University of Glasgow | College of Science & Engineering

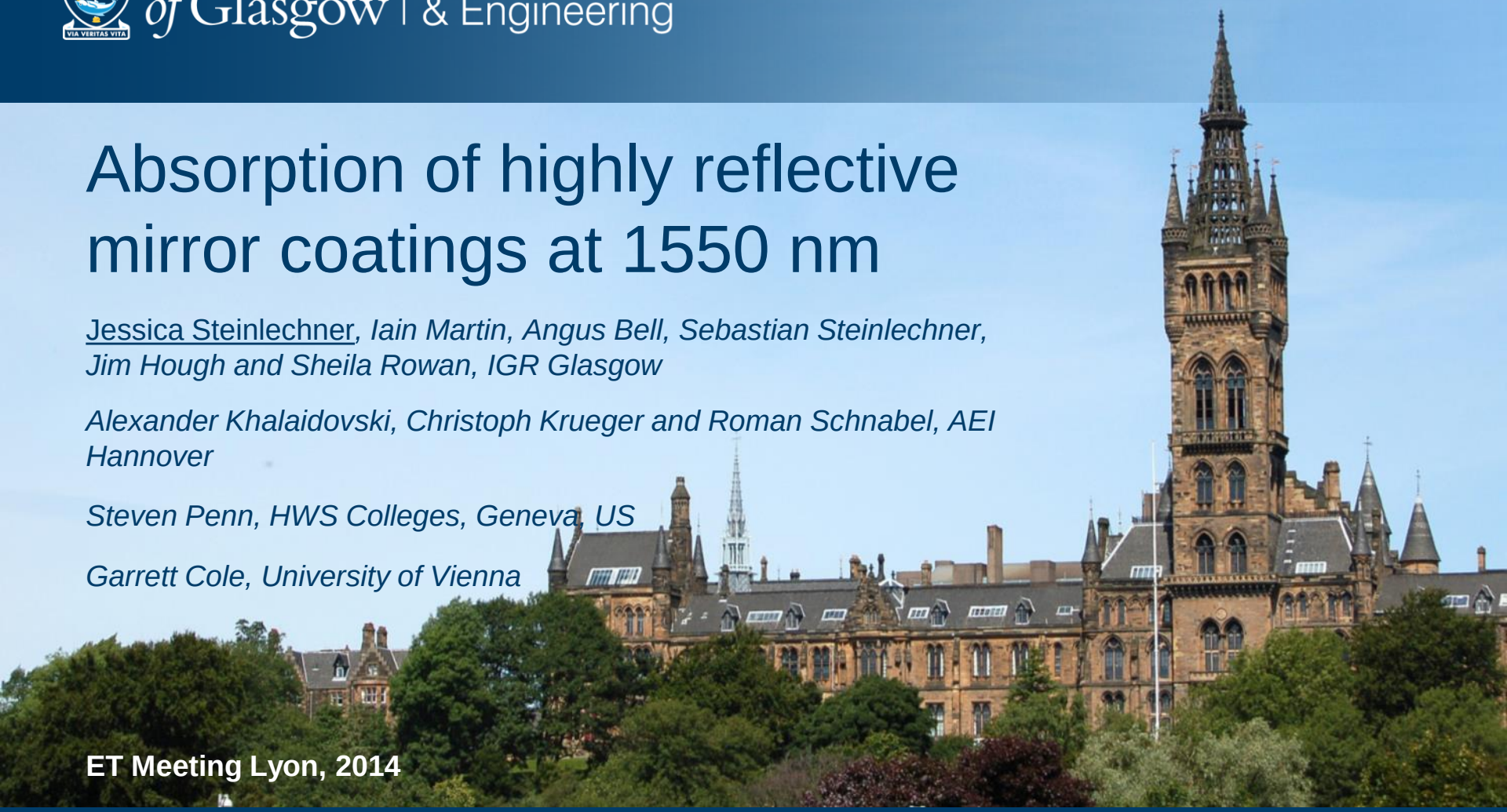
Absorption of highly reflective mirror coatings at 1550 nm

Jessica Steinlechner, *Iain Martin, Angus Bell, Sebastian Steinlechner, Jim Hough and Sheila Rowan, IGR Glasgow*

Alexander Khalaidovski, Christoph Krueger and Roman Schnabel, AEI Hannover

Steven Penn, HWS Colleges, Geneva, US

Garrett Cole, University of Vienna



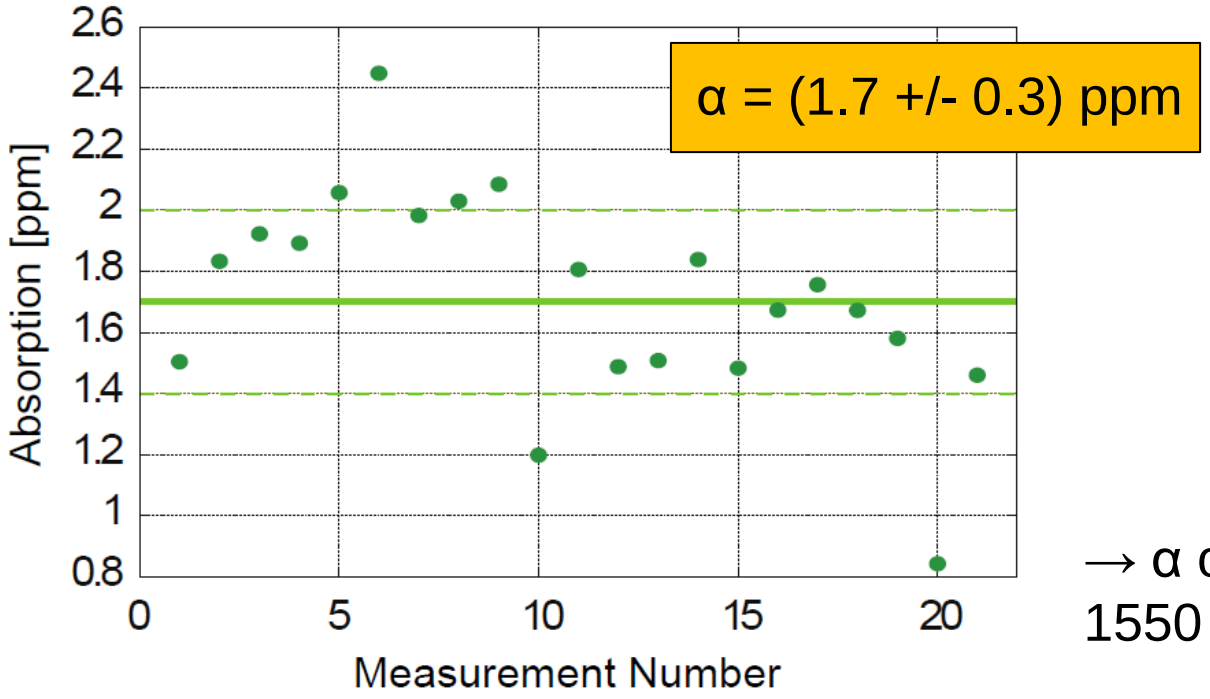
ET Meeting Lyon, 2014

LSC IGR ET EINSTEIN TELESCOPE

Optical absorption of SiO_2/Ta_2O_5 coatings at 1550 nm

We know: Optical absorption α of SiO_2/Ta_2O_5 @ 1064 nm is very low
(< 1 ppm for LIGO and VIRGO optics)

What about 1550 nm?



Coating:

- ATF
- HR (T≈ 530 ppm)
- Good quality, but not optimized for low absorption in particular

→ α of SiO_2/Ta_2O_5 at 1550 nm very promising

Coating Thermal Noise of SiO_2/Ta_2O_5

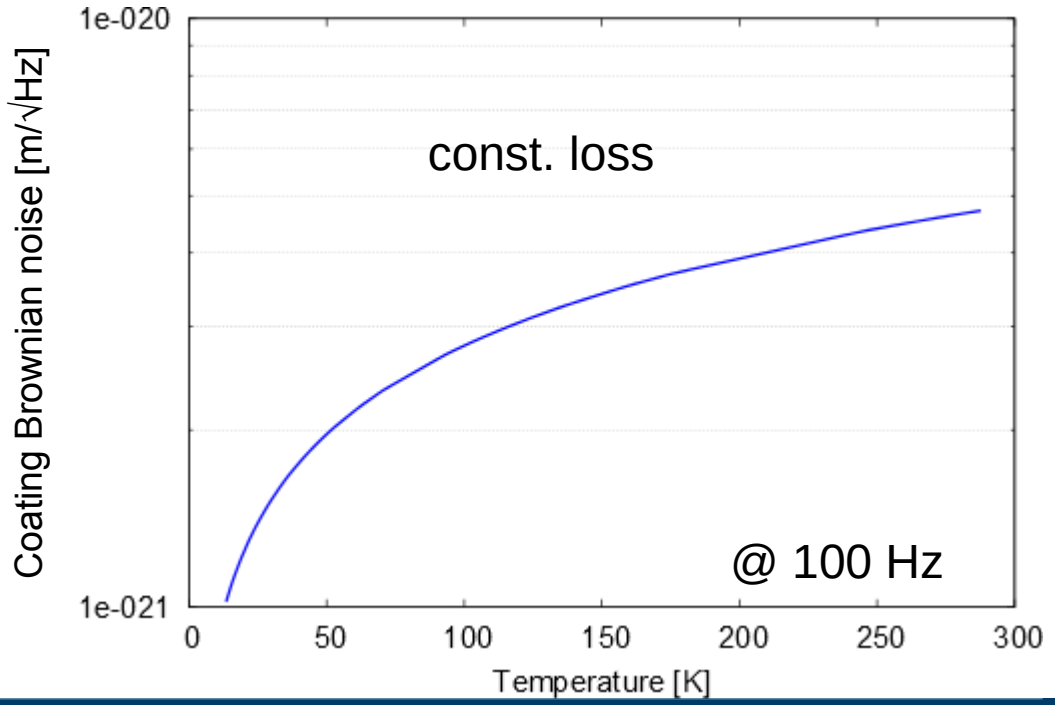
Temperature

Coating thickness

$$S_x(f,T) \approx \frac{2k_B T}{\pi^2 f} \frac{d}{w^2 Y} \phi\left(\frac{Y'}{Y} + \frac{Y}{Y'}\right)$$

Interferometer laser beam radius

Coating mechanical loss



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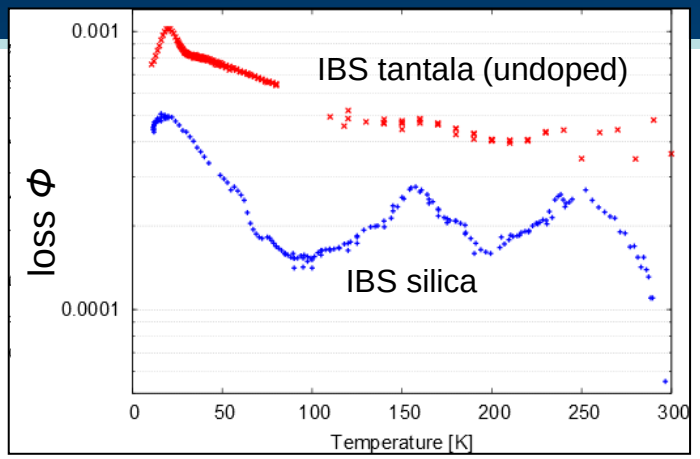

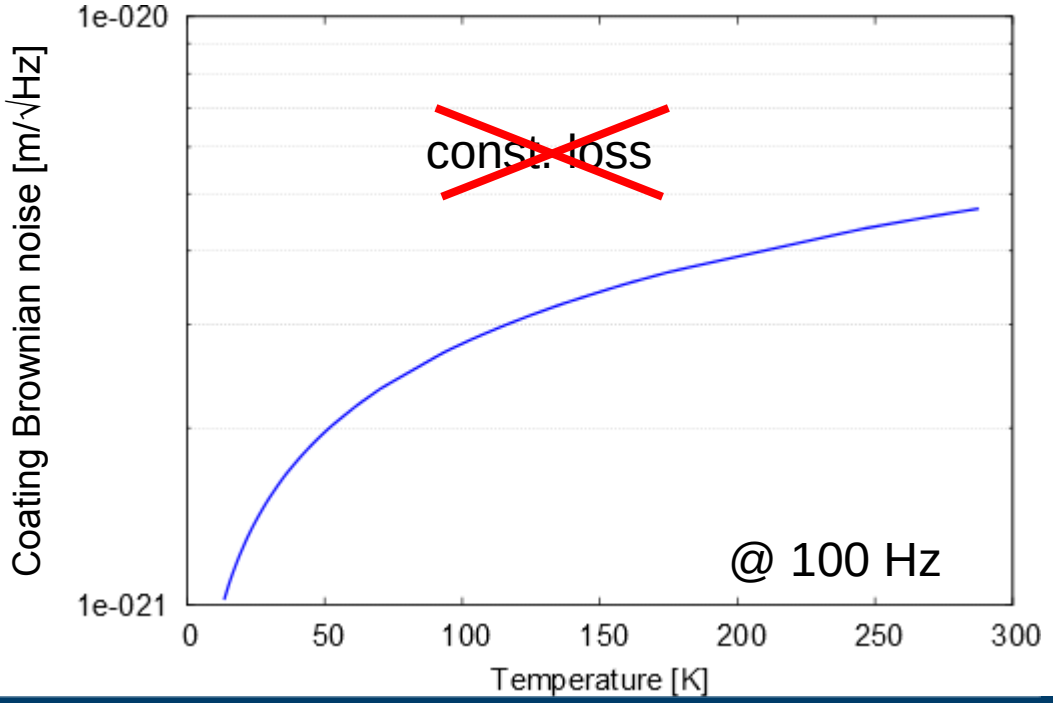

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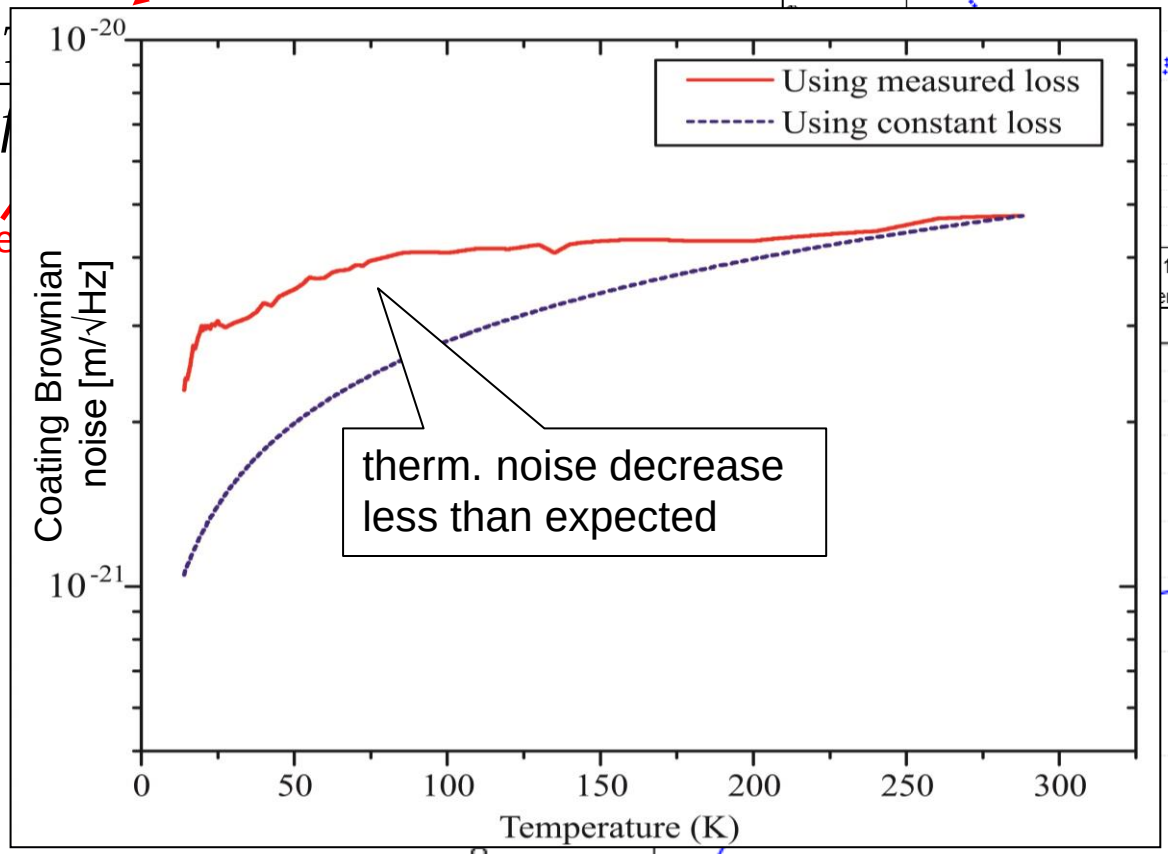
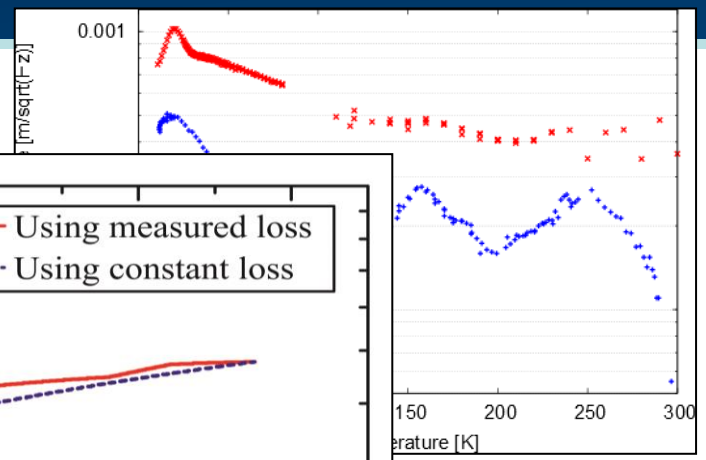
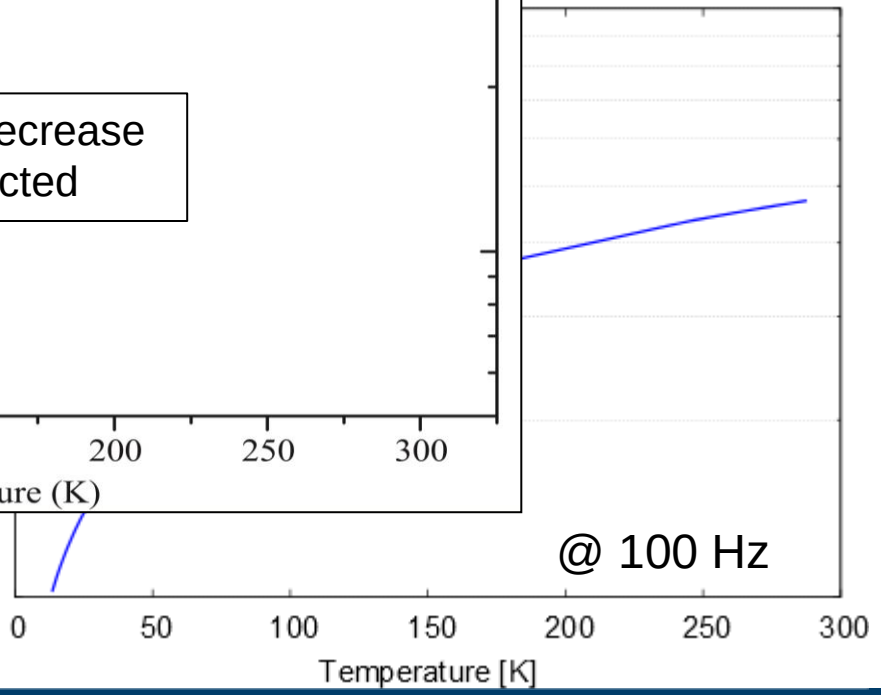


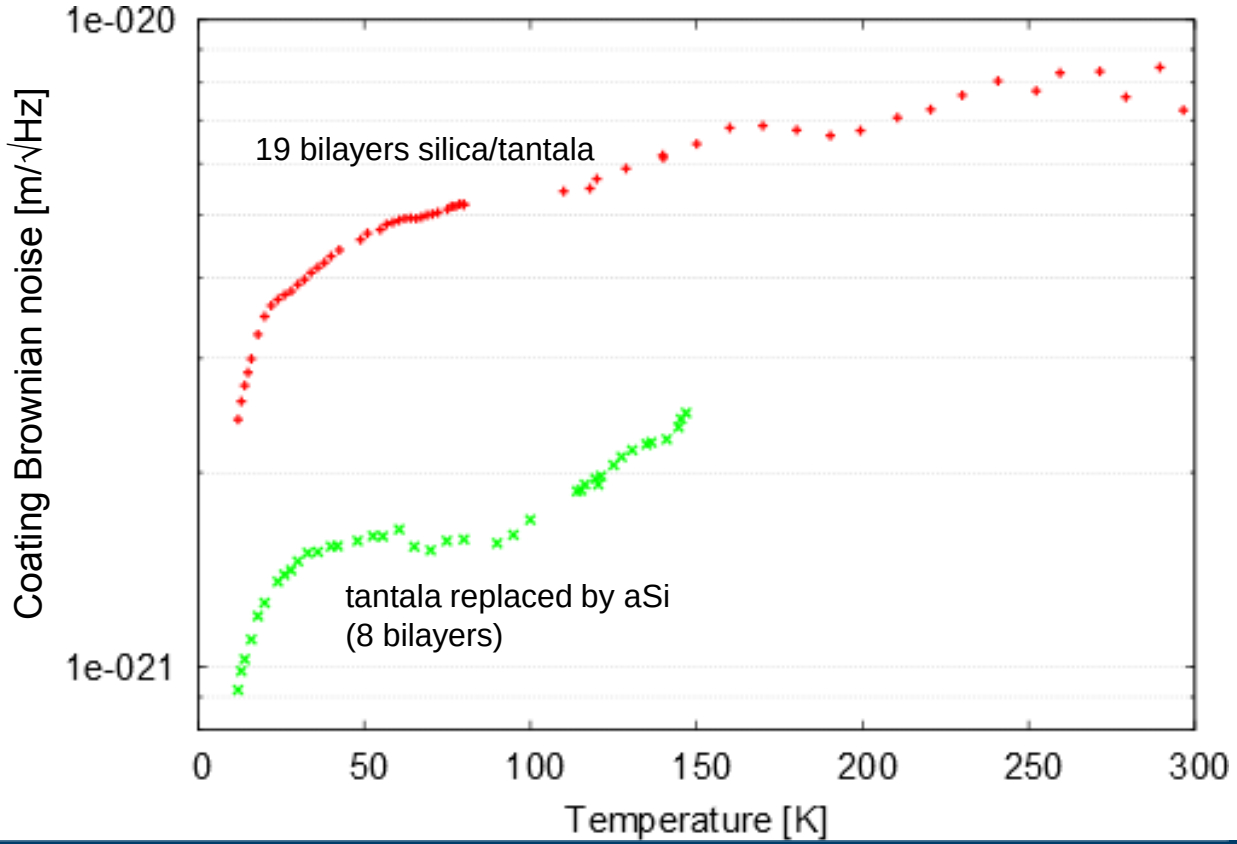




aSi for coatings? – Thermal noise ☺

aSi: significant lower loss than Ta_2O_5

Additionally: high refractive index (n = 3.5) reduces thickness of HR stack from about 8.7µm to 3.7 µm (when replacing tantala by aSi)

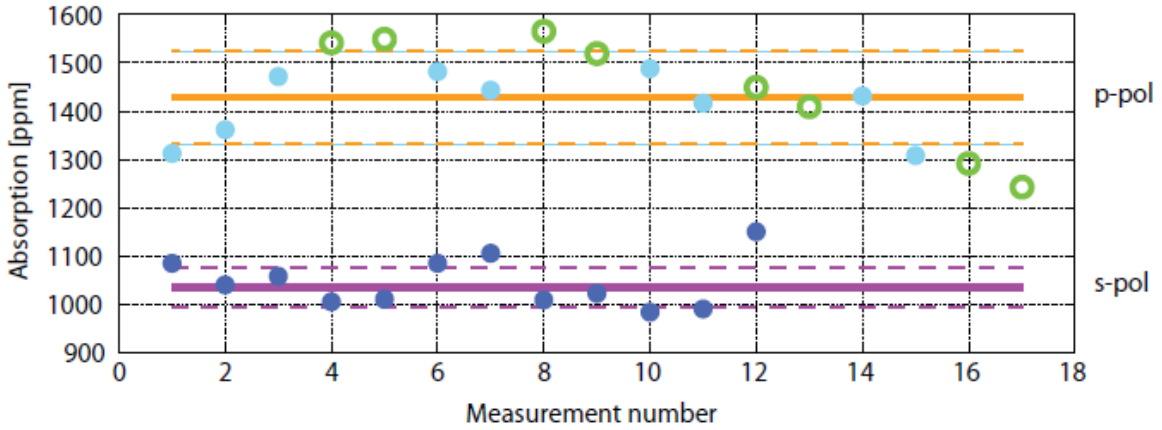


aSi for coatings? – Optical absorption at 1550 nm ☹

Absorption for aSi/SiO_2 very high:

Absorption of *IBS* coatings extremely high (not measurable in cavity)

α ≈ 1000 ppm for *Ion Plating* HR stack @ AOI = 42 deg



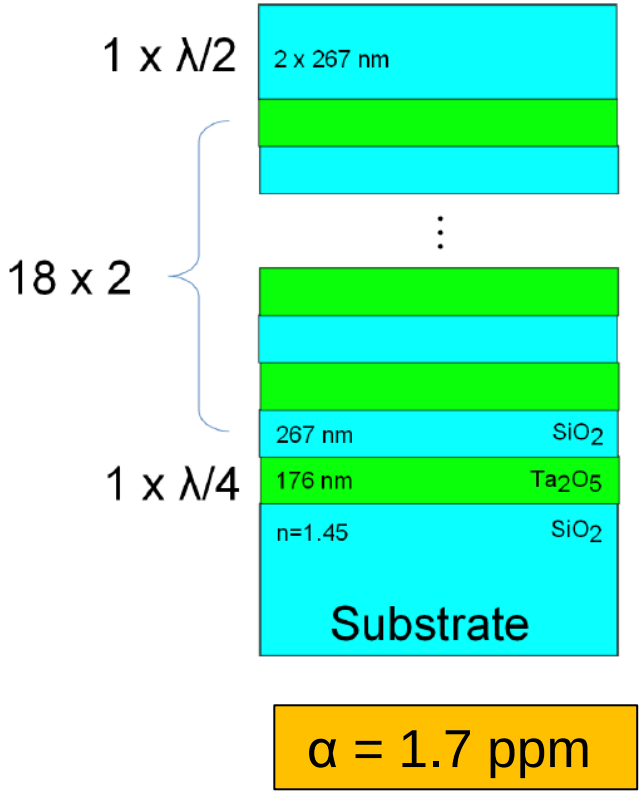
Steinlechner, Khalaidovski and Schnabel, CQG (2014)

PCI measurement : α ≈ 8000 ppm for 500 nm single layer
→ ≈ 2700 ppm for a HR stack
450ºC heat treatment: α reduces by about 75%

Combining aSi with SiO_2/Ta_2O_5 - absorption

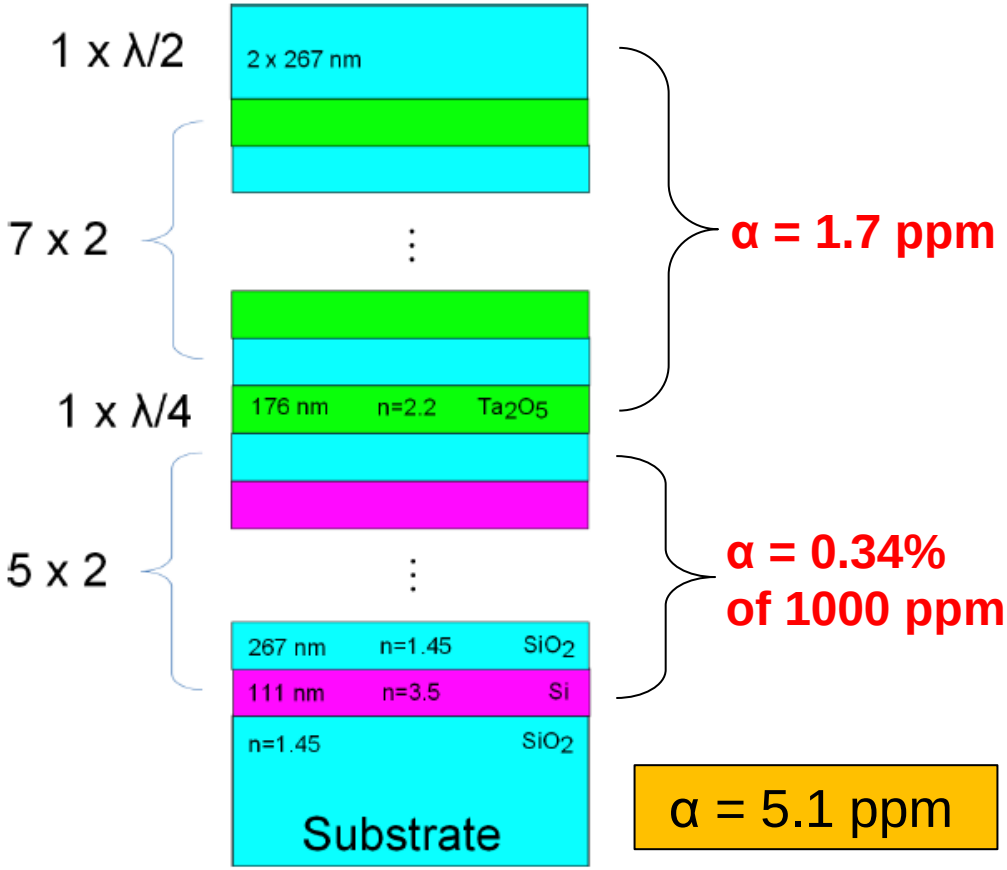
SiO_2/Ta_2O_5 vs. SiO_2/Ta_2O_5 /aSi

38 layers, T ≈ 0.5 ppm



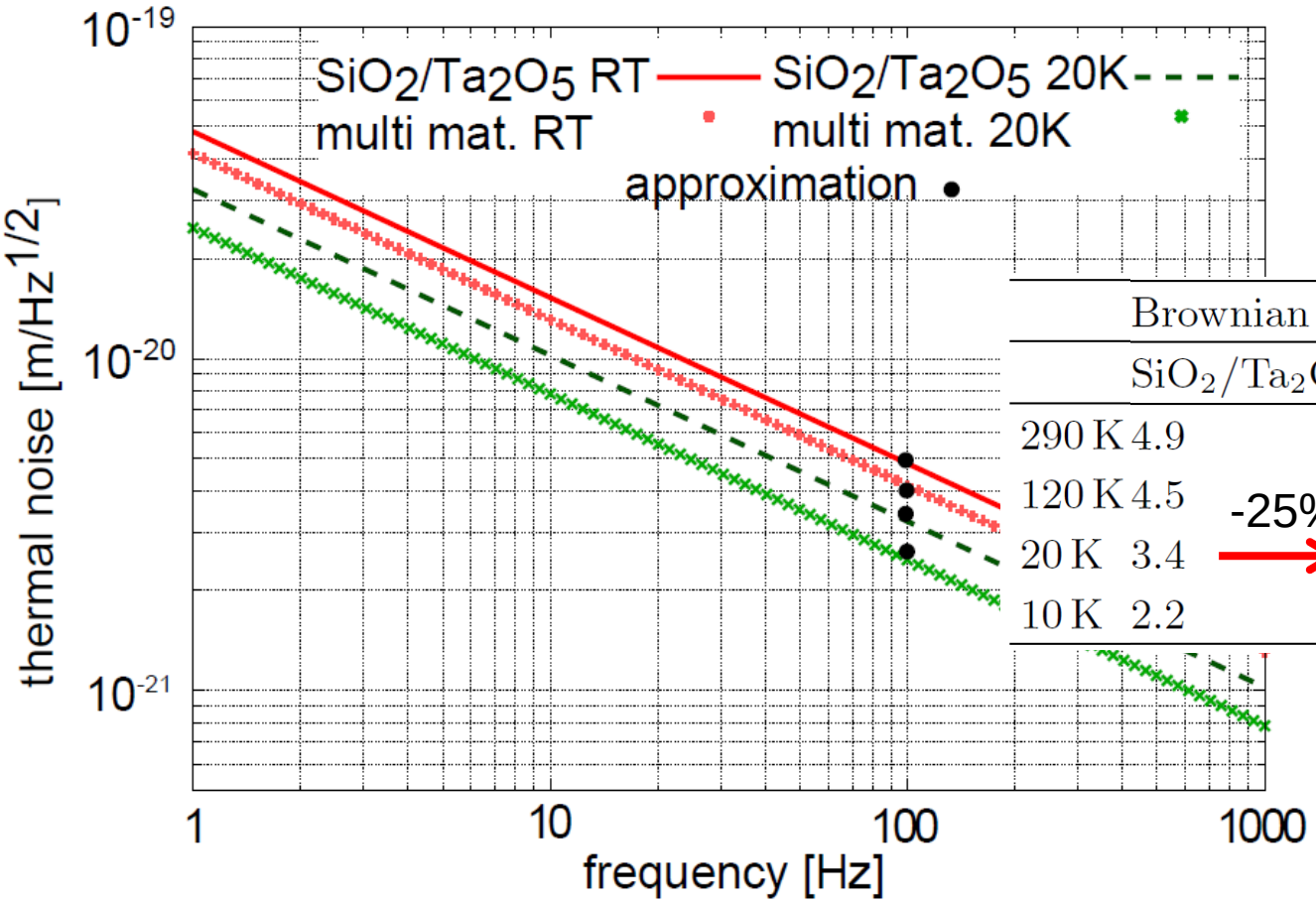
α = 1.7 ppm

26 layers, T ≈ 0.5 ppm



α = 5.1 ppm

Combining aSi with SiO_2/Ta_2O_5 – thermal noise

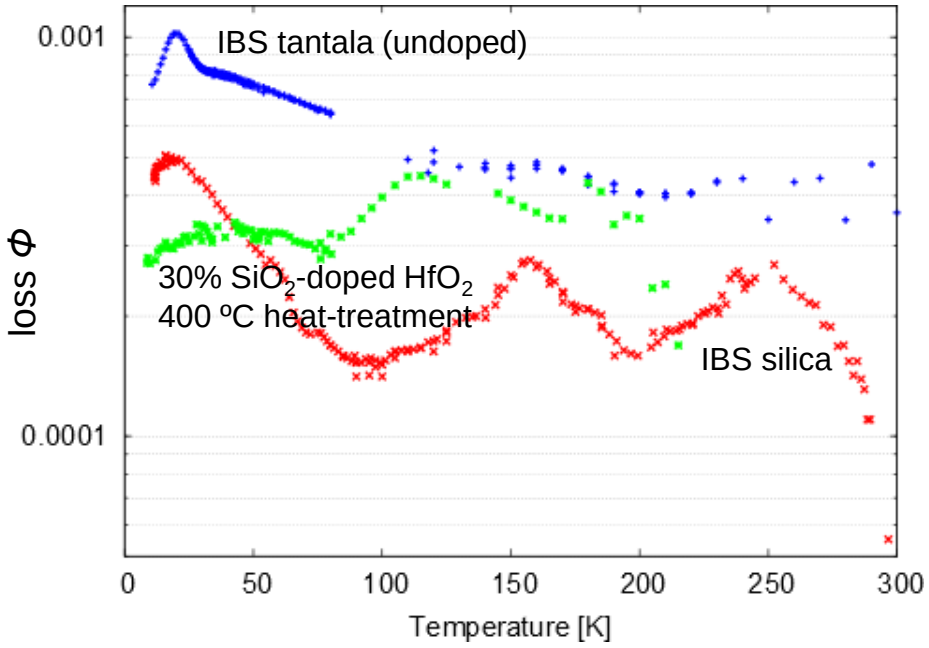


	Brownian th. noise (100 Hz) $\times 10^{-21}$	
	SiO_2/Ta_2O_5	multi mat.
290 K	4.9	4.3
120 K	4.5	3.5
20 K	3.4	2.6
10 K	2.2	1.7

-25%

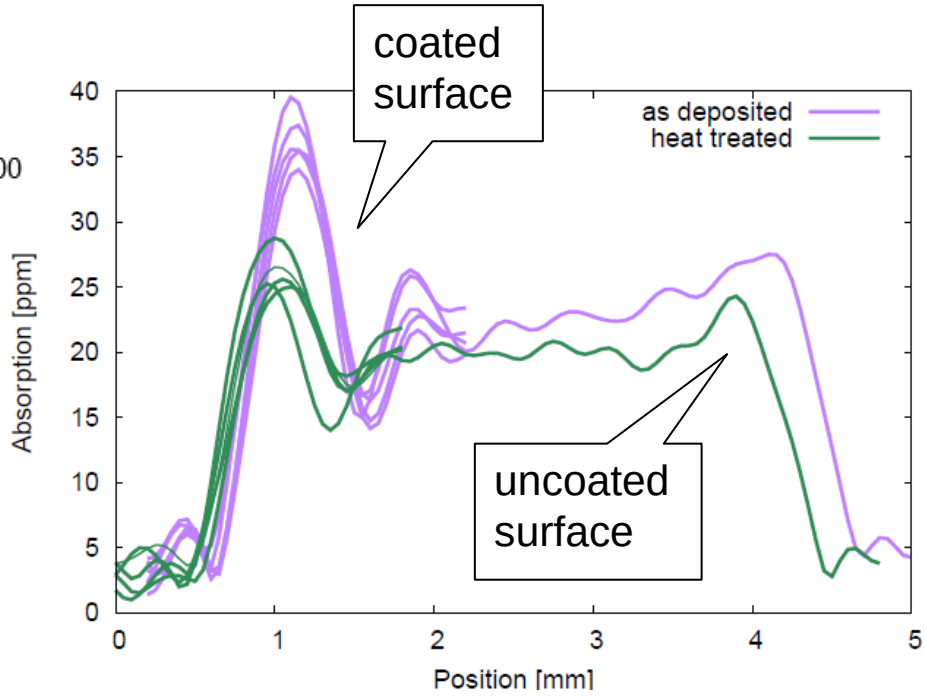
Steinlechner et al. arXiv:1411.3150 [physics.optics]
Yam, Gras, Evans arXiv:1411.3234 [physics.optics]

Silica doped Hafnia



SiO_2 doped HfO_2 (n=1.91):
Absorption of 500 nm single layer

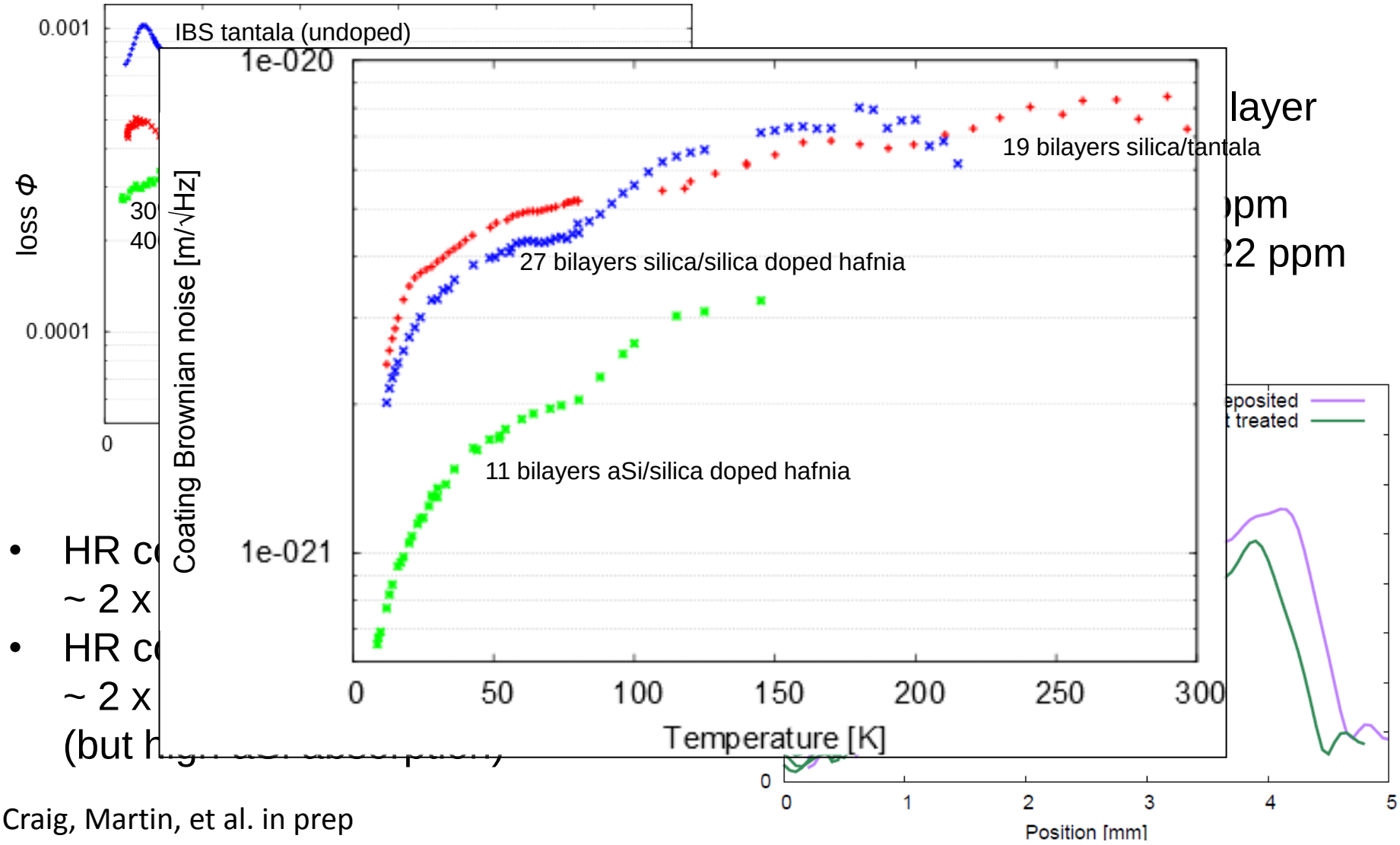
- as deposited: ~36 ppm
- 400 ºC heat treated: ~26 ppm
- uncoated back surface: ~22 ppm



- HR coating combined with silica:
  ~ 2 x 1000 nm → α ≈ 20 ppm
- HR coating combined with aSi:
  ~ 2 x 600 nm → α ≈ 10 ppm
  (aSi absorption will dominate!)

Craig et al. in prep

Silica doped Hafnia

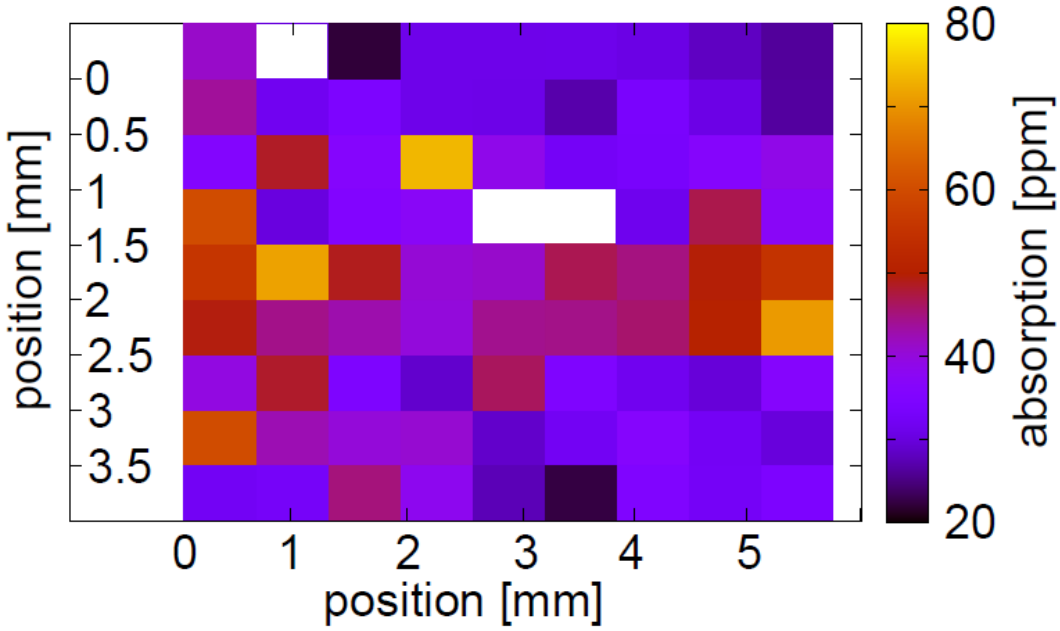


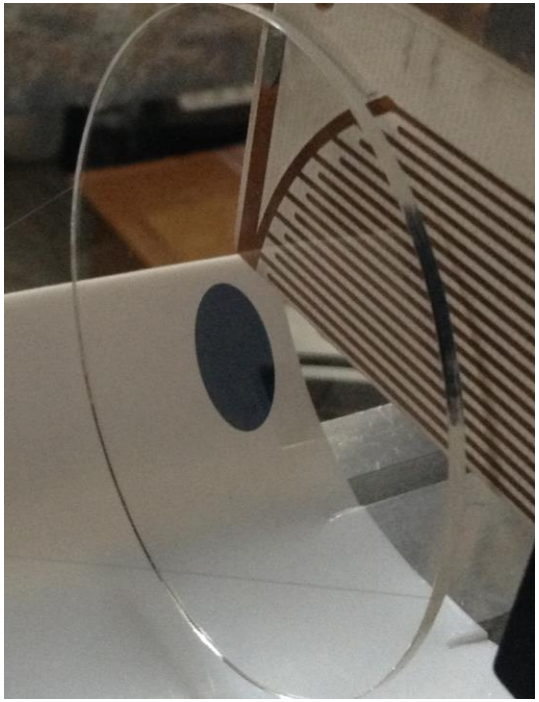
- HR c… layer
  ~ 2 x … ppm
- HR c…
  ~ 2 x … 22 ppm
  (but h… absorption)

Craig, Martin, et al. in prep

Crystalline AlGaAs Coating – Optical Absorption

- 40.5 × GaAs/$Al_{0.92}Ga_{0.08}As$
- HR for 1064 nm
- Absorption measurement with PCI
- Measurement wavelength: 1530 nm (T ≈ 70%)



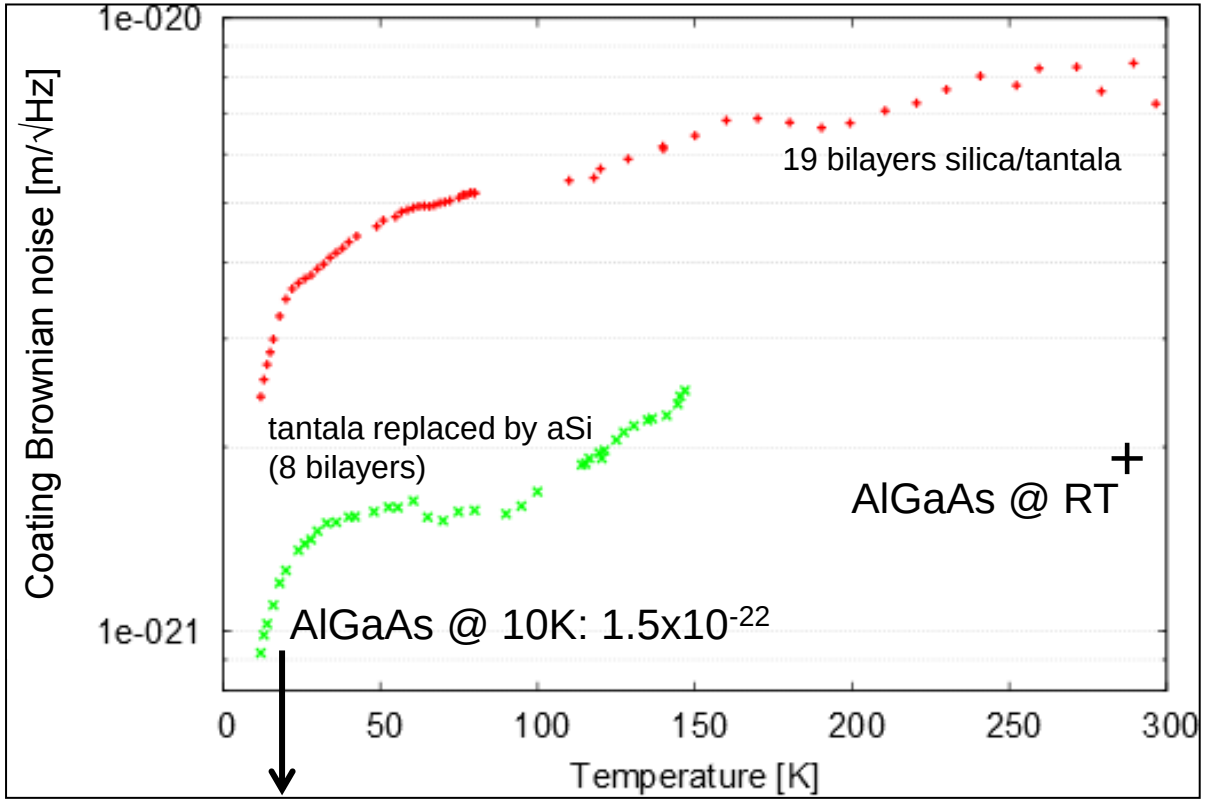


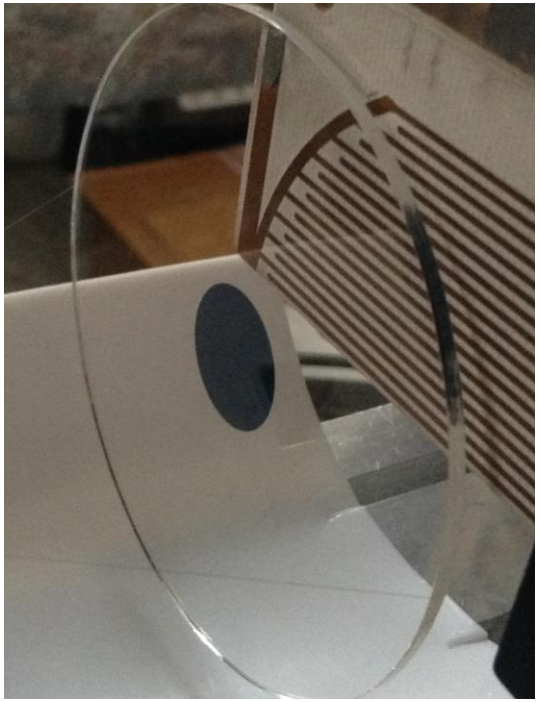
Mean value: α_{1530} = 30.2 ppm
Scaled to HR: α_{HR} < 3.6 ppm

Steinlechner, Martin, Cole et al. in prep. (DCC P1400226)

Crystalline AlGaAs Coating – Thermal Noise

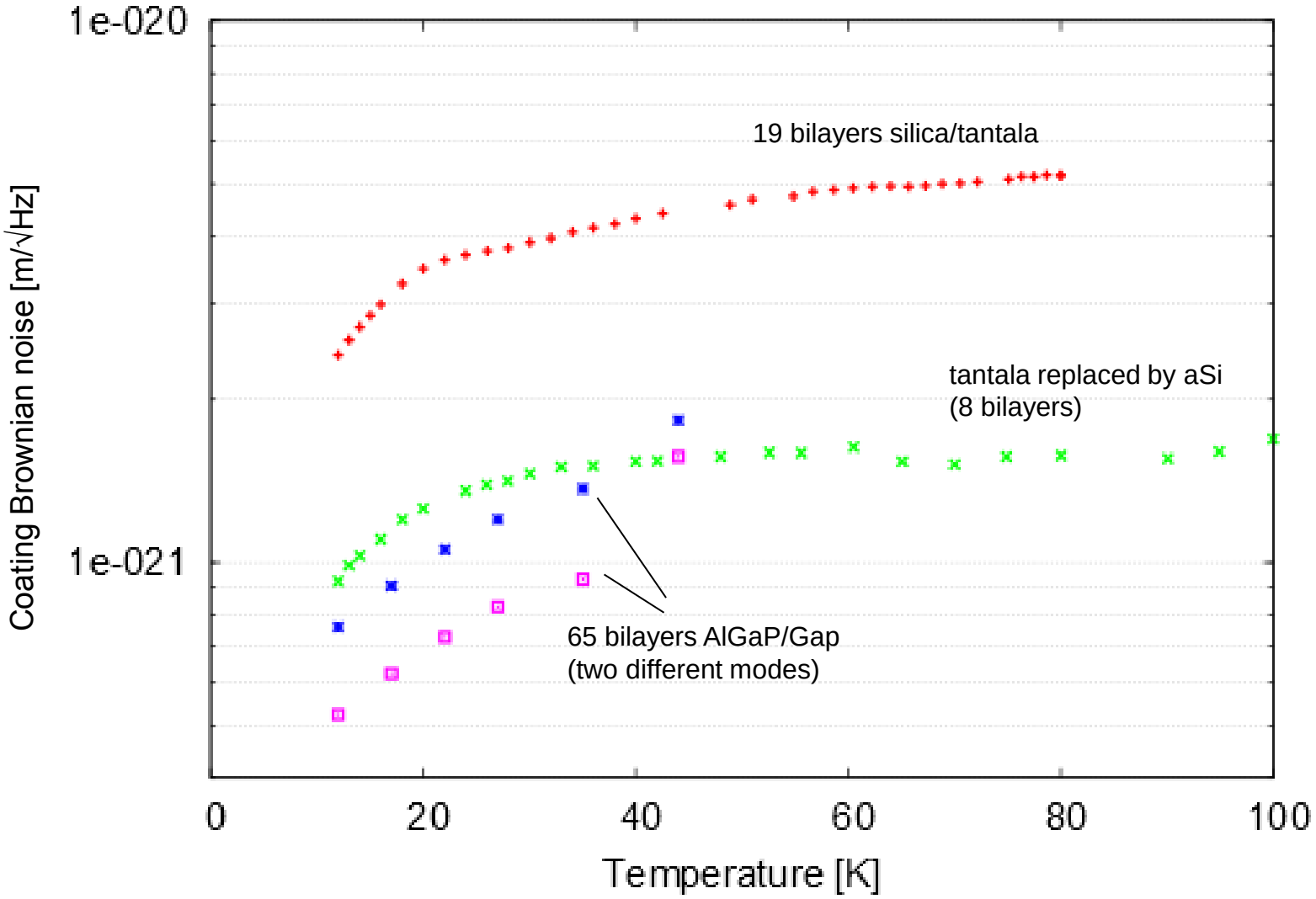
- 40.5 × GaAs/$Al_{0.92}Ga_{0.08}As$*
- HR for 1064 nm



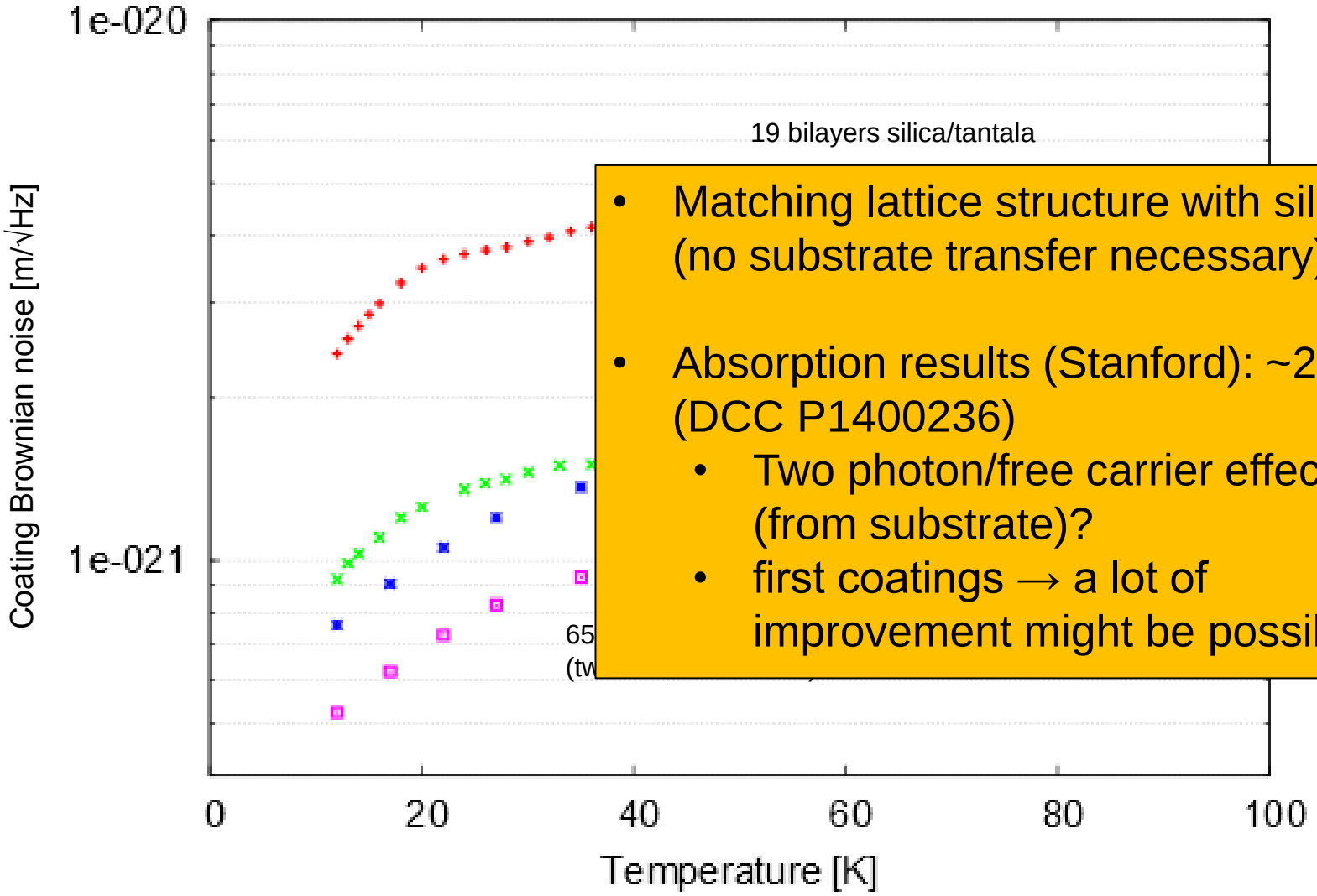


*Garrett D. Cole et al., Nature Photonics, 7, 644–650 (2013)

Crystalline AlGaP Coating – Thermal Noise



Crystalline AlGaP Coating – Thermal Noise



- Matching lattice structure with silicon (no substrate transfer necessary)
- Absorption results (Stanford): ~2.3% (DCC P1400236)
  - Two photon/free carrier effects (from substrate)?
  - first coatings → a lot of improvement might be possible

Summary

~ -50%

~ 1ppm (?)

	Therm. noise [m/√Hz] @ 20 K	Absorption [ppm] @1550 nm
SiO_2/Ta_2O_5	3.5×10^{-21}	1.7
aSi/SiO_2	1.7×10^{-21}	1000
$aSi/SiO_2/Ta_2O_5$	2.6×10^{-21}	5
SiO2-doped HfO_2/SiO_2	2.7×10^{-21}	20
SiO2-doped HfO_2/aSi	1×10^{-21}	1000
AlGaAs	1.5×10^{-22} (10 K)	4
AlGaP	1×10^{-21}	2.3%

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Thanks for your attention!