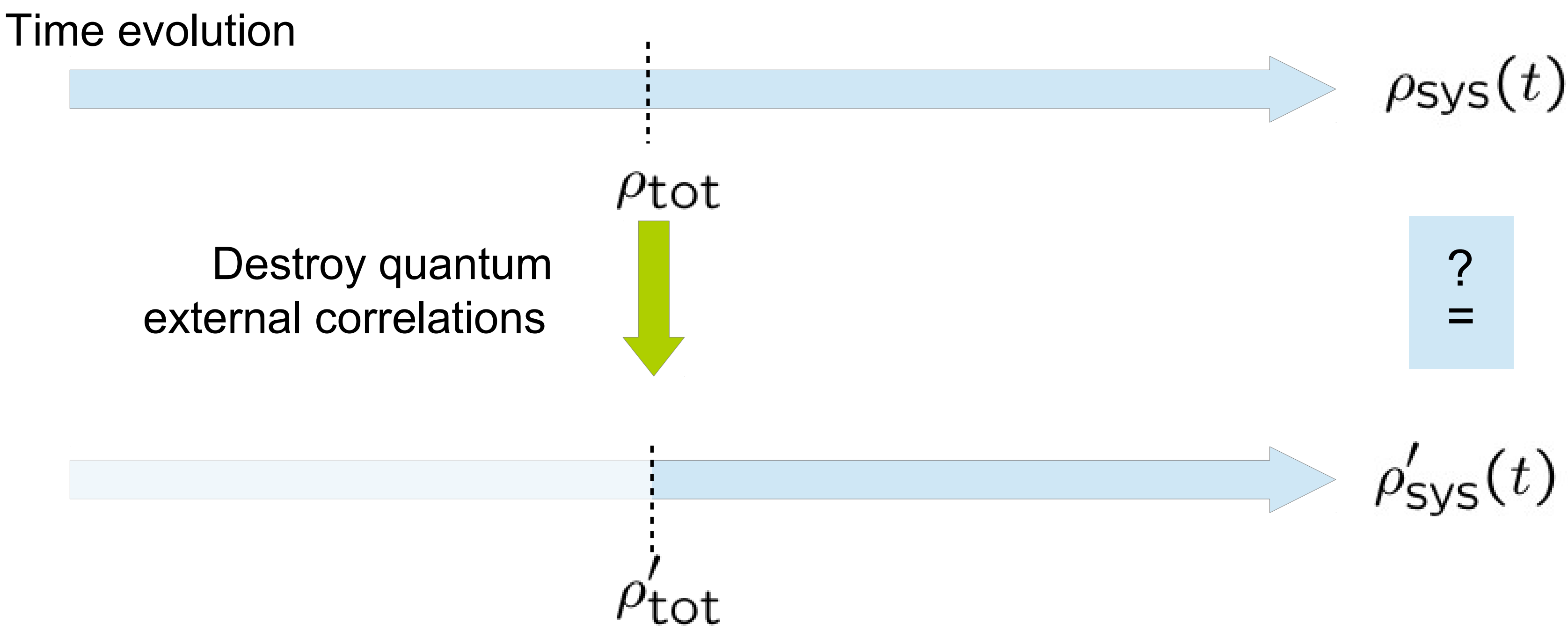


Quantum correlations



$$\rho_{\mathrm{sys}} = \mathrm{Tr}_{\mathrm{env}}(\rho_{\mathrm{tot}}) = \mathrm{Tr}_{\mathrm{env}}(\rho'_{\mathrm{tot}}) \quad \text{but} \quad \rho_{\mathrm{tot}} \neq \rho'_{\mathrm{tot}}$$

Local detection of quantum correlations



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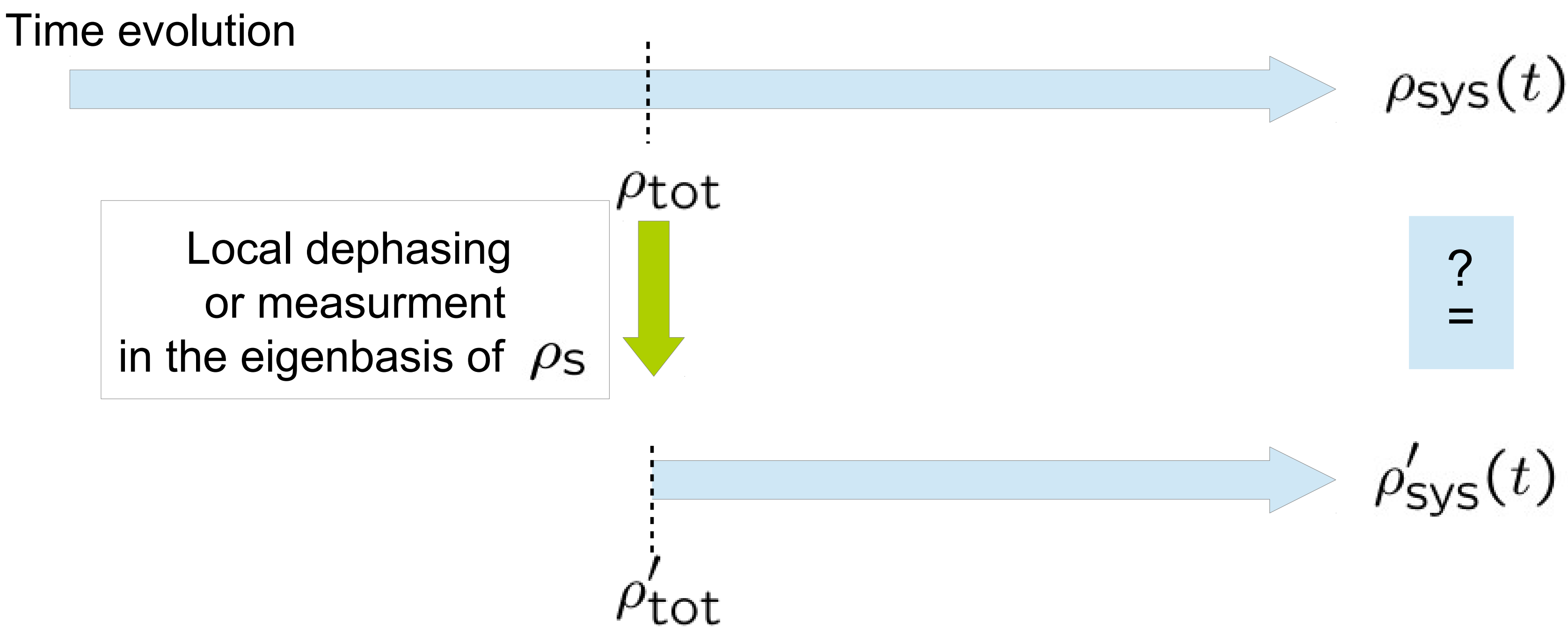


Leaves the systems density matrix intact but removes quantum correlations

➡ Local detection of quantum correlations

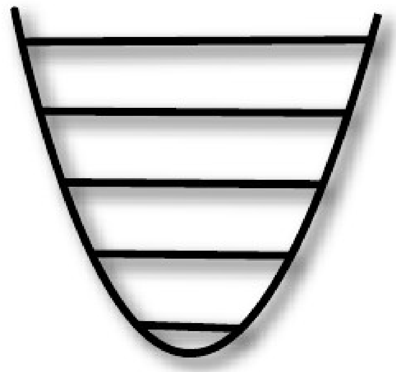
Local detection of quantum correlations

$|e\rangle = |D_{\frac{5}{2}}\rangle$

$\hbar\omega_0$

$|g\rangle = |S_{\frac{1}{2}}\rangle$

$\otimes$



$\hbar\nu a^\dagger a$

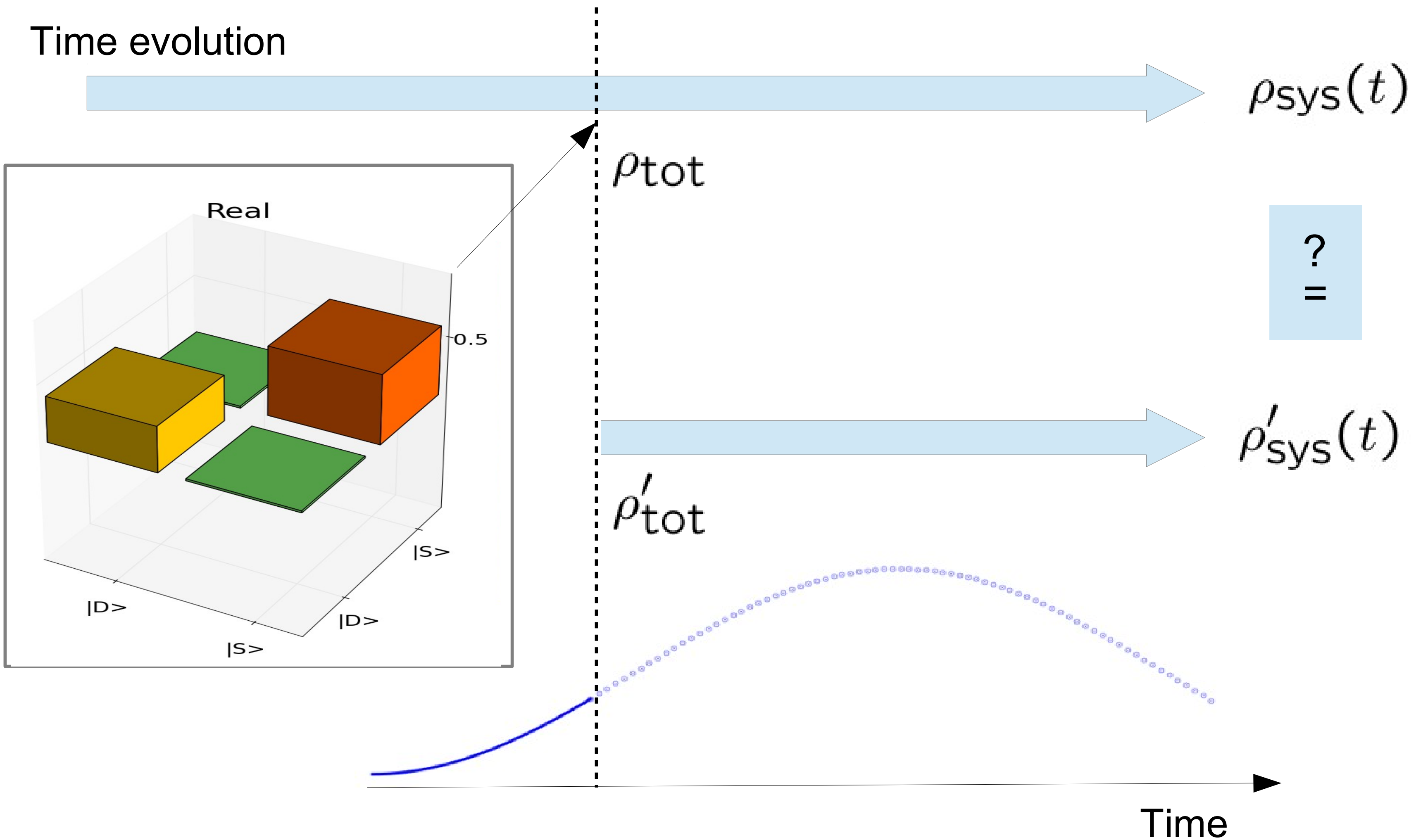
"System"
Electronic Degree of Freedom = Qubit

"Environment"
Motional Degree of Freedom = Harmonic Oscillator

Open system – environment dynamics:

Blue sideband: $H = \sigma_+ a^\dagger + \sigma_- a$

Local detection of quantum correlations



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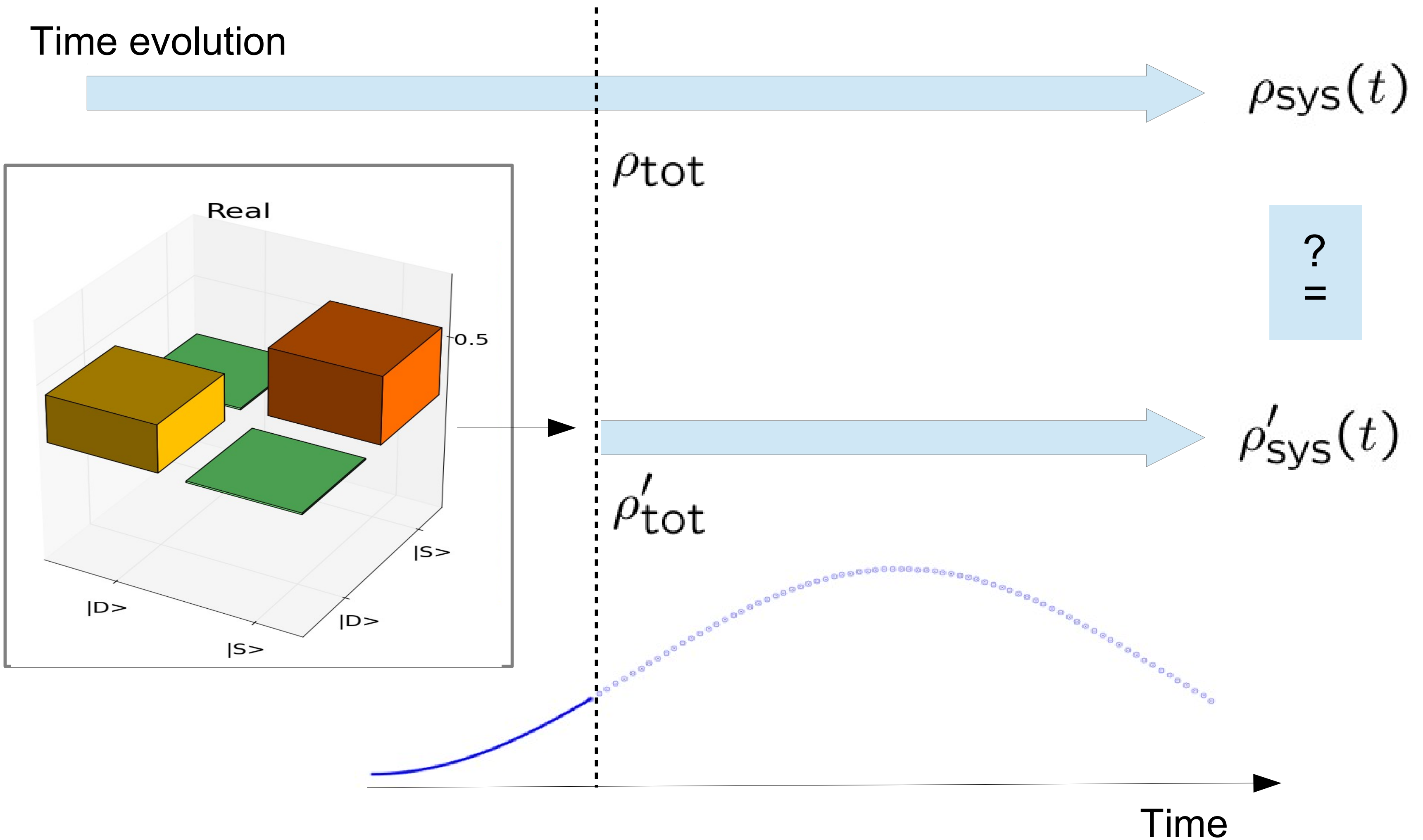

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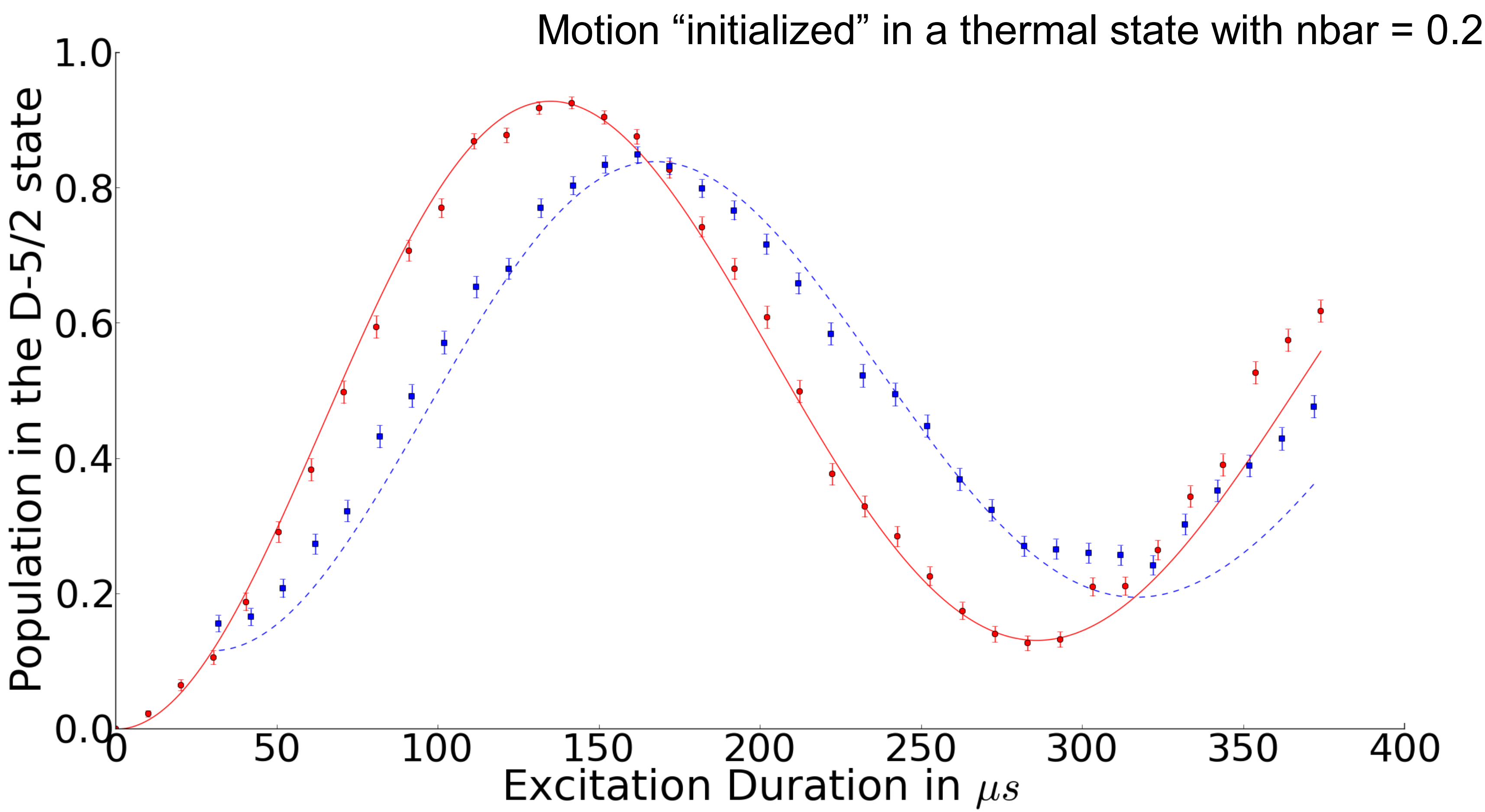
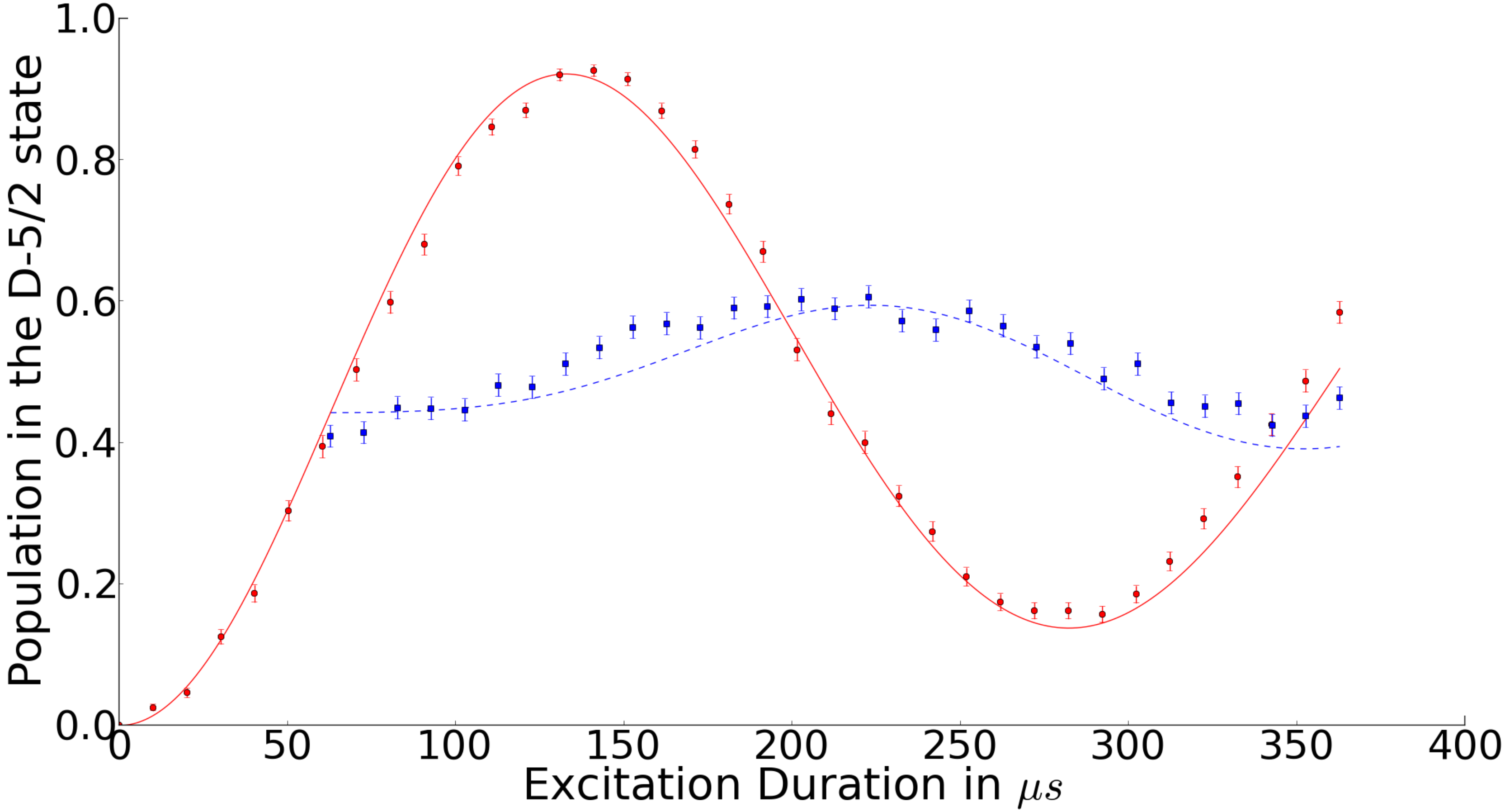
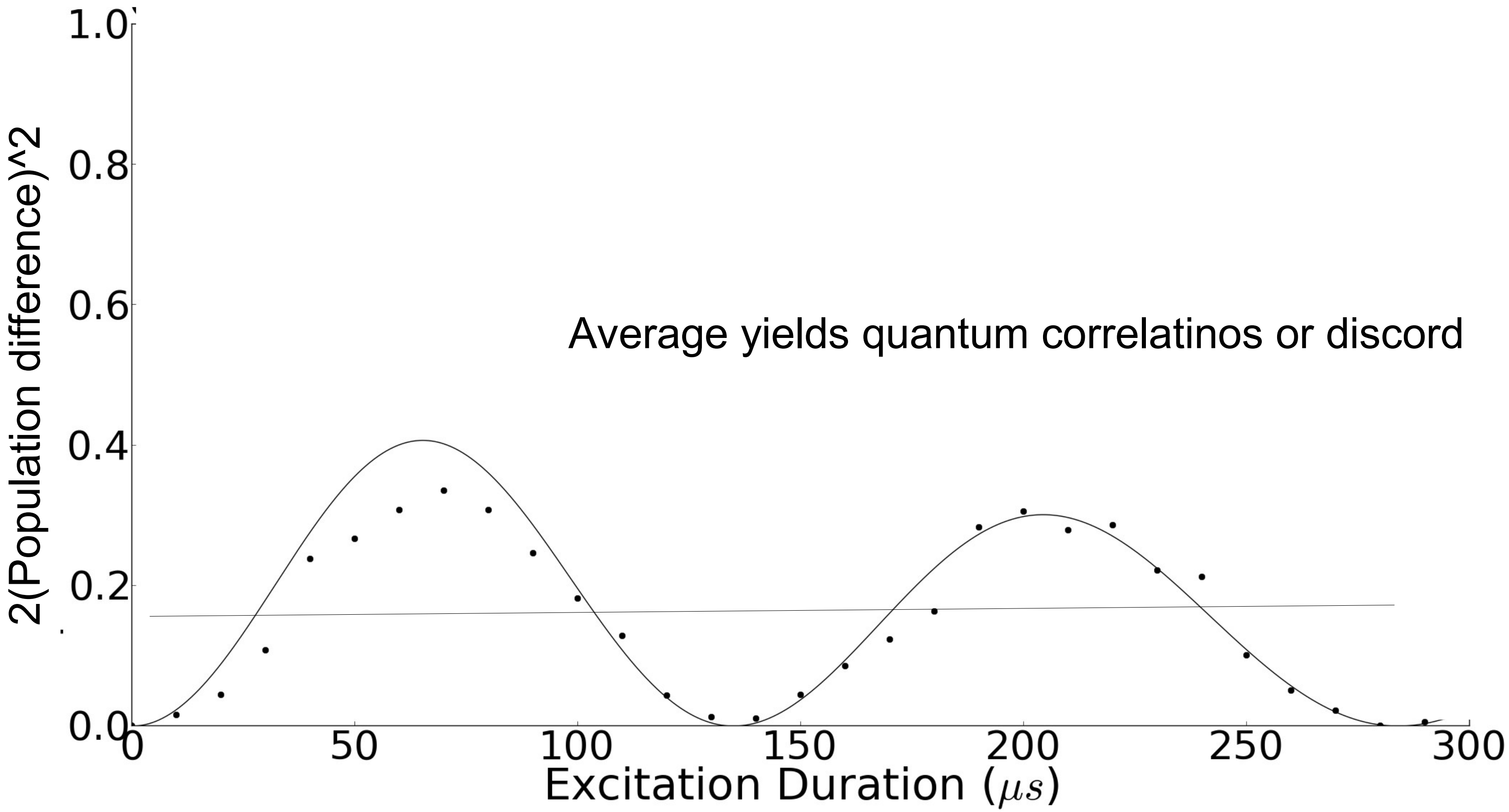


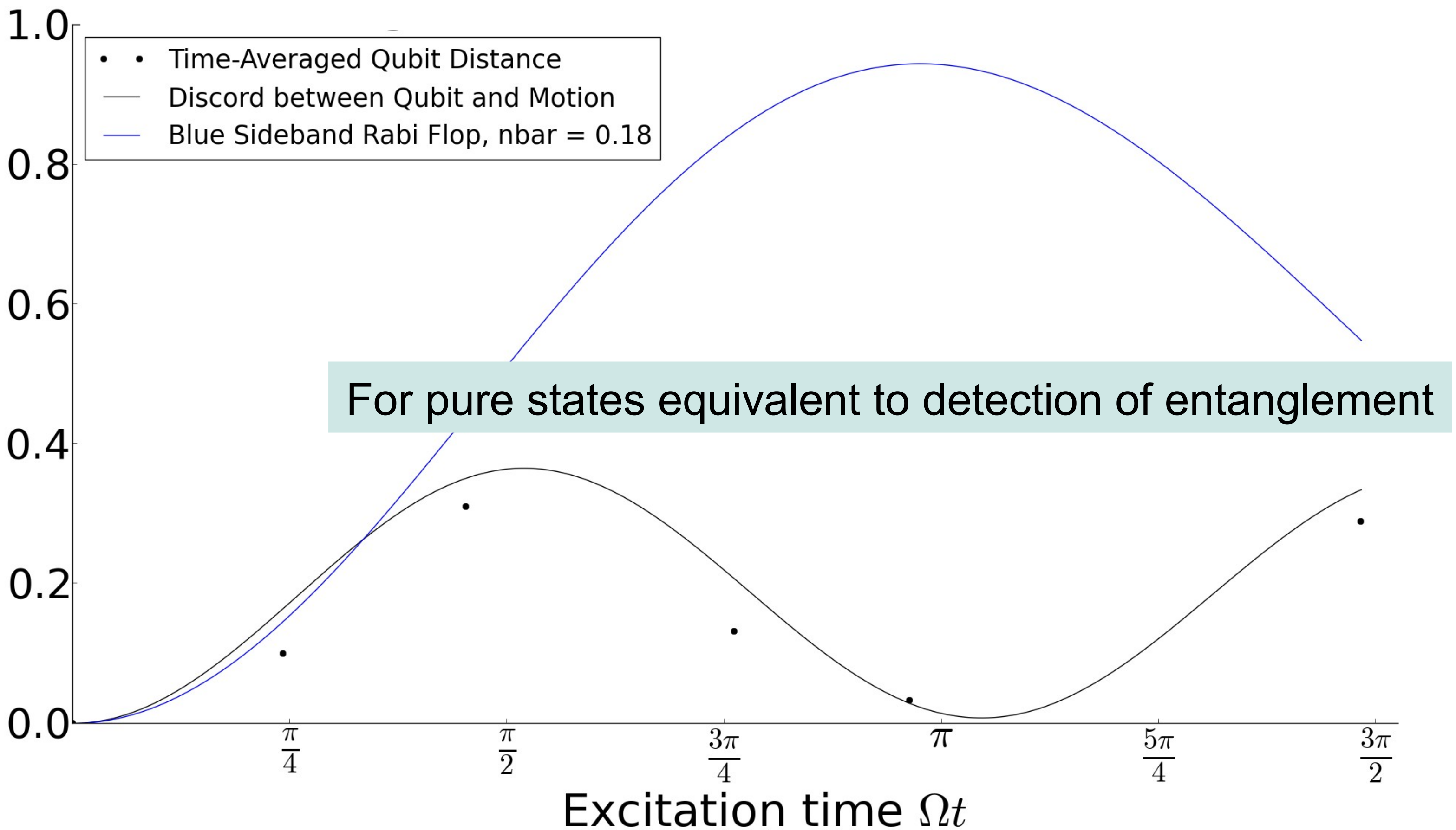
Local detection of quantum correlations



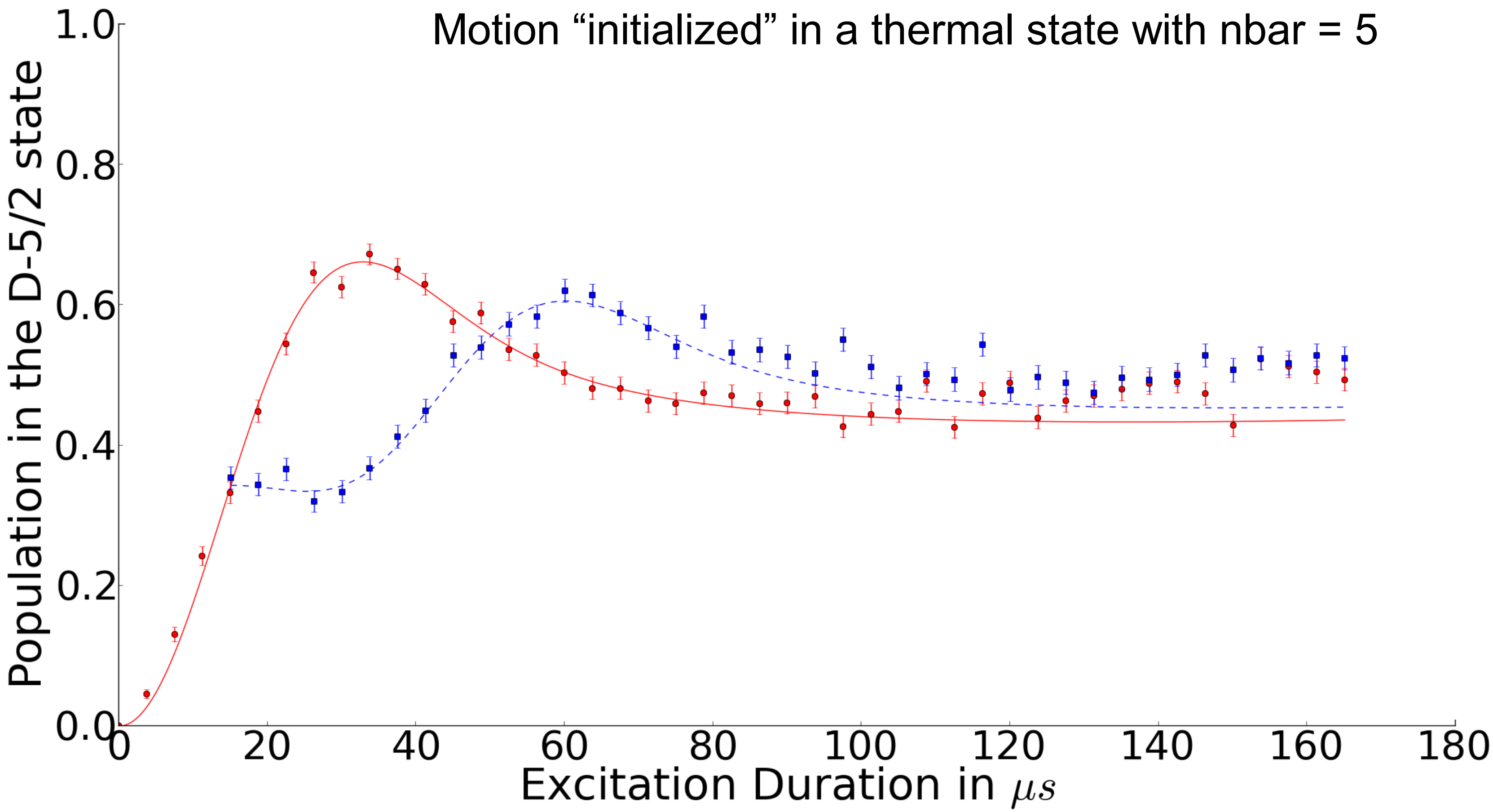
Operator distance



Discord during the sideband dynamics



Detection of discord in the interesting case



Summary

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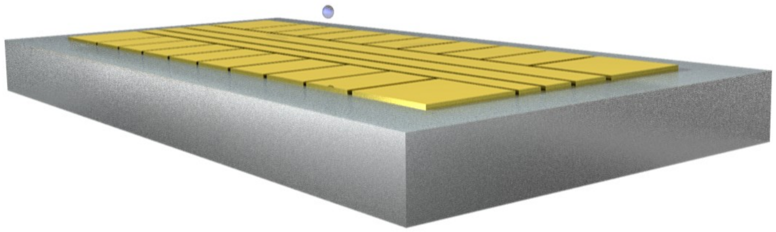

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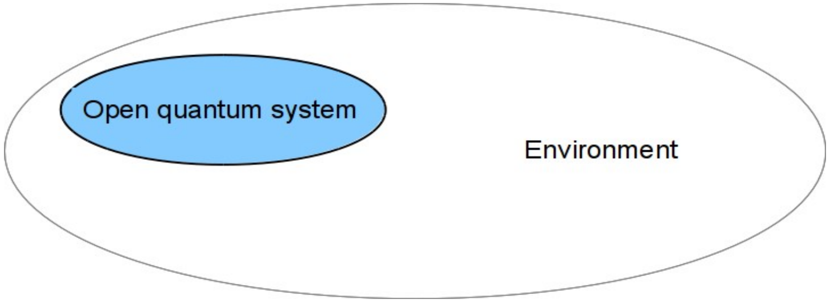

The group

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