Piecing Things Together: From Fabrication to Integration of a Membrane Mirror AO System

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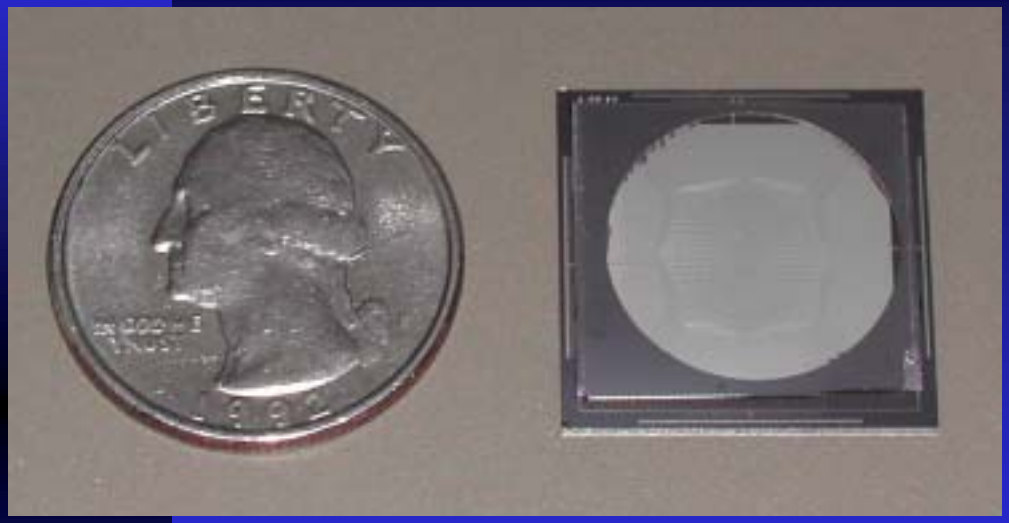
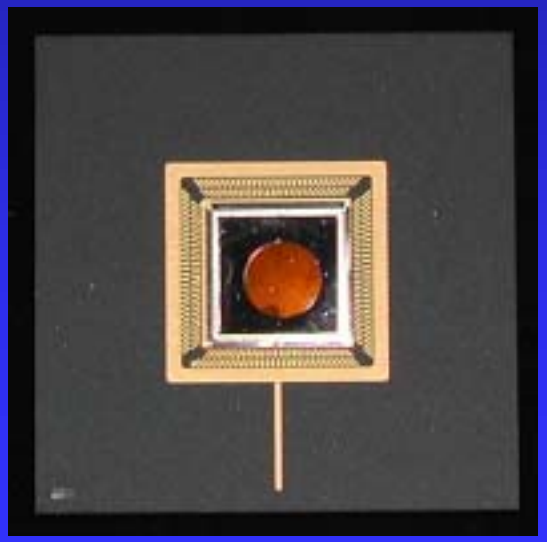
Membrane devices fabricated at Lucent/NJNC



- 256 (1024) electrode array, 8 (10) mm diameter.
- 15 mm diameter membrane (removed).

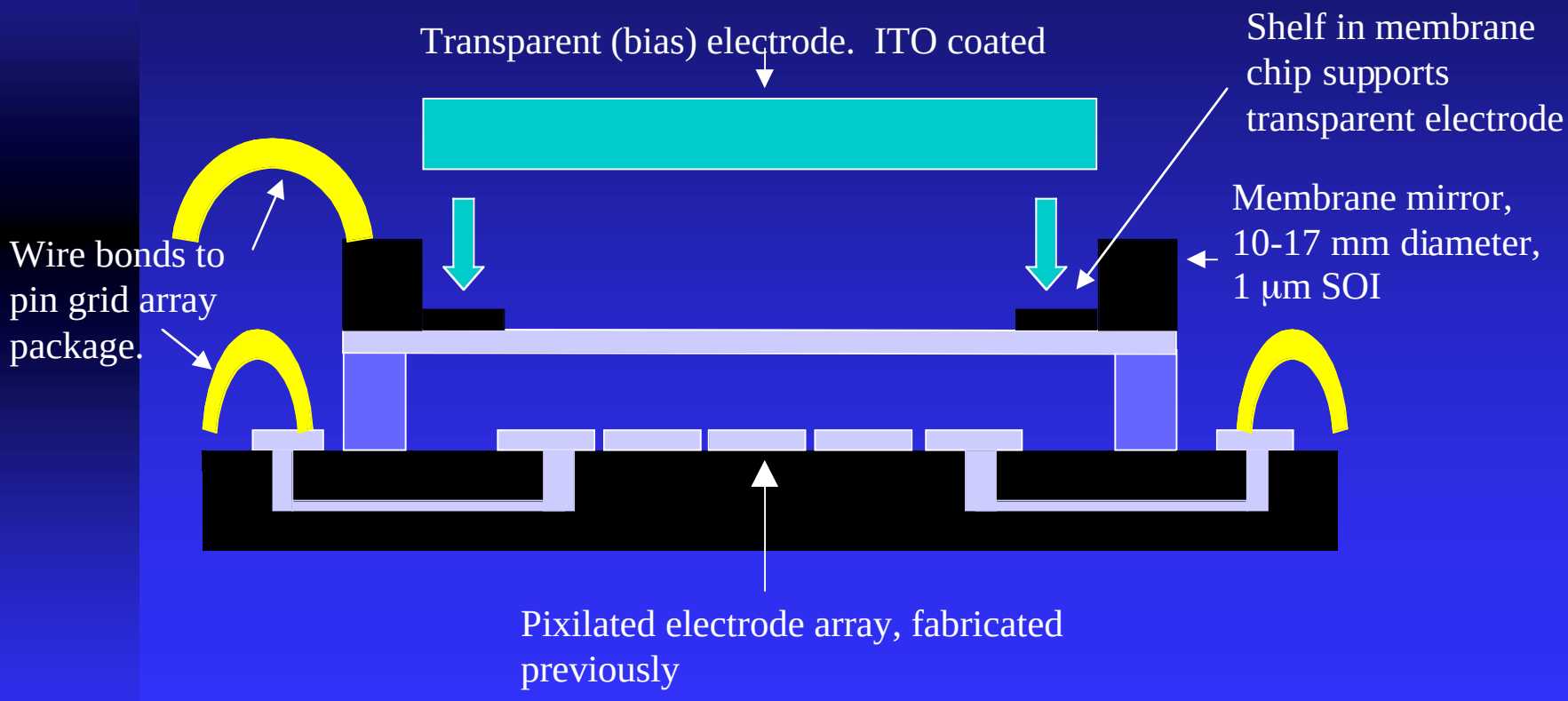


- 256 electrode array, 8 mm diameter.
- 8 mm diameter membrane.
- Package/wire bonded.

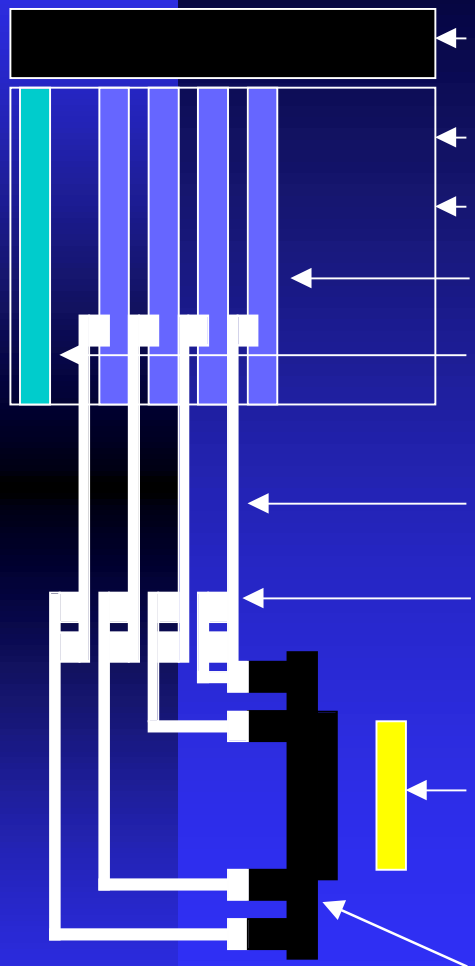
Prototypes for Univ. of Rochester

- 12 mm membrane (SOI).
- 1024 electrode array / 10 mm diameter.
- 18 μm membrane-electrode spacing.
- <130 V actuating voltage.
- 2-4 μm stroke (based on previous devices).
- Surface flatness: 800 nm PV / 8 mm ; 500 nm PV / 6 mm (based on previous 8 mm device).
- Metalization: shadow mask deposition / low stress aluminum. (in progress).
- 25 μm gap/160 V/5+ μm stroke device (in progress).

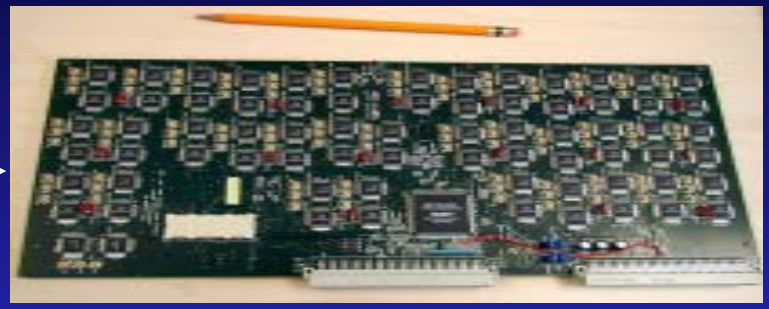
Transparent electrode design



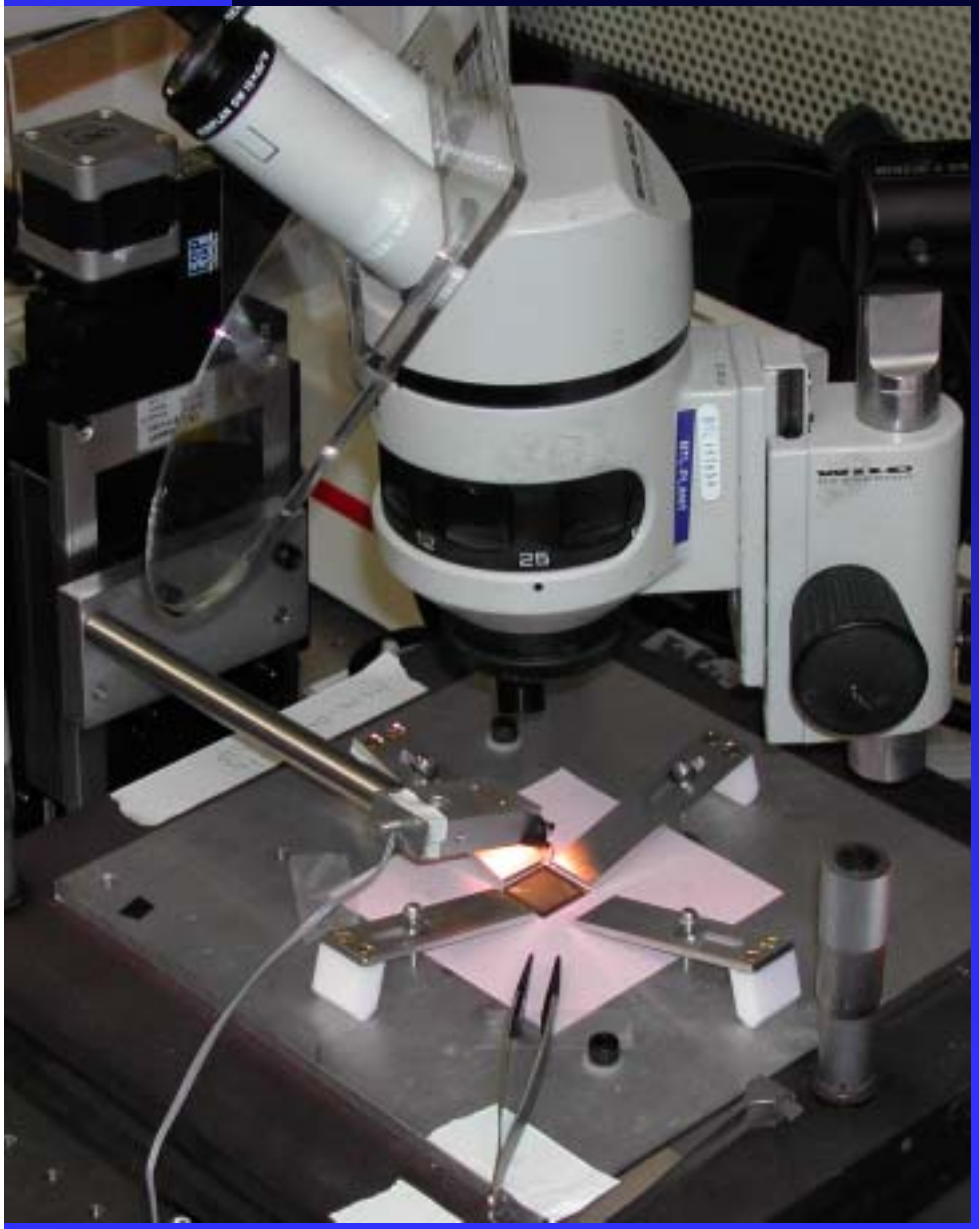
System for University of Rochester Vision Science Research Group

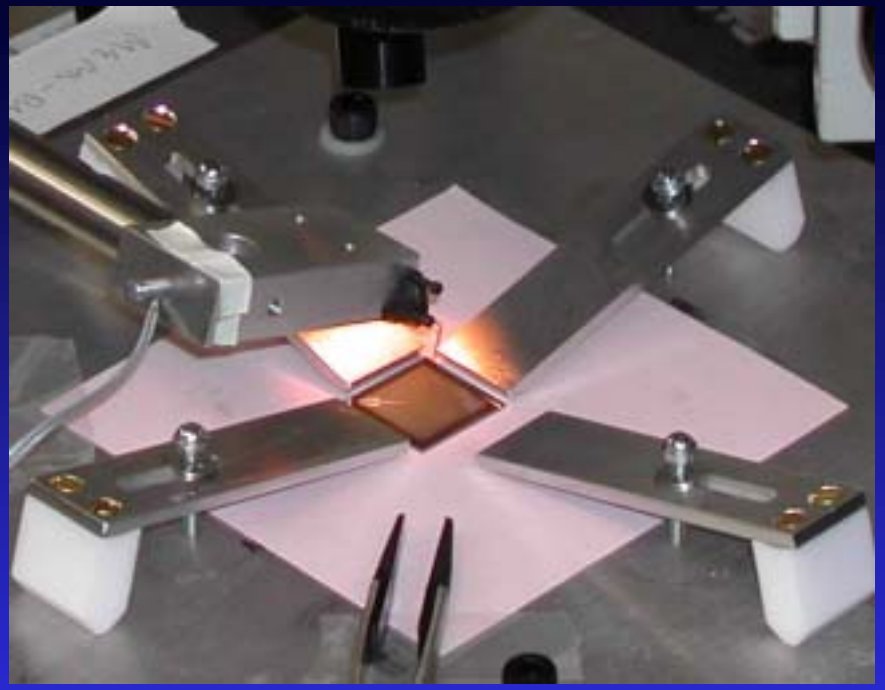


- Amrel Power Supply
- Tracewell VME Crate
- 288 Channel HV DAC
- PCI-VME Controller
- Flex cable (300 pin)
- Flex extender cable (300 pin)
- MEMS Device in 1032 PGA package (wire bonded)
- 300 MEMS Package Carrier Card



Automated electrode tests





- Automated test of 1024 electrodes: ~ 40 minutes.
- Test for open circuits.
- **One** open circuit found.
- Future tests: one chip per wafer.

Stress of free membranes

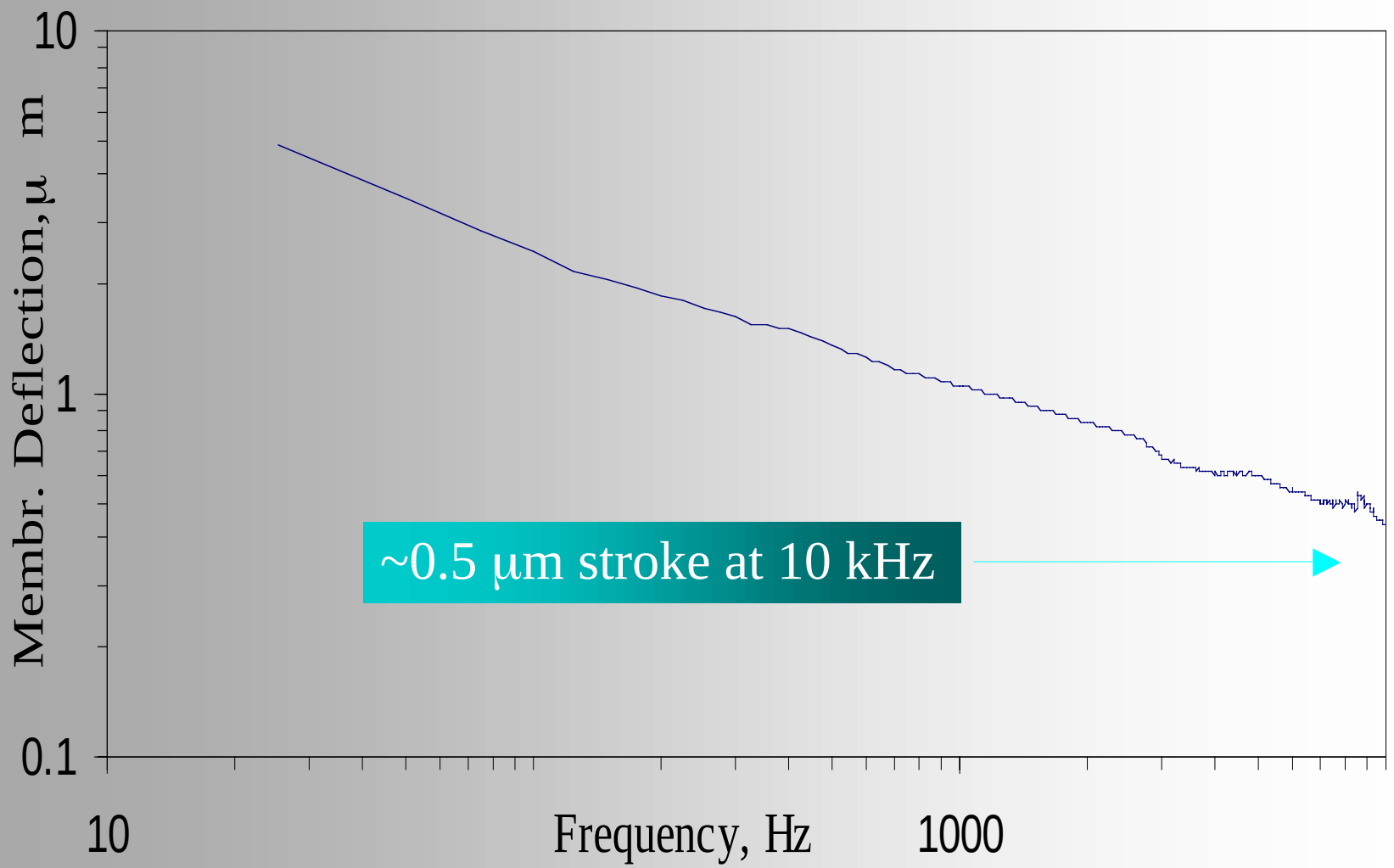
- Bare Si: 2.2 MPa (avg. 3 membranes)
- Si+Al: 2.0 MPa (avg. 2 membranes)
- Si+Al+oxide: 2.4 MPa
- Al+Si+oxide+T-cycle (25C→70C→25C): **2.9 MPa**

Measured, kHz	Model fit, kHz
2.28	2.26
3.55	3.58
4.81	4.80

Measured, kHz	Model fit, kHz
2.18	2.21
3.45	3.49
4.67	4.69

Measured, kHz	Model fit, kHz
2.41	2.40
3.72	3.80
5.13	5.10

Time frequency response: 20 Hz – 10 kHz



Model of membrane deformation

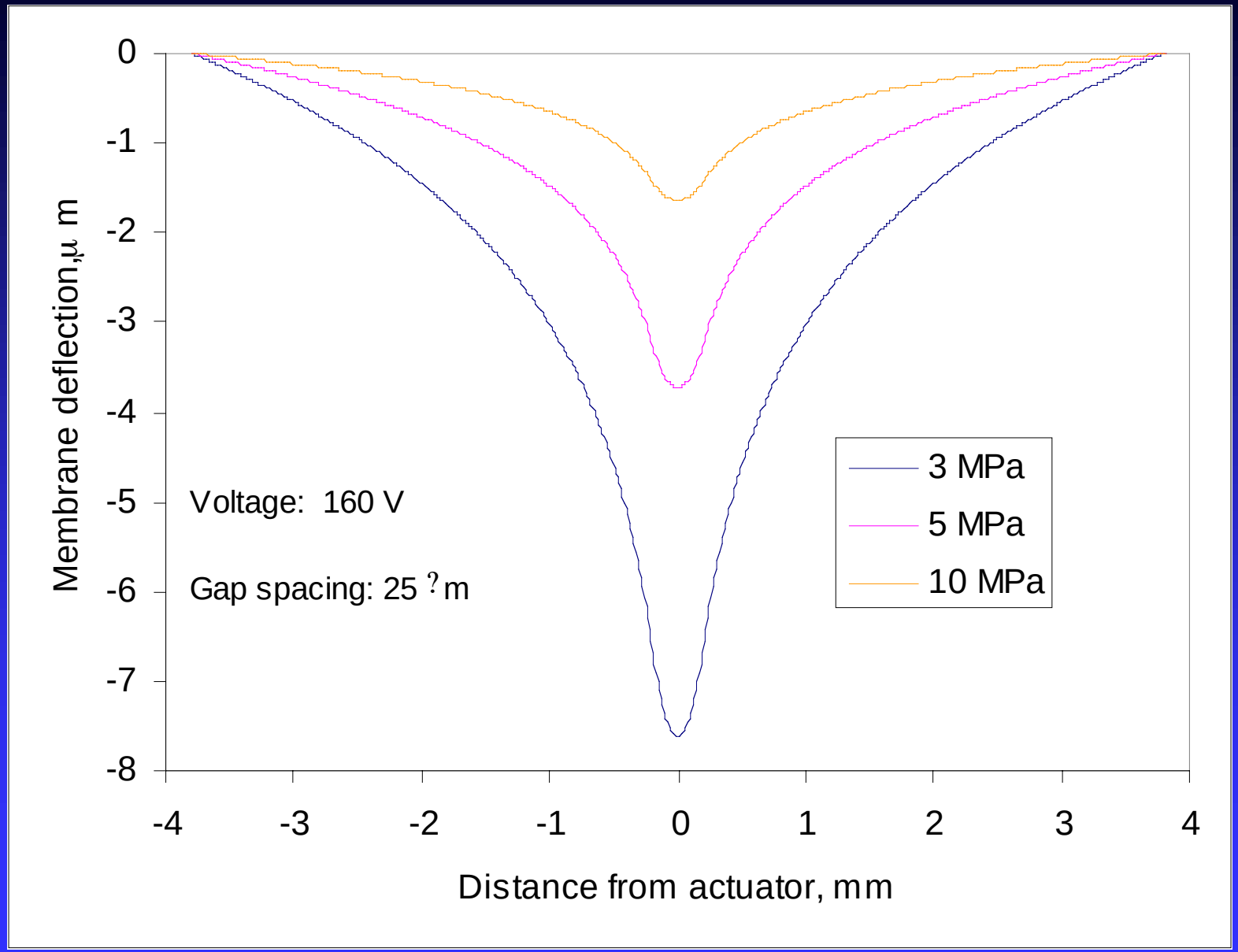
- Poisson equation.
- Expansion of pressure to first order.
- Analytically solvable (e.g. single, centered electrode, circular membrane).
- "Toy" model ignores fringe field and bending stress (off diagonal terms in stress tensor).
- Special case of 4'th order ODE (flexural rigidity, bending stress)

$$\nabla^2 \xi = -\frac{P}{T}$$

$$P = \frac{1}{2}\varepsilon_0 \frac{V^2}{d^2}$$

$$= \frac{1}{2}\varepsilon_0 \frac{V^2}{d_0^2}\left(1 + 2\frac{\xi}{d_0} + \ldots\right)$$

Influence functions



Membrane spatial frequency response

- Power law follows from Poisson equation.
- Well matched to atmospheric turbulence.
- Attenuated at large amplitude & high spatial frequency due to bending stress.
- Bending stress ~ material stress…leads to amplitude frequency relationship.

$$\nabla^2 \xi = -\frac{P}{T}$$

$$\tilde{\xi}(k) \propto \frac{1}{k^2}$$

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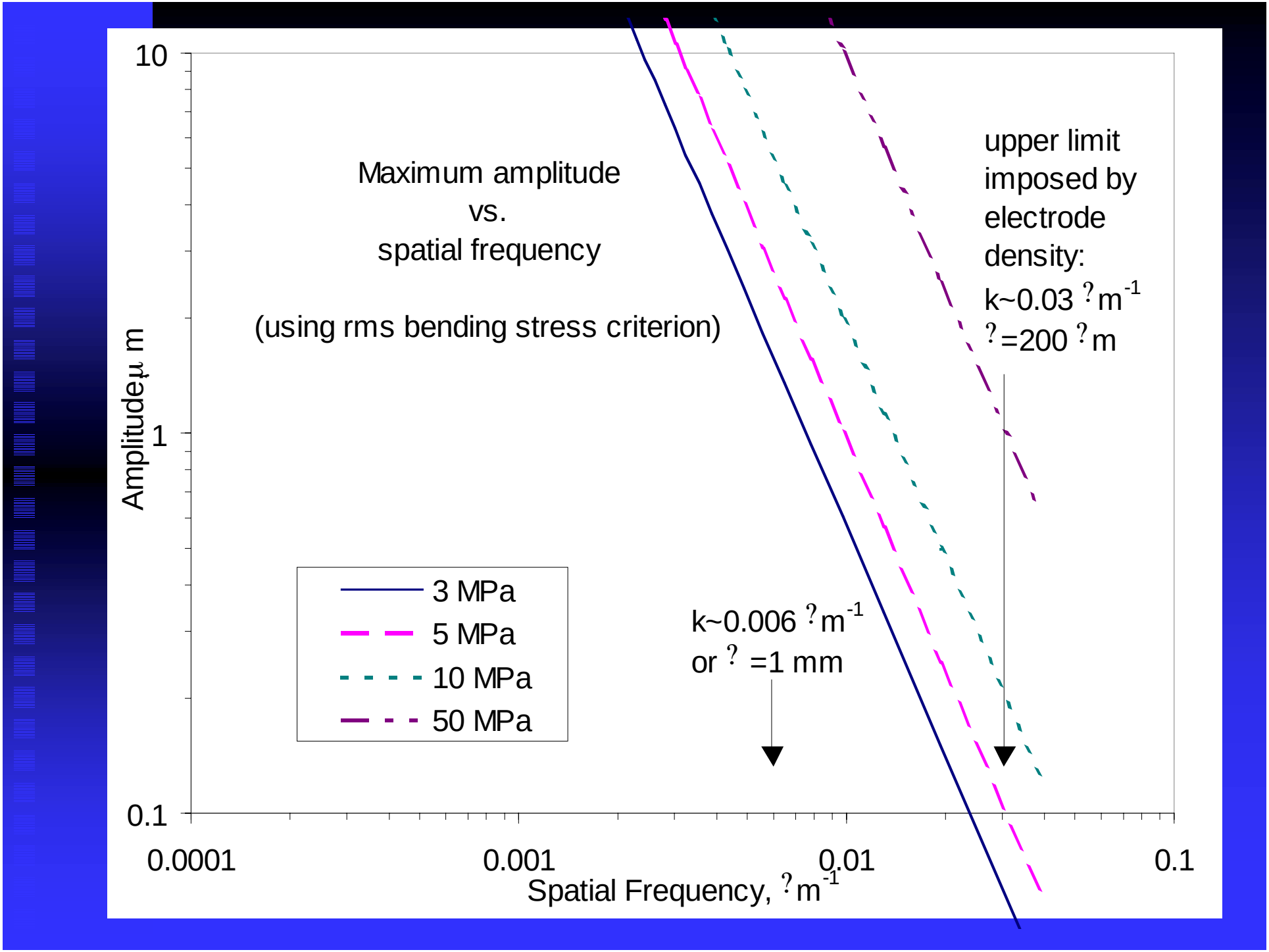
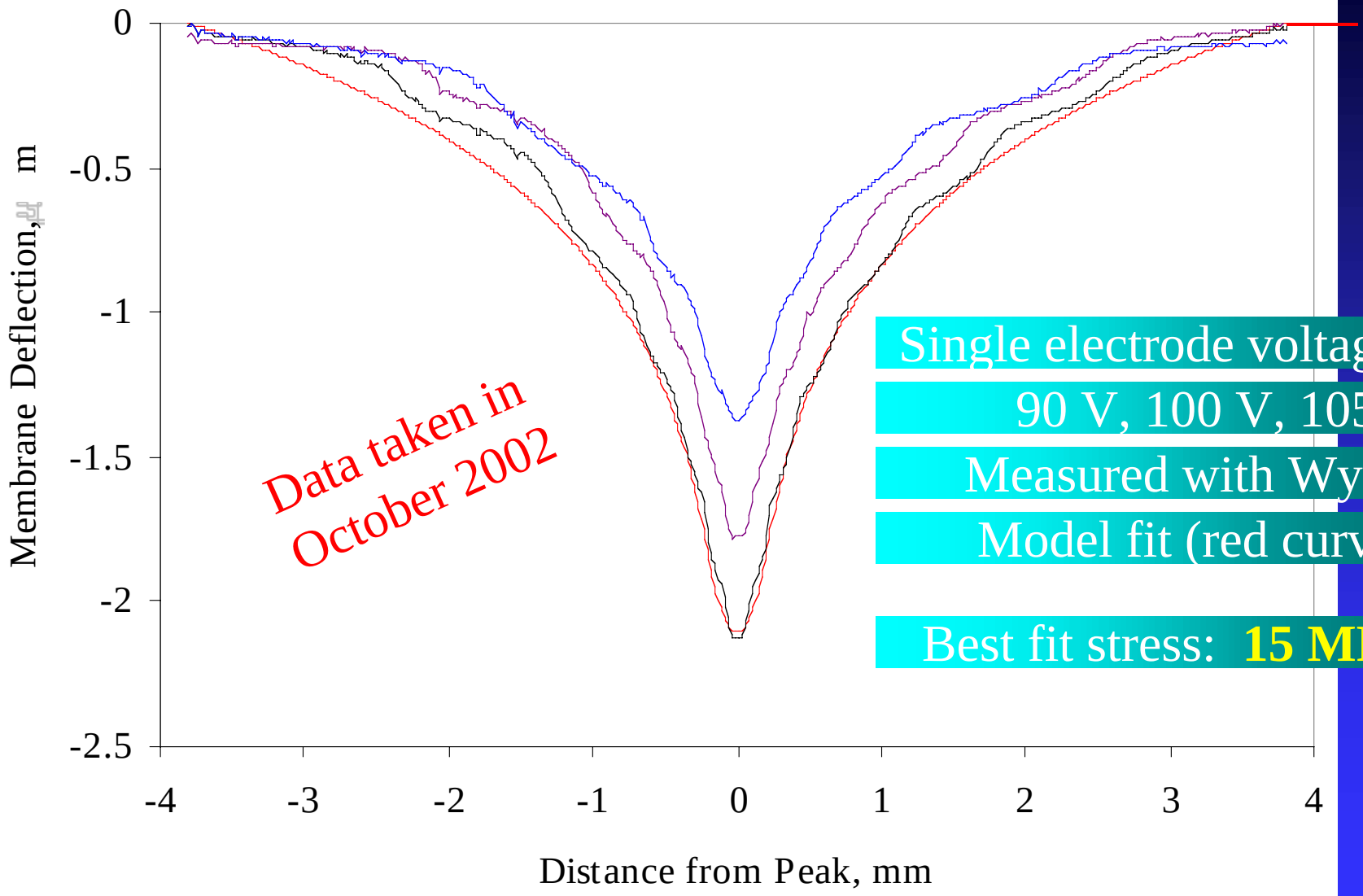
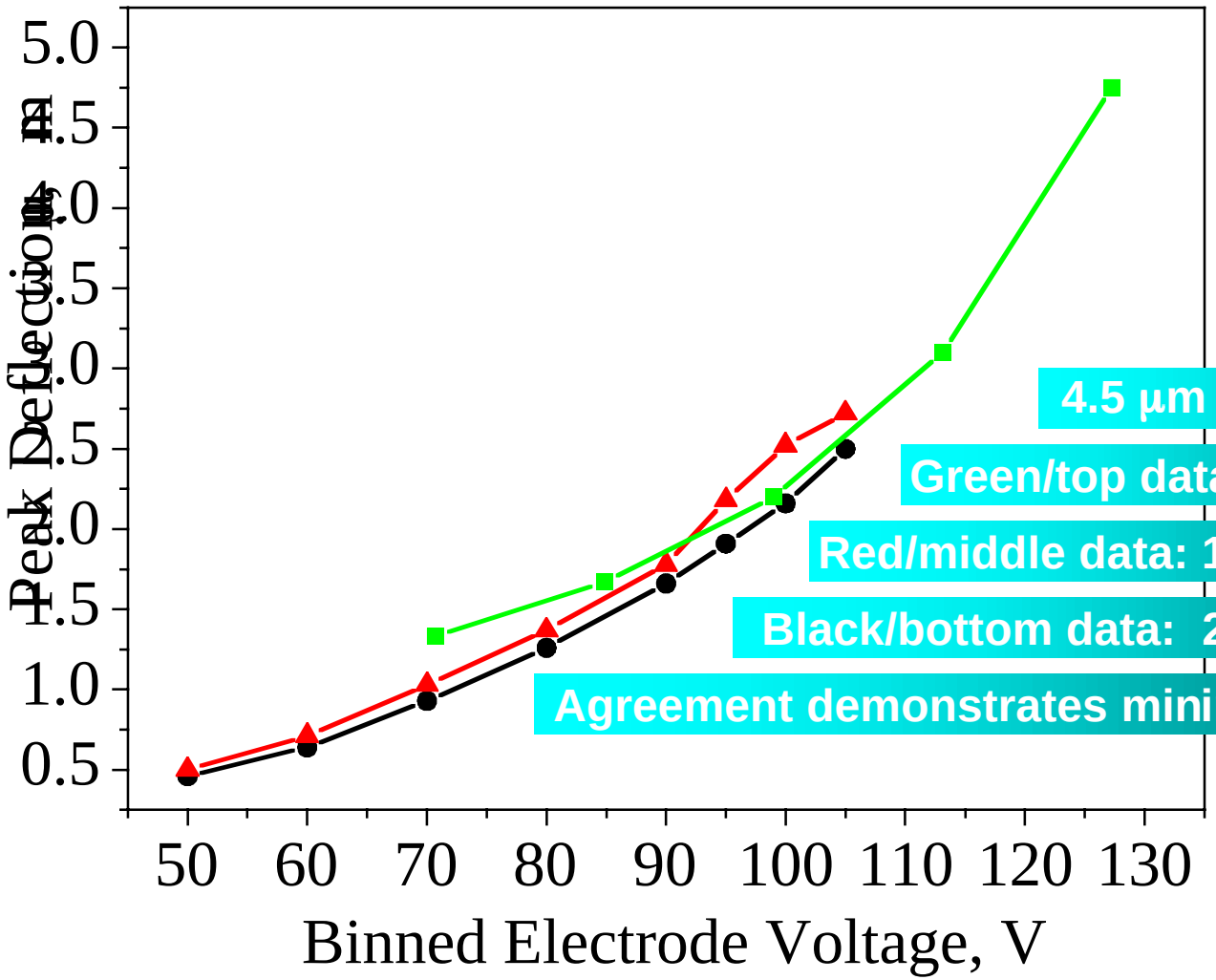

Maximum amplitude
vs.
spatial frequency
(using rms bending stress criterion)
upper limit
imposed by
electrode
density:
k~0.03 ?m-1
?=200 ?m
k~0.006 ?m-1
or ? =1 mm
3 MPa
5 MPa
10 MPa
50 MPa
Amplitudeμ m
10
1
0.1
0.0001
0.001
0.01
0.1
Spatial Frequency, ?m-1

Influence function



Two Binned electrodes



4.5 μm stroke achieved

Green/top data: Static (Wyko)

Red/middle data: 10 Hz membrane

Black/bottom data: 20 Hz membrane

Agreement demonstrates minimal air damping

Frequency response: 50 Hz – 1 kHz