

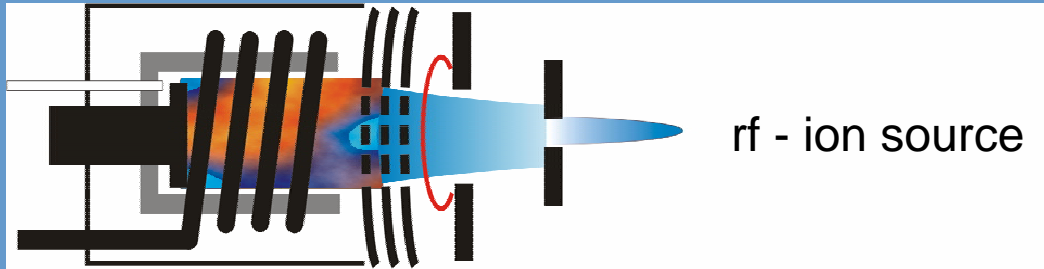
Ion beam etching process parameter optimization with artificial neural nets

Seidel, P., Hänsel, T., Tartz, M., Neumann, H.

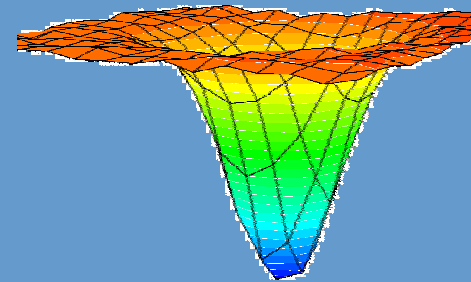


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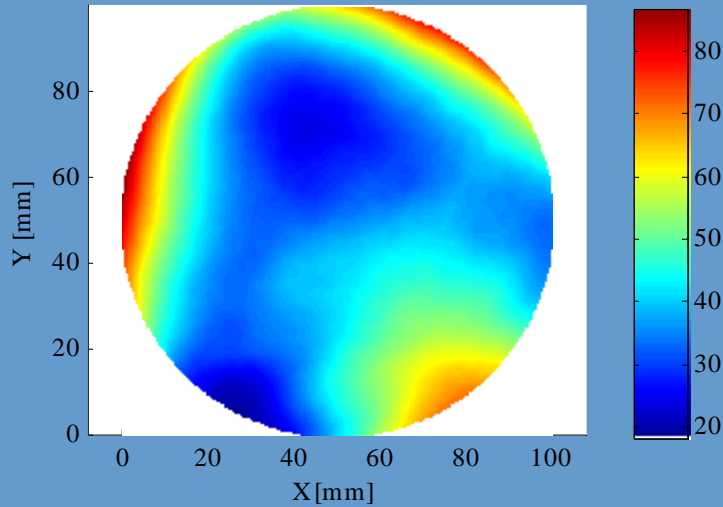
Ion beam etching



removal function



Ion beam polishing



mechanical dwell time method
(Lucy-Richardson-deconvolution)

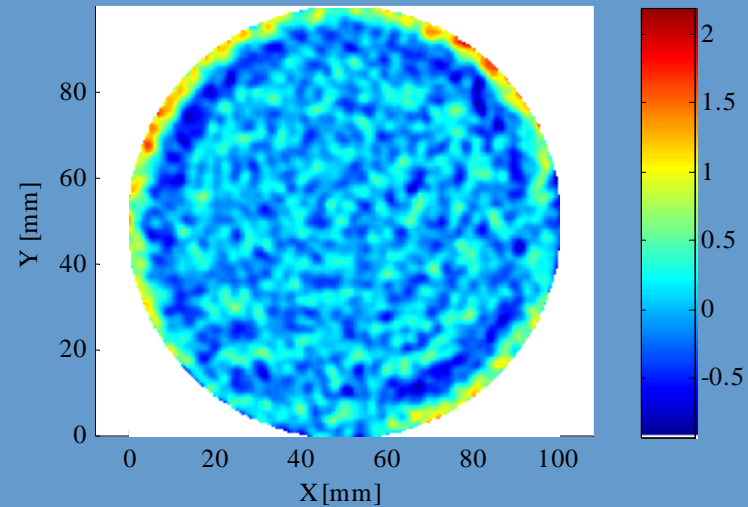
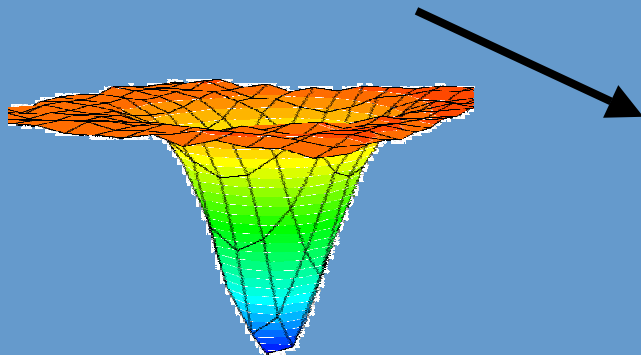
etching time: 65 min.

PV_{in} : 68 nm

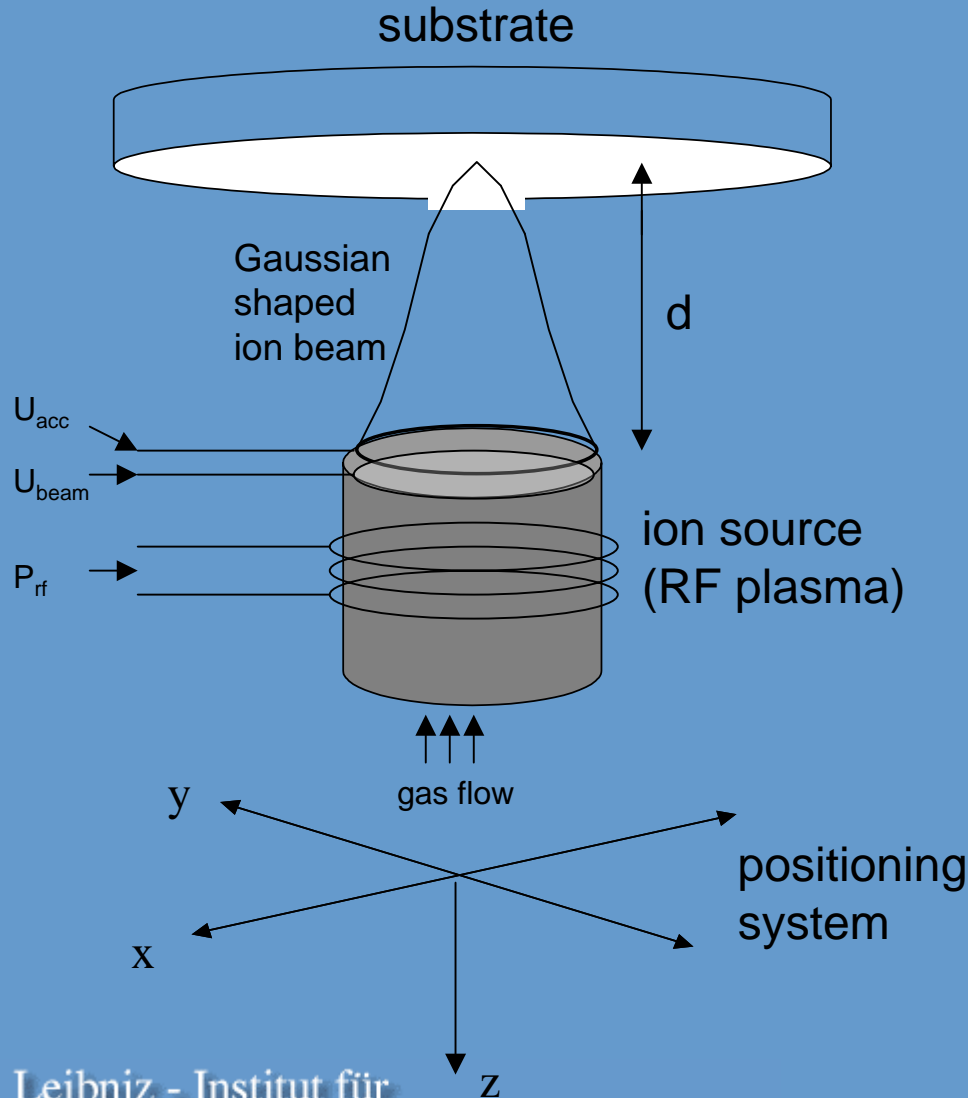
PV_{out} : 3.1 nm

RMS_{in} : 11.9 nm

RMS_{out} : 0.3 nm



Process parameters



flow=5sccm
(1e-6 mbar/1e-4 mbar)

$P_{rf}=100W$
13.56 MHz

$U_{beam}=1000V$
 $I_{beam}=10mA$

$U_{acc}=300V$
 $I_{acc}=2mA$

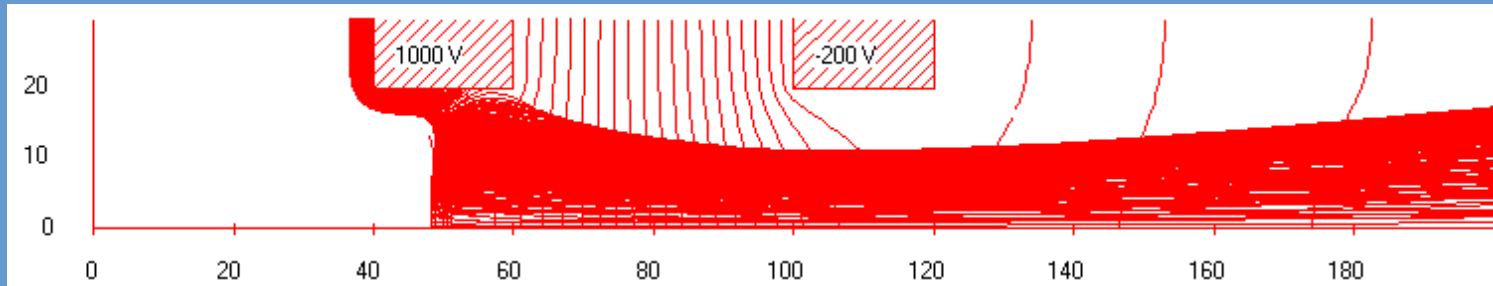
d=80 mm

FWHM=15mm
2 mA / cm²

etching rate

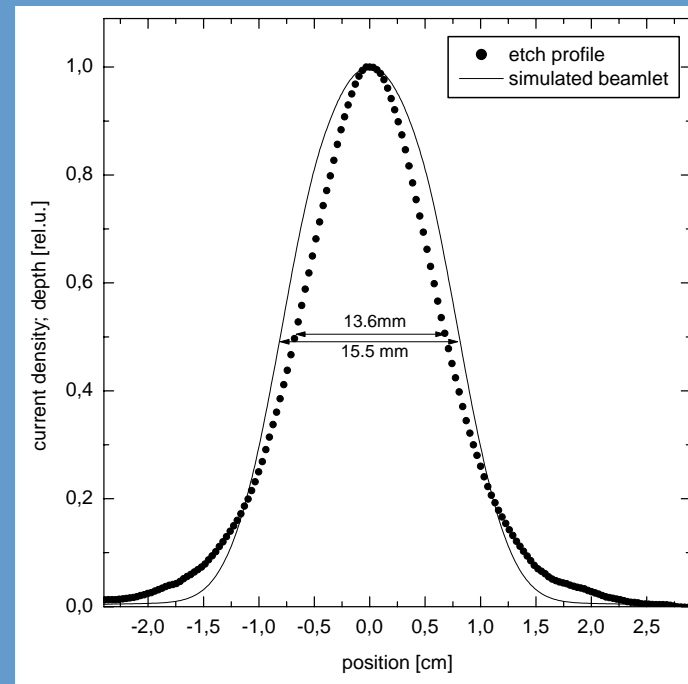
SiO₂ ~1 nm/s
Si ~4 nm/s

From first principles?



IGUN-Code:

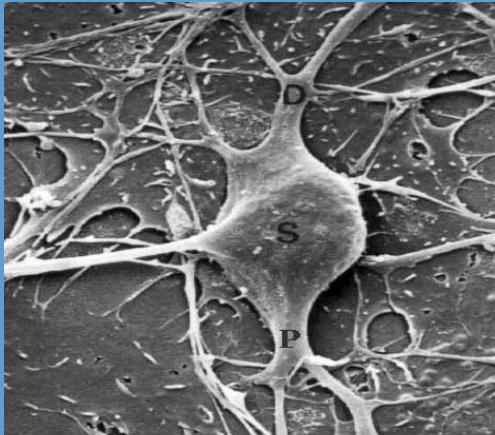
- complex plasma physics
- high effort
- need of adjusting model parameters
- only electrical beam properties
- no etching model
 - etched FWHM ?
 - etching rate ?



Neural nets

Human brain:

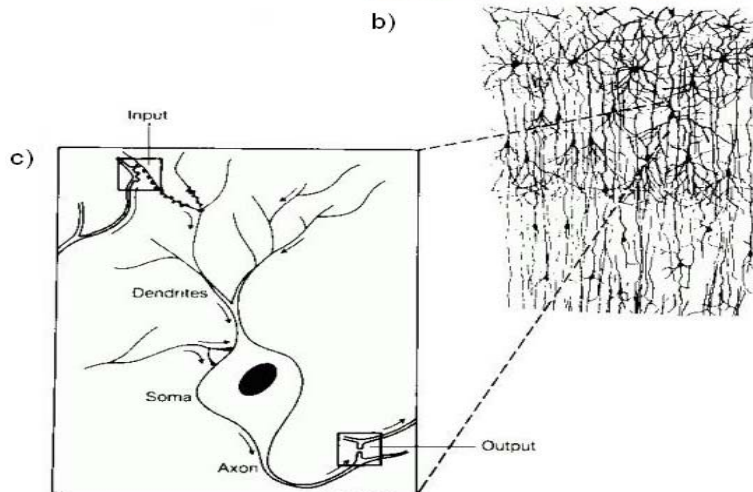
- ca. 10^{10} neurons
- $1\text{mm}^3 = 100.000$ neurons
- each neuron connected to ~ 10000 other neurons
- spike voltage: 60..80 mV
- spike time: ~ 1 ms
- fire rate: ~ 100 sp/s
- integrate and fire - model



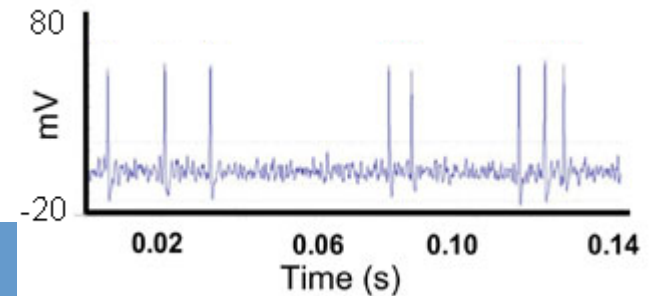
a)



b)



c)

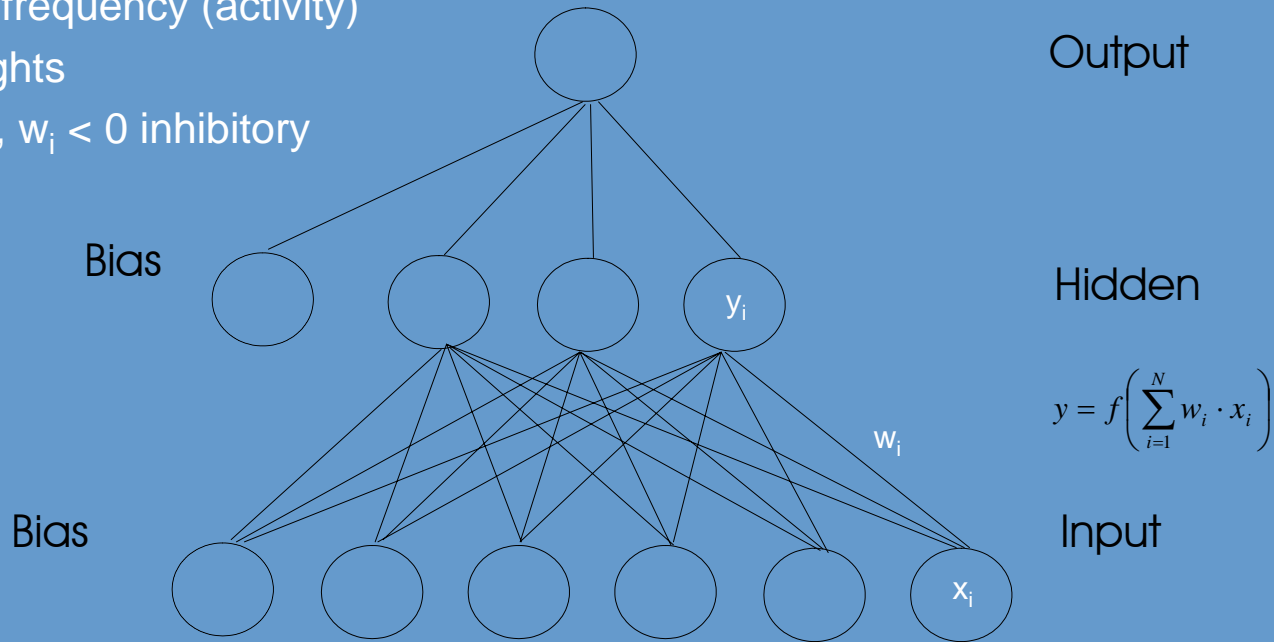


Perceptron model

y_i : neuron spike frequency (activity)

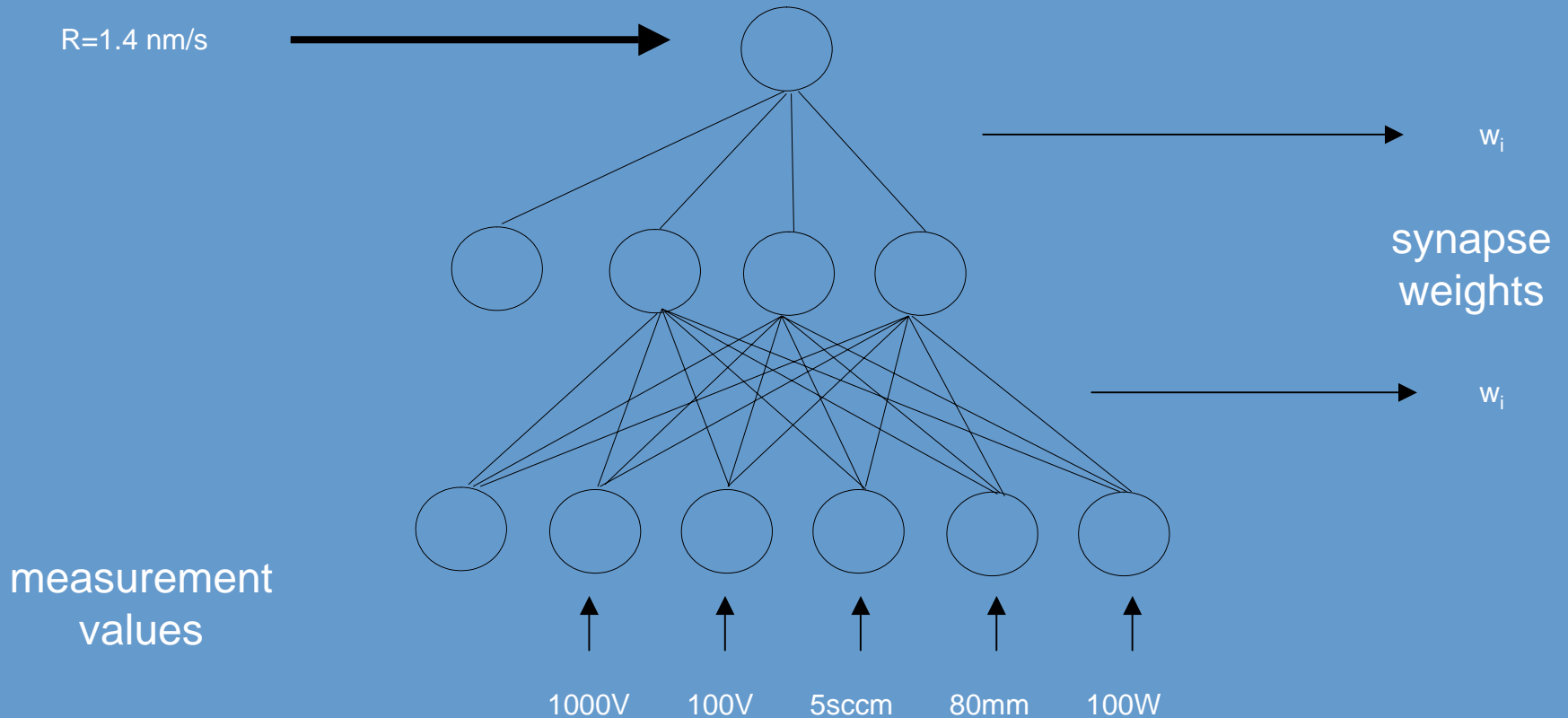
w_i : synapse weights

$w_i > 0$ excitatory, $w_i < 0$ inhibitory



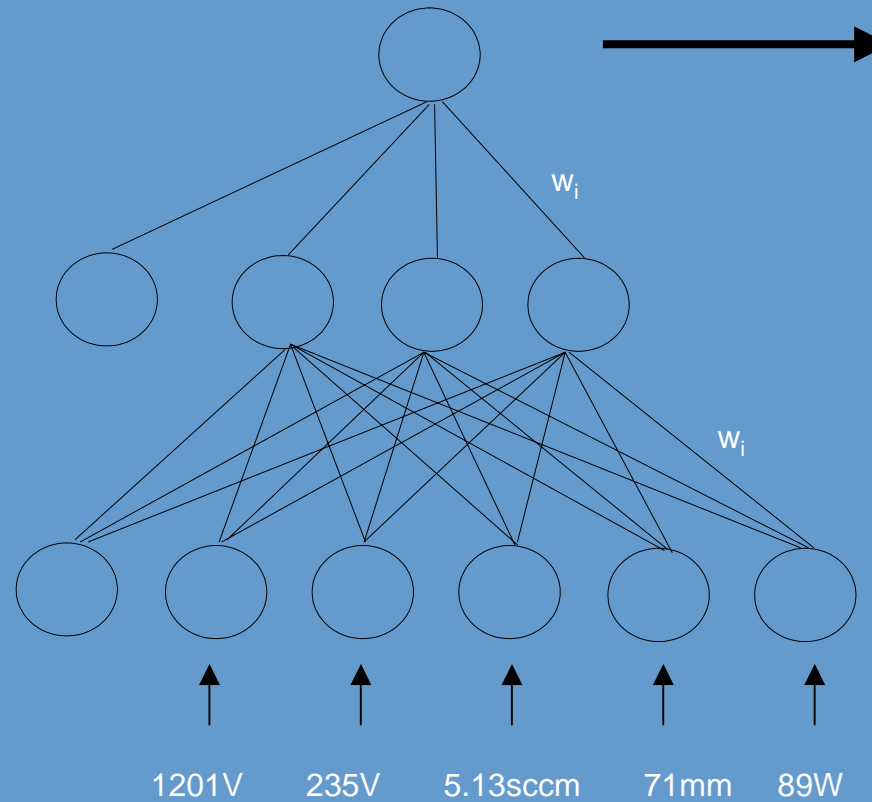
sigmoid transfer-function: $f = \frac{1}{1 + \exp(-cx + d)}$

Learning phase



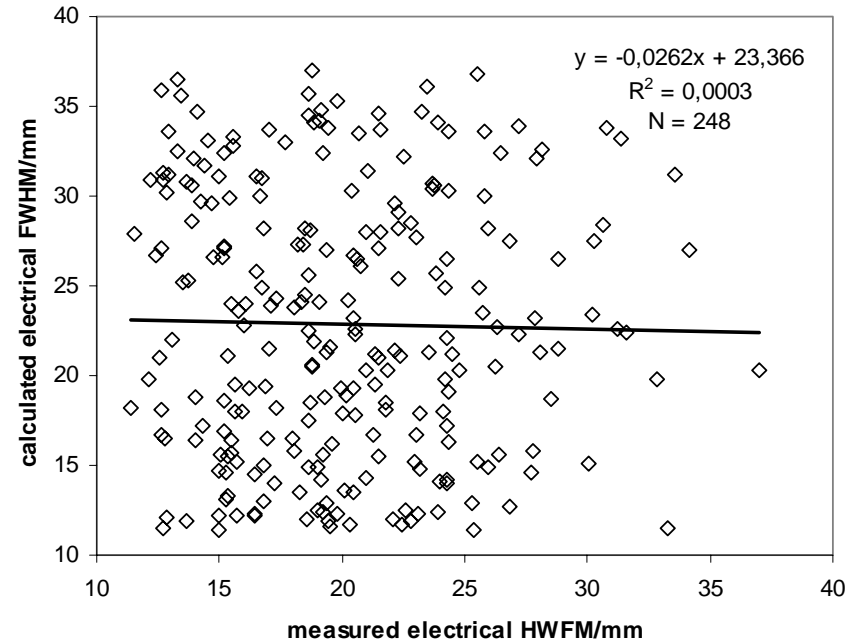
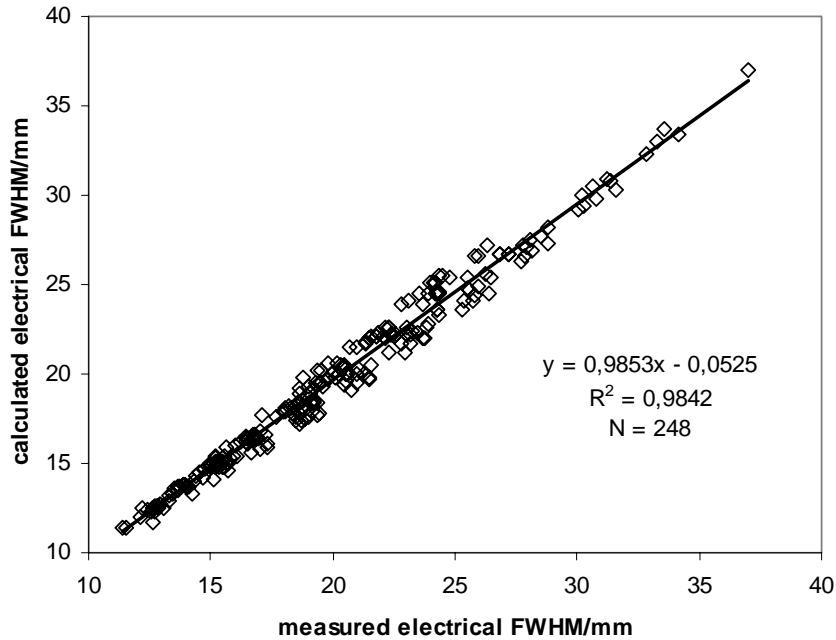
Application phase

synapse
weights
fixed



prediction:
R=2.1 nm/s

Data overfitting?

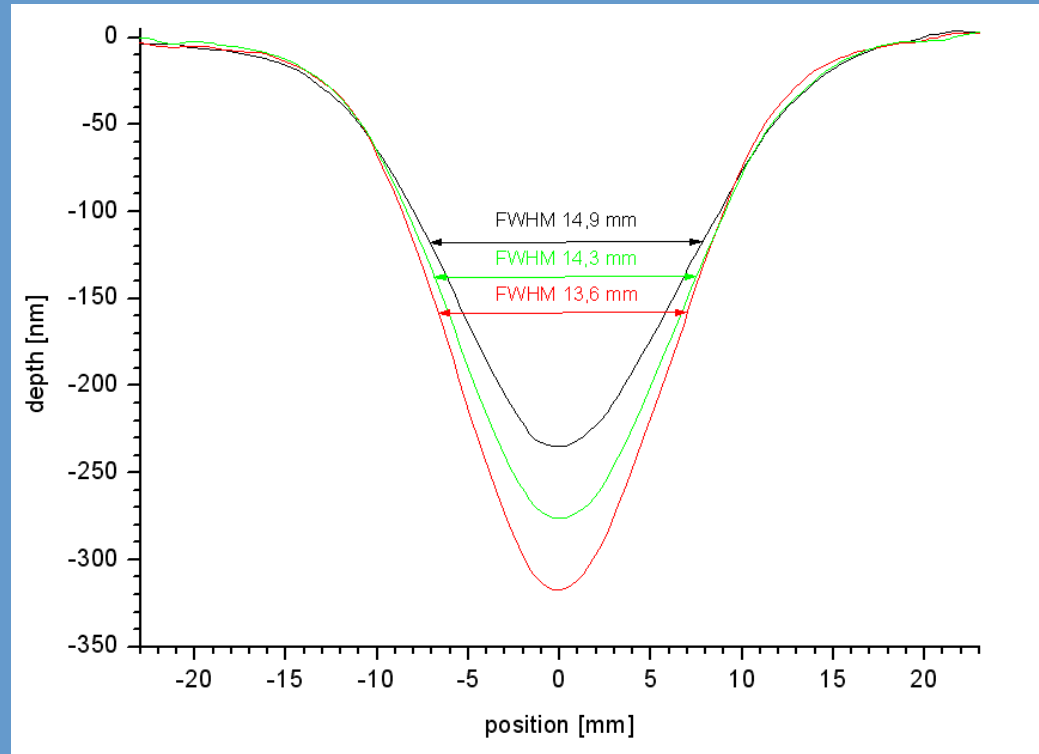
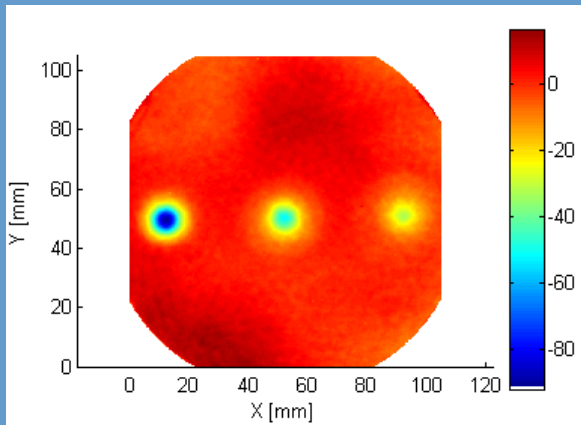


- calculation of the electrical FWHM for $N = 248$ data points to an uncertainty of ca. 2 mm
- testing against possible data overfitting by evaluating a randomized data set

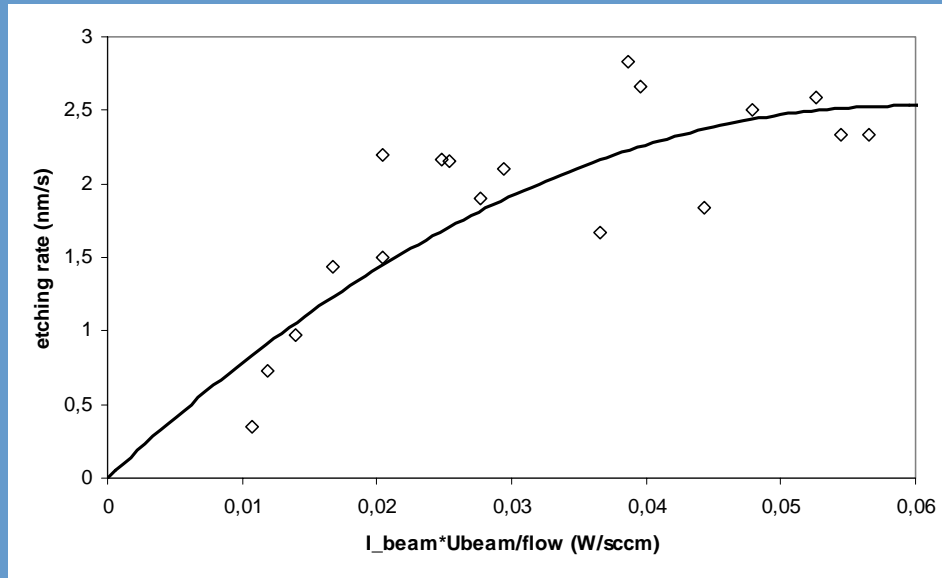
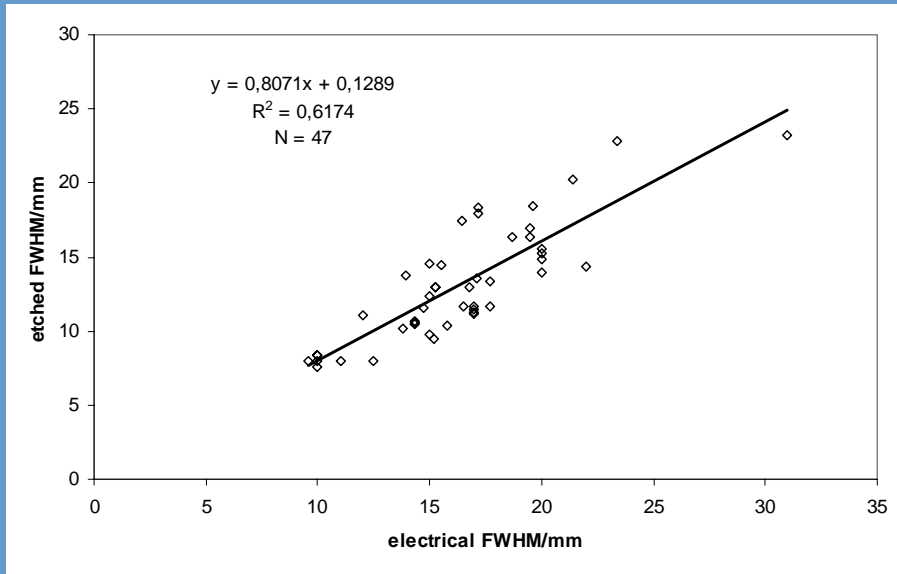
Results

Example: Optimal process parameters for fulfilling a given etching FWHM at maximal etching rate

	gas(sccm)	P(W)	Uacc(V)	Ubeam(V)	d(mm)	FWHM(mm)	Ibeam mA/cm ²	R (nm/s)
predicted	7	80	200	1100	105	15.6	1.84	1.8
experiment	7	80	200	1100	100	14.9	1.96	2.1



Results



Experimental etched and electrical full width at half maximum and dependence of etching rate (SiO_2) on process parameters

Conclusions

Neural Nets:

- special Design of Experiments – approach
- simple algorithm, simple programming, short computing times
- no physical understanding but predictions with reasonable significance
- advantage: computing unsteadiness, additional boundary conditions
- disadvantage: possible data overfitting

