Surface specifications for ET mirrors: state of the art

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Rationale

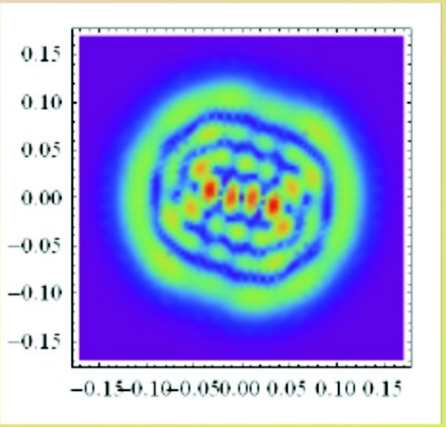
Why care about mirror defects at this stage?

➢ probably no major problems for TEM00: main subjet is reduction of cavity r.-t. losses

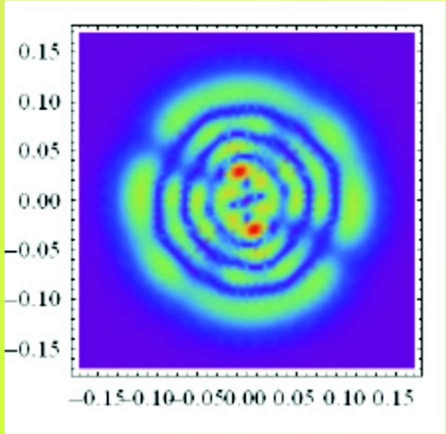
➢ but LG33 is degenerate: defects → excitation of unwanted modes

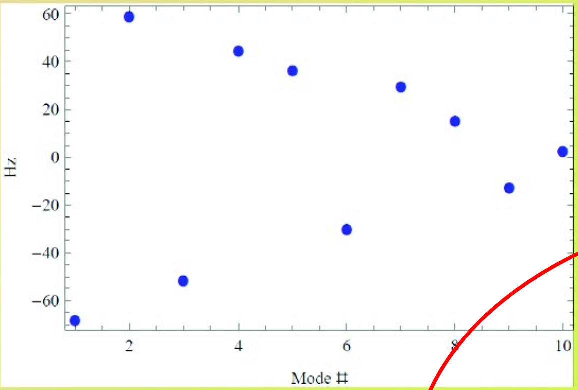
How bad is it?

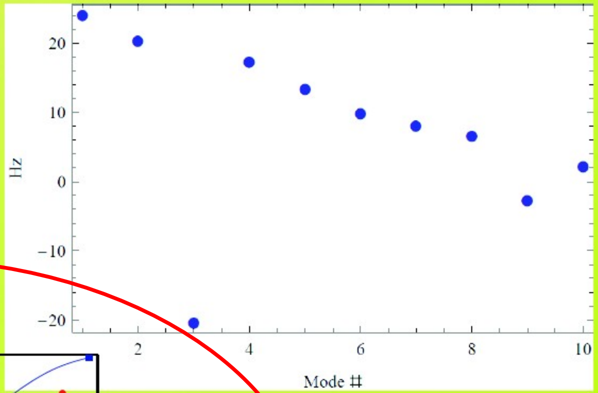
From last GWADW in May

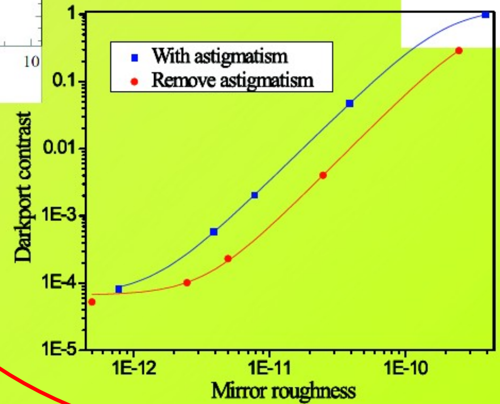


Are Laguerre-Gauss Modes Doomed?



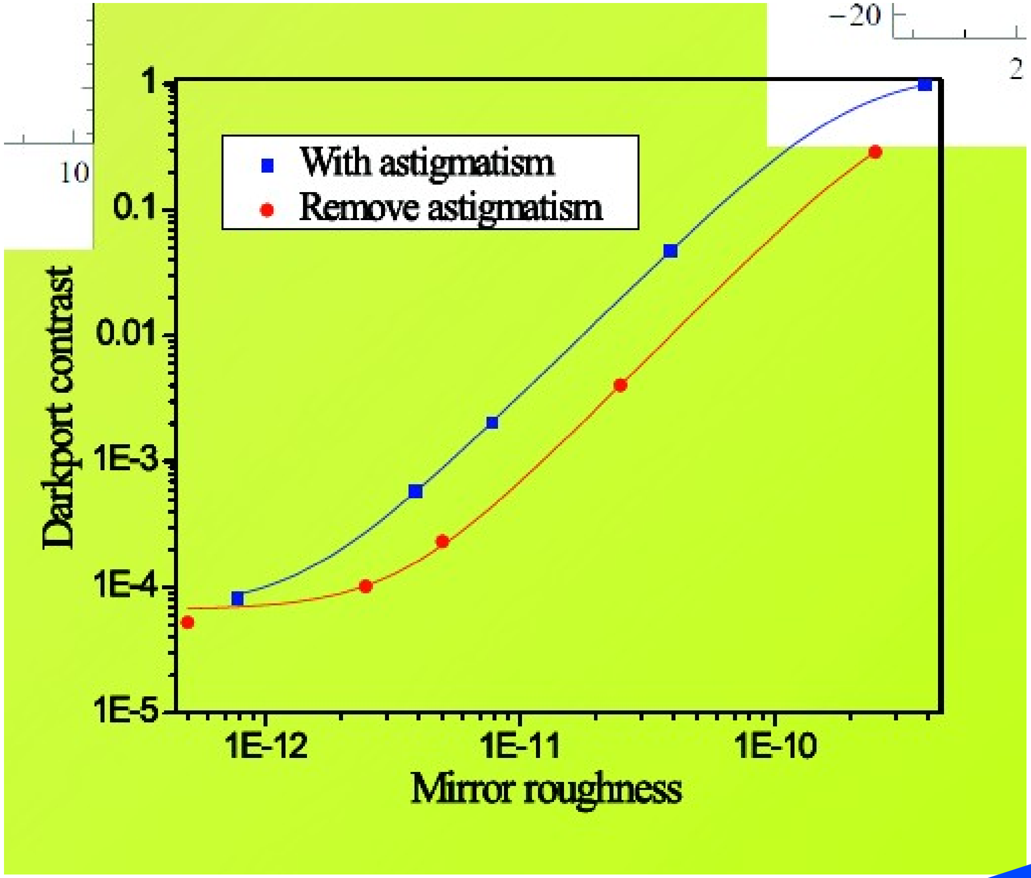






Rana Adhikari's talk

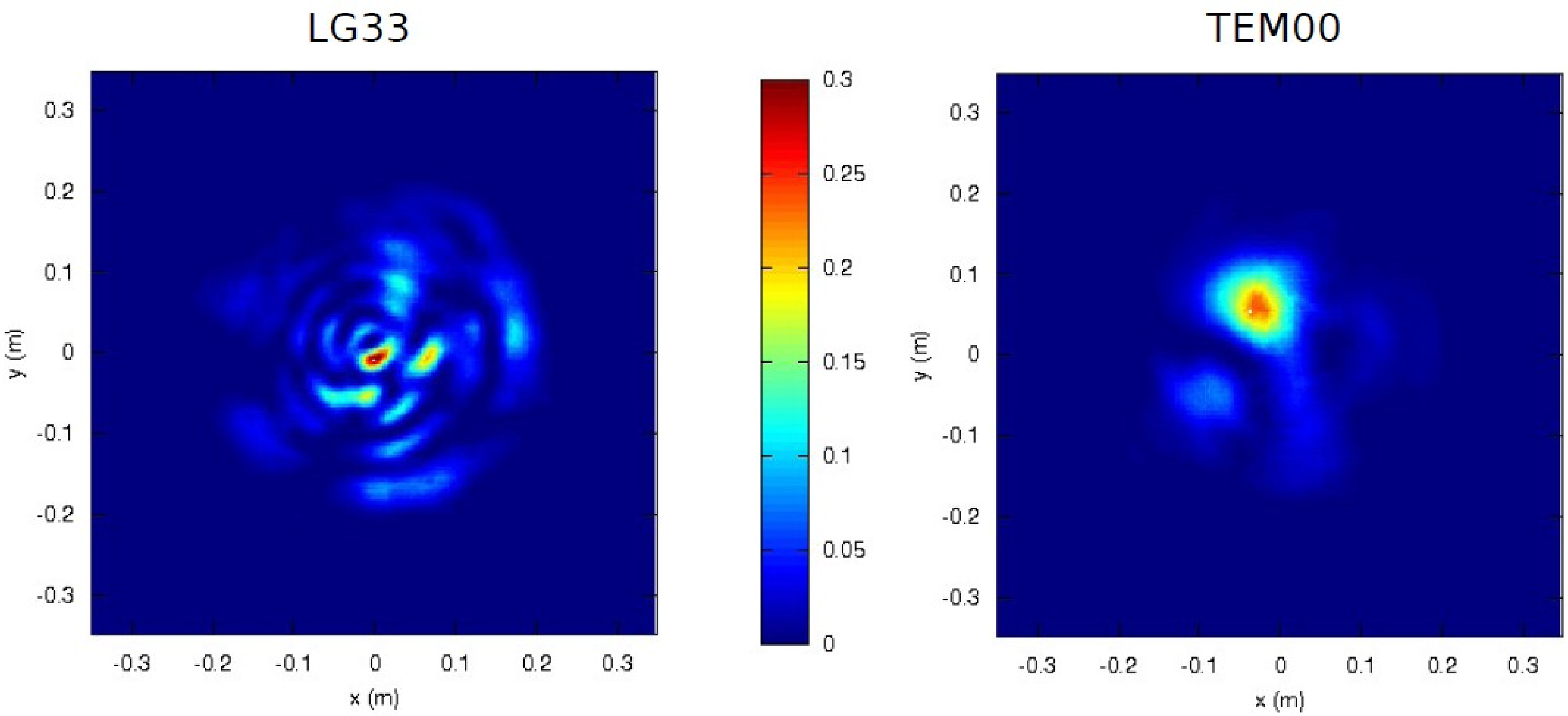
From last GWADW in May



Rana Adhikari's talk

From last GWADW in May

dark fringe: all possible cavity pairs with **1.0 nm rms** ("Ad-detectors-like")



contrast = $(1.9 \pm 0.6) \cdot 10^{-3}$

contrast = $(1.1 \pm 0.5) \cdot 10^{-3}$

M. Galimberti's talk

What do LG33 beams really do?

More investigations have been done...

Some bad news for people working on LG33:

➔ in FFT simulations, convergence tolerance for LG33 must be tigthened with respect to TEM00

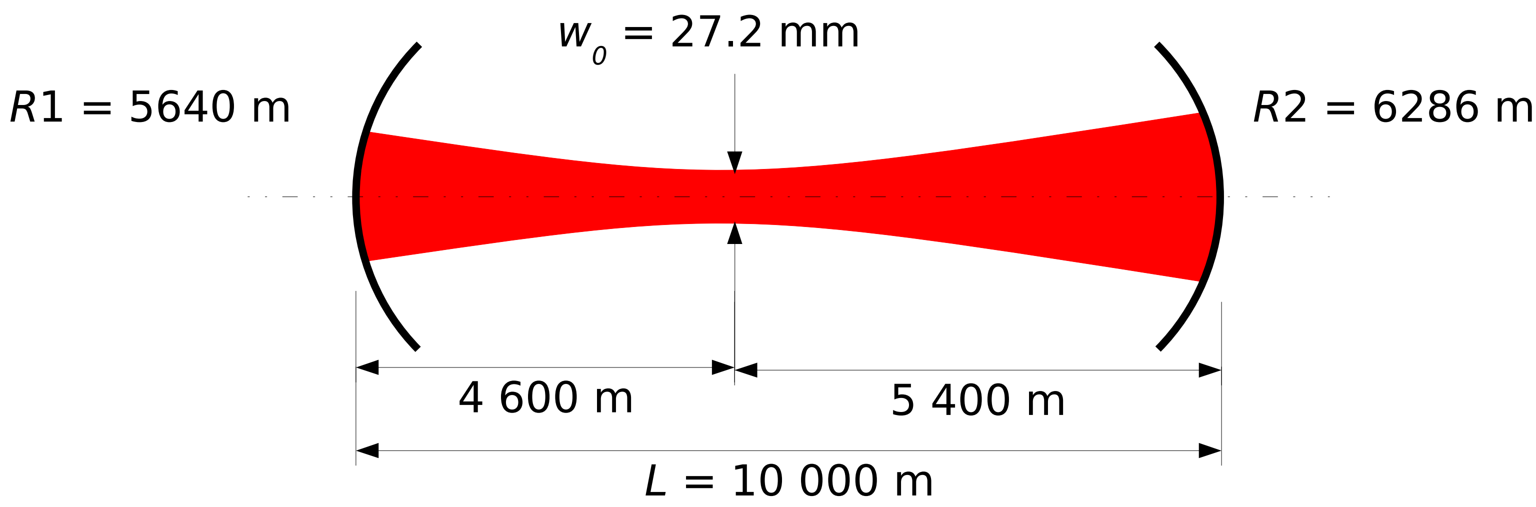
➔ new results show that indeed degenerate modes resonate even with very small surface defects

➔ bad contrast

Configuration for FFT simulations

- Cavity length L = 10 km
- Test masses diameter: 620 mm
- Finesse = 900
- Wavelength = 1064 nm
- Input mode: LG33
- Spotsizes: 63.4 mm on ITM, 72.5 mm on ETM
- Same g-factors as in AdV baseline:

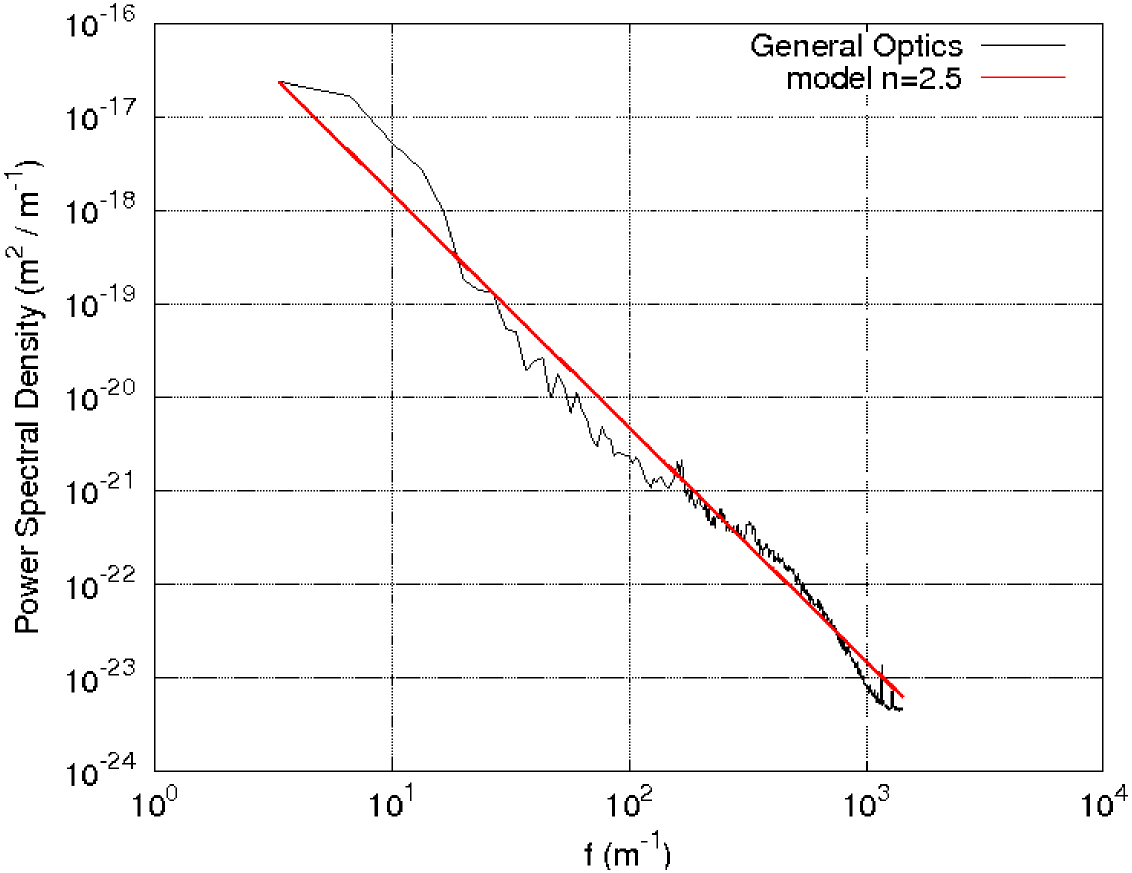
see A. Freise & S. Hild
ET optical layout draft
15 oct. 2010



A rough model for surface defects

Surfaces with defects have to be simulated

Defects described via their Power Spectral Density (PSD)



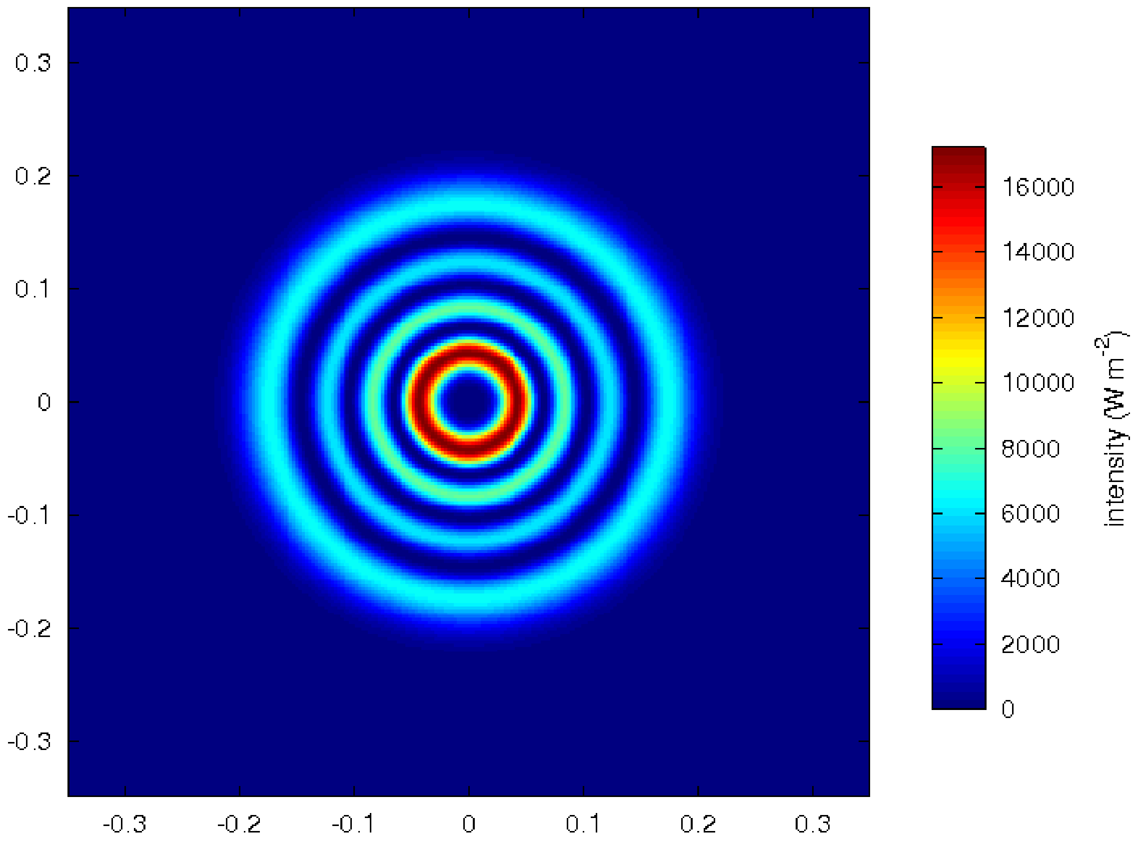
Take a “naive” model $1/f^n$ $(n \sim 2)$

some nm RMS = what can be obtained today with mechanical polishing

Results with $1/f^2$ surface

rms flatness	Pcirc all modes (W/W)	Pcirc LG33 (W/W)	fraction LG33	contrast
no defects	566.3	566.3	100.0%	0

circulating beam



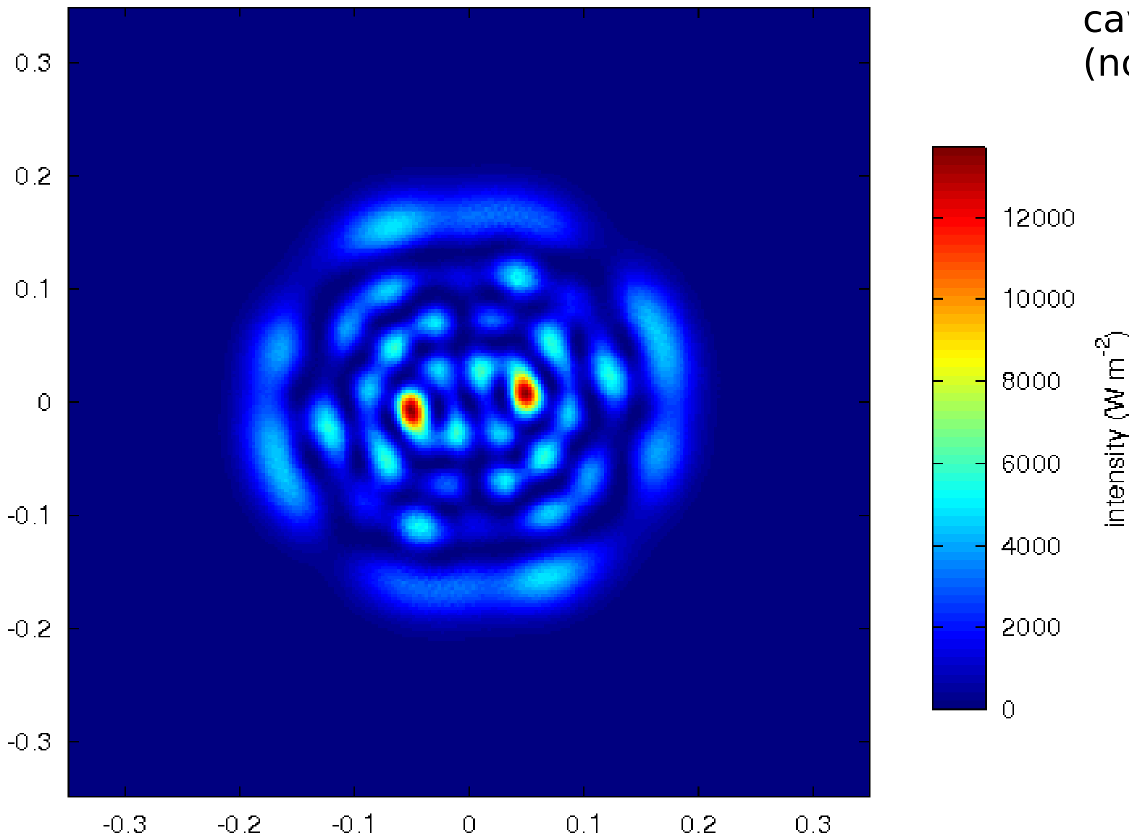
Results with $1/f^2$ surface

rms flatness	Pcirc all modes (W/W)	Pcirc LG33 (W/W)	fraction LG33	contrast
no defects	566.3	566.3	100.0%	0
1.0 nm – f^{-2}	257.5 ± 91.1	133.0 ± 94.8	46.6 ± 15.9%	68.4 ± 15.3%

average over 10 cavities

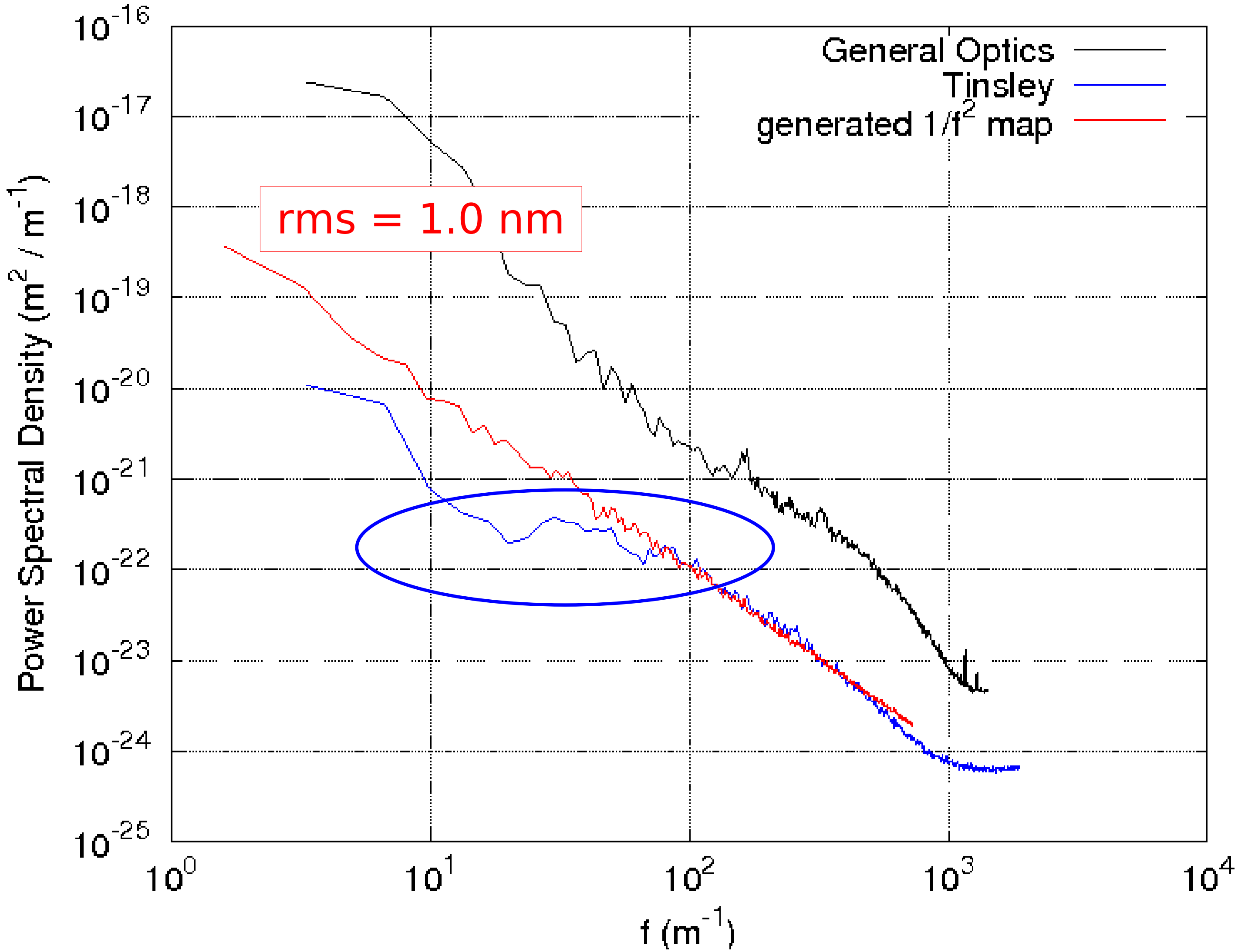
average over all cavity pairs (no recycling)

circulating beam

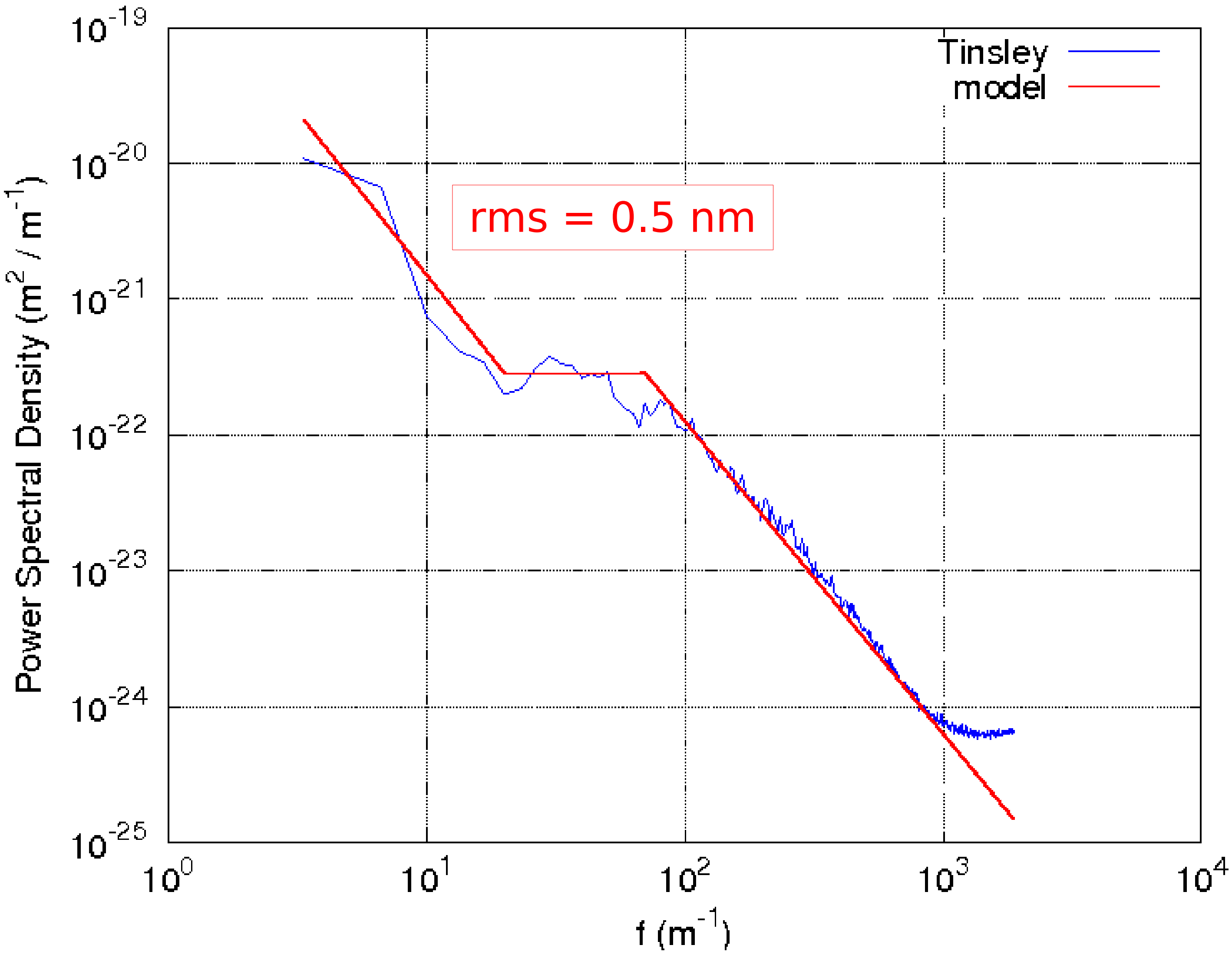


More realistic surfaces

State-of-the art ion beam polishing (AdLIGO)



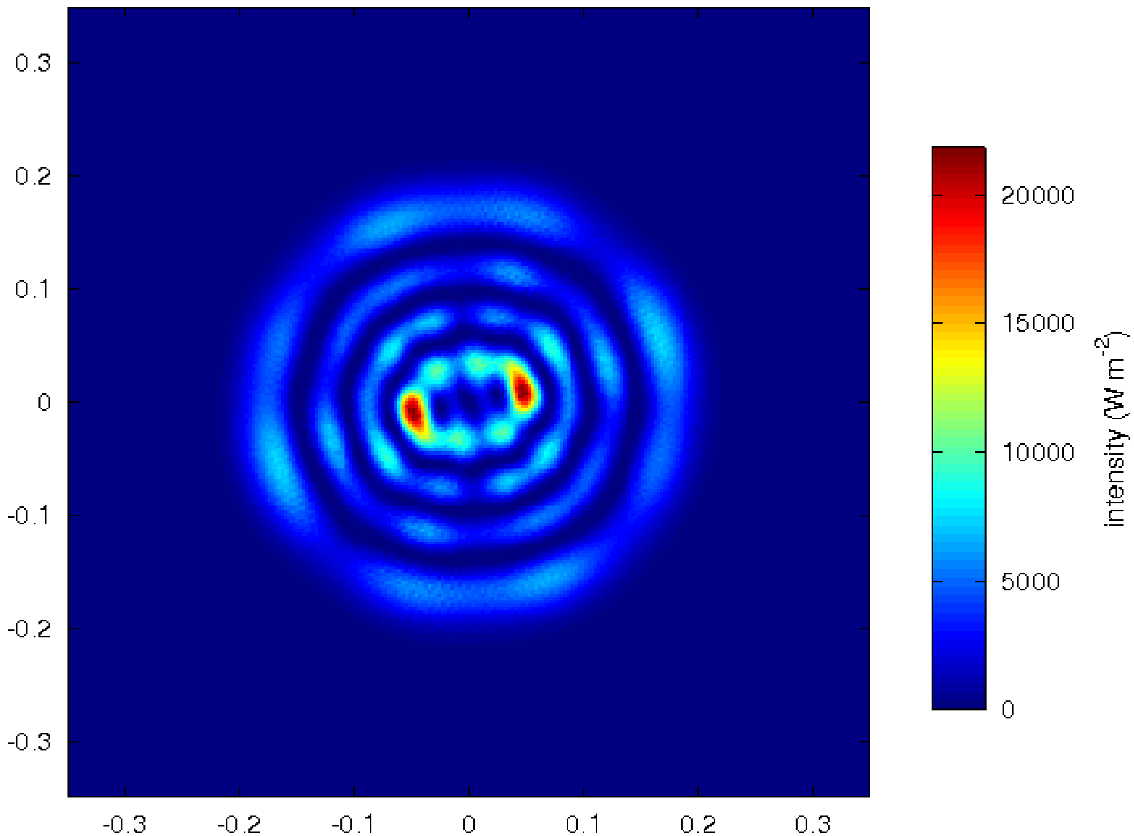
More realistic surfaces



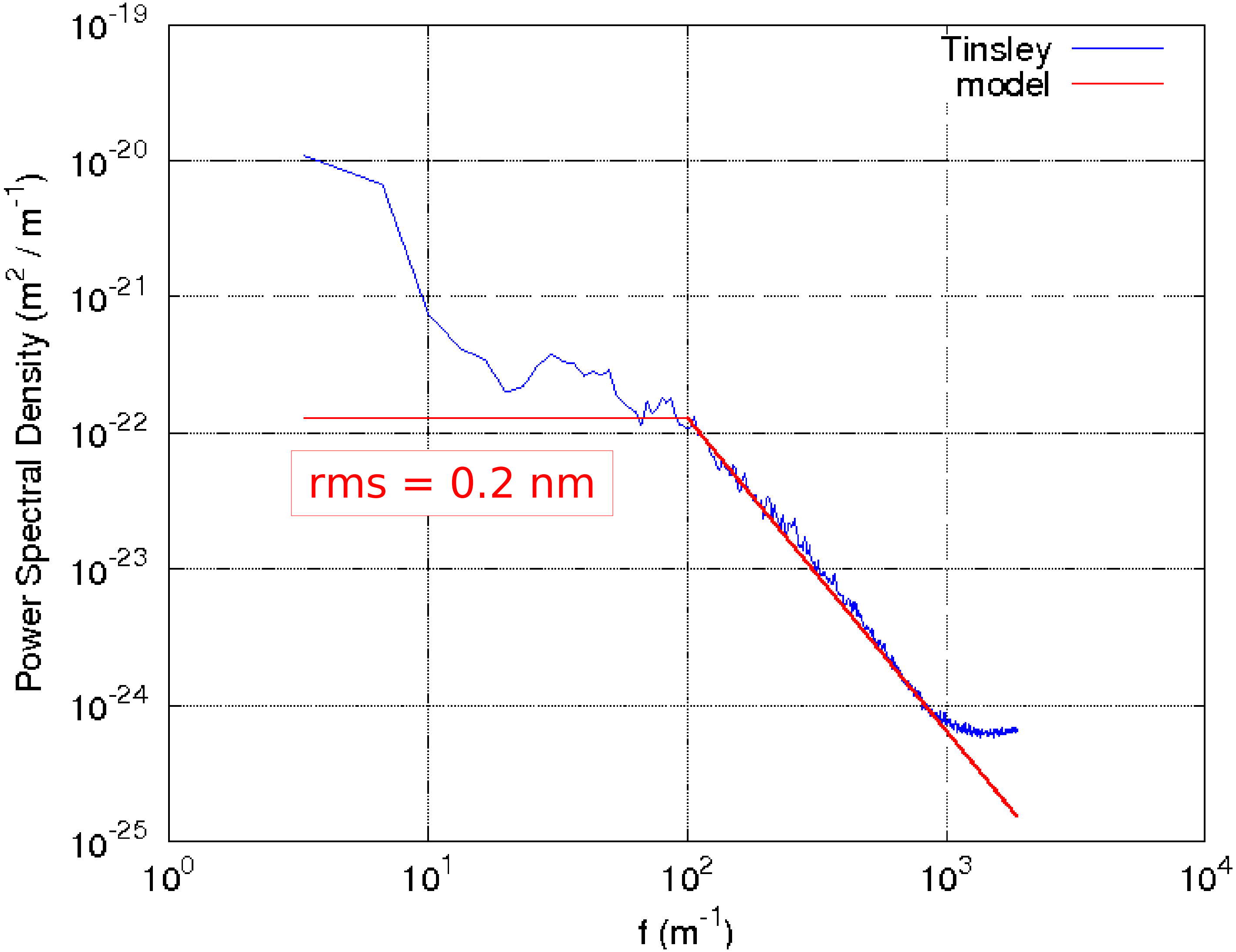
Results – ion beam polishing

rms flatness	Pcirc all modes (W/W)	Pcirc LG33 (W/W)	fraction LG33	contrast
no defects	566.3	566.3	100.0%	0
1.0 nm – f^{-2}	257.5 ± 91.1	133.0 ± 94.8	46.6 ± 15.9%	68.4 ± 15.3%
ion beam polishing	400.3 ± 79.2	294.6 ± 11.5	71.1 ± 13.9%	60.5 ± 20.4%

circulating beam



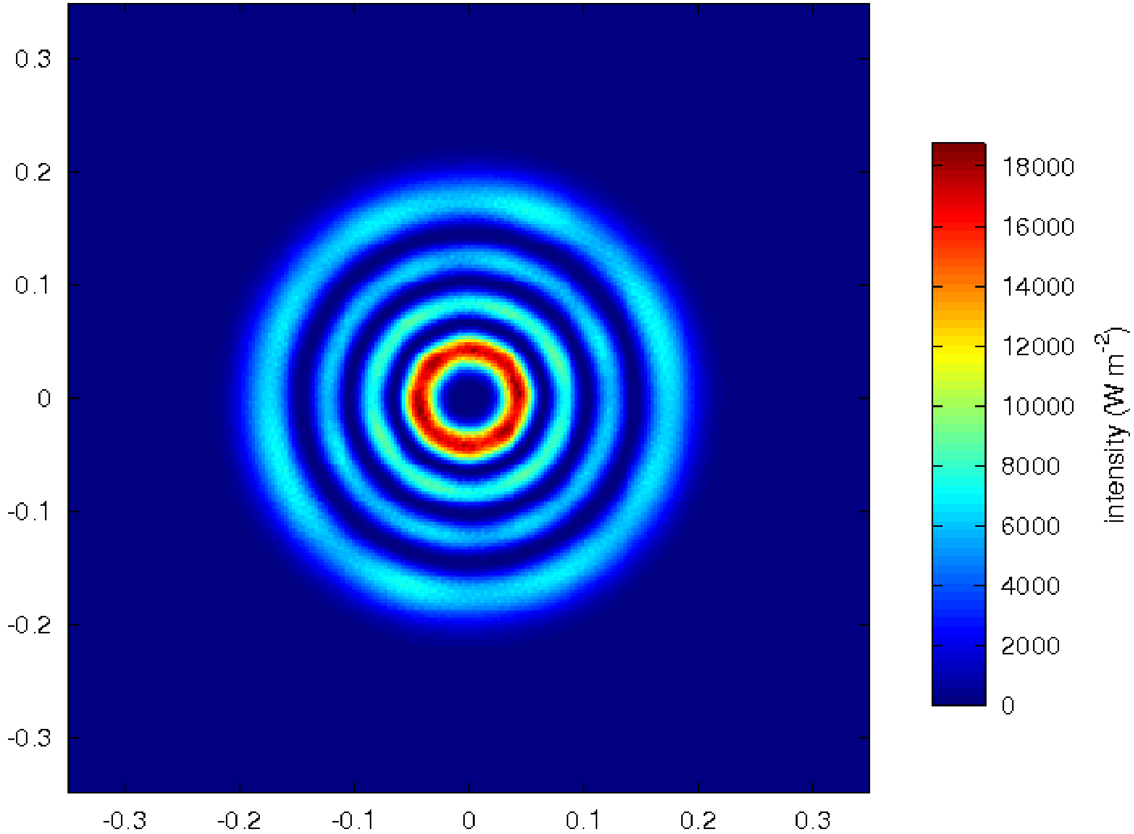
Can we cut the low-frequency defects?



Results – cutoff model

rms flatness	Pcirc all modes (W/W)	Pcirc LG33 (W/W)	fraction LG33	contrast
no defects	566.3	566.3	100.0%	0
1.0 nm – f^{-2}	257.5 ± 91.1	133.0 ± 94.8	46.6 ± 15.9%	68.4 ± 15.3%
ion beam polishing	400.3 ± 79.2	294.6 ± 11.5	71.1 ± 13.9%	60.5 ± 20.4%
cutoff @ 100 m^{-1}	562.9 ± 1.6	560.2 ± 3.1	99.5 ± 0.3%	1.8 ± 0.8%

circulating beam



Are simulations reliable?

PRELIMINARY

- results comparable with those obtained by H. Yamamoto using SIS
- collaboration ongoing with APC to compare simulations to experiment: for the moment, order-of-magnitude agreement

Summary

• at this stage, simulations are not to be taken literally, but more like order-of-magnitude estimations

• troubles come from low-frequency defects (less than ~ 10^2 m^{-1})

⚠ astigmatism is virtually absent in the “cutoff” model

• LG33 much more demanding than what previoulsy thought

Spares

LG00 vs LG33

1.0 nm – f^{-2}	Pcirc all modes (W/W)	Pcirc input mode (W/W)	fraction input mode	contrast
LG00	555.9 ± 3.7	555.6 ± 3.7	99.95 ± 0.03%	0.15 ± 0.07%
LG33	257.5 ± 91.1	133.0 ± 94.8	46.6 ± 15.9%	68.4 ± 15.3%

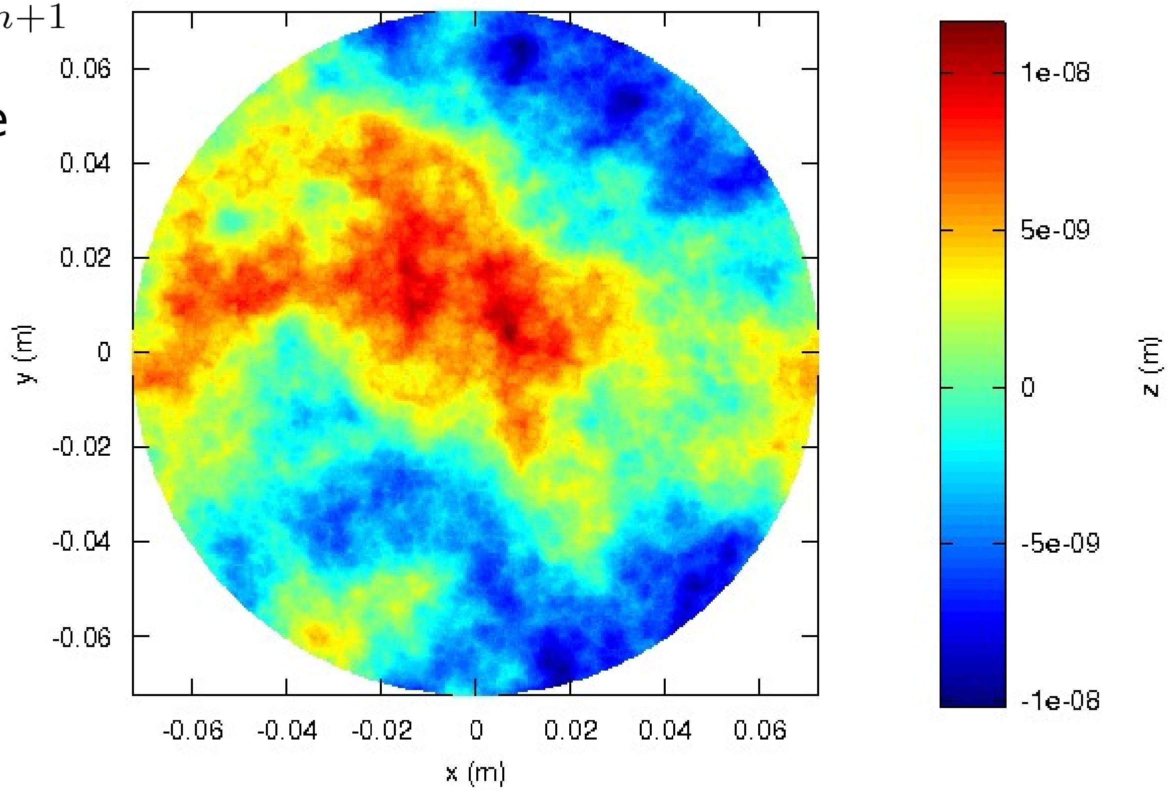
Simulation of mirror surfaces (1)

1) create a map in the frequency plane $S_2 \sim 1/f^{n+1}$ → modulus of the FT of the surface

2) add a random phase

3) iFFT → random surface

4) scale surface to the required rms



Simulation of mirror surfaces (2)