

Substrate-transferred Crystalline AlGaAs Coatings: Promise, Progress, and Plans

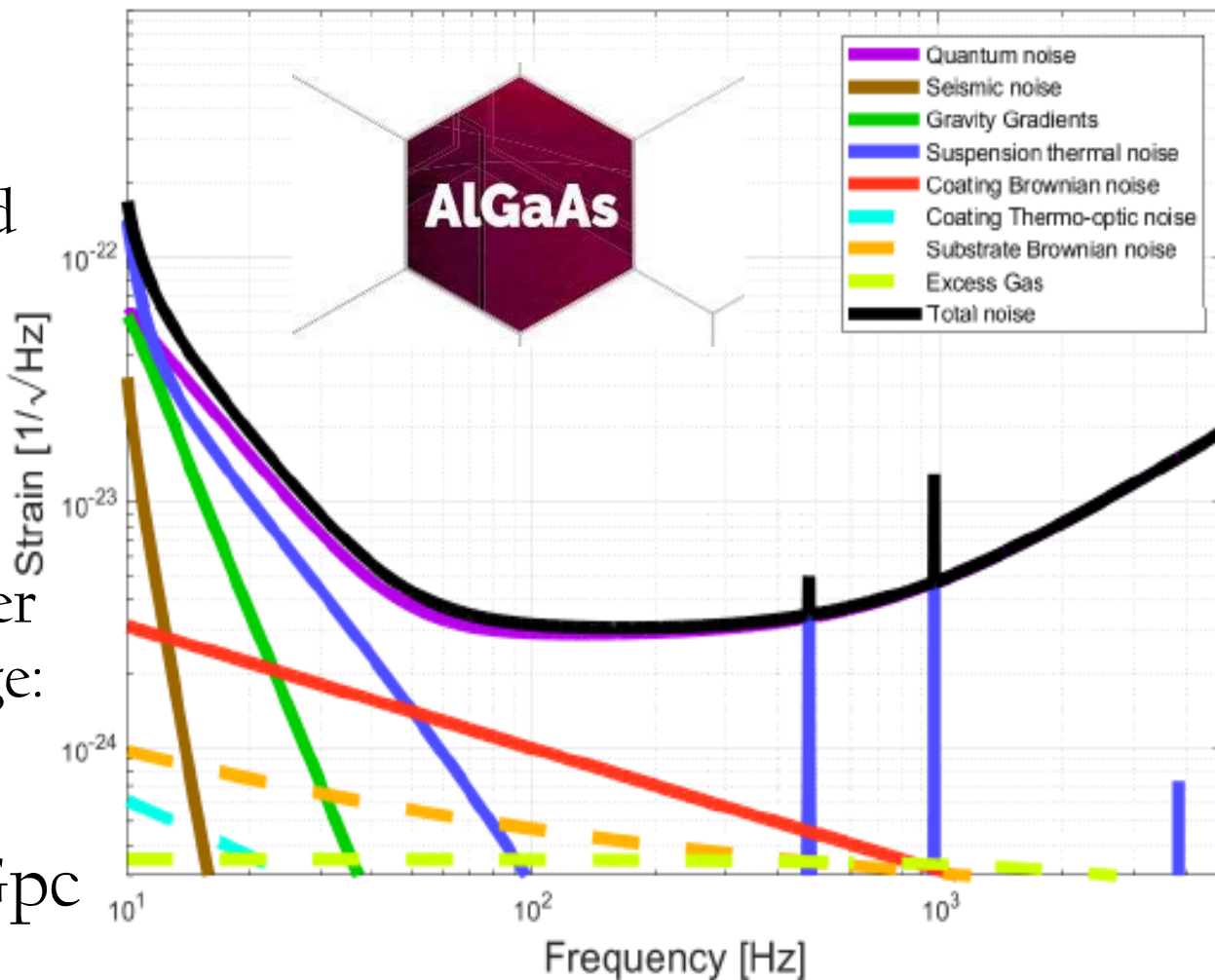
*Gregg Harry, Garrett Cole, Andri
Gretarsson, Steve Penn*

Gravitational Wave Advanced
Detector Workshop

May 2021

The Promise of AlGaAs

AdvLIGO Noise Curve: $P_{in} = 125.0 \text{ W}$



- Promise of coating thermal noise not limiting in any band
- Without other sensitivity improvements to Advanced LIGO: single interferometer angle averaged range:
 BNS: 225 Mpc
 $30 M_{\odot}$ BBH: 1 Gpc

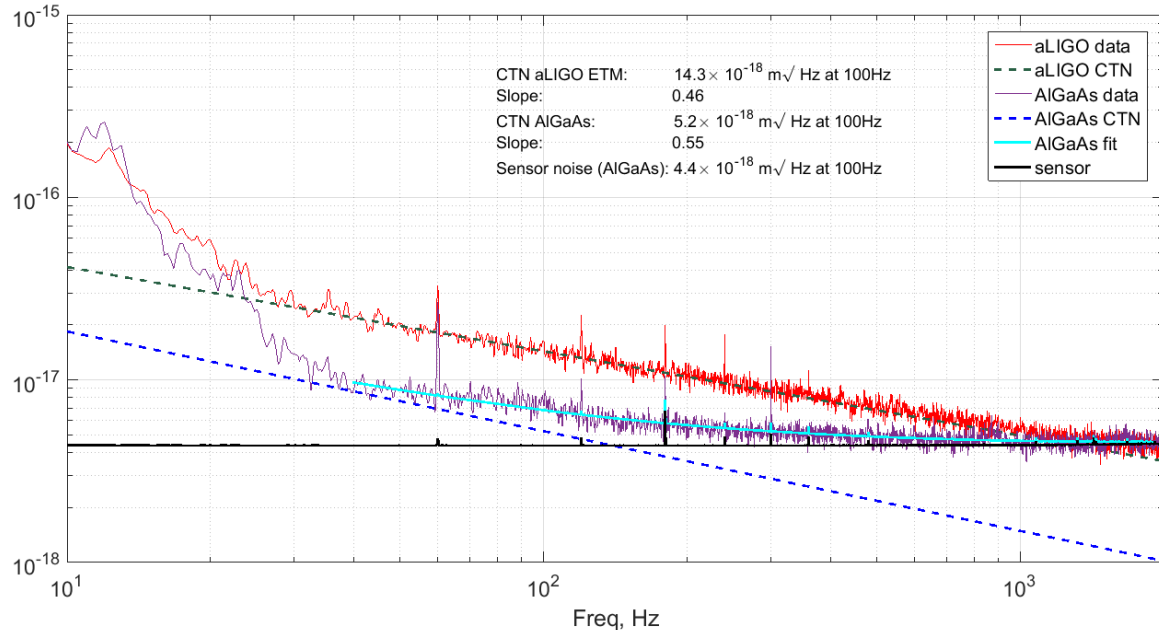
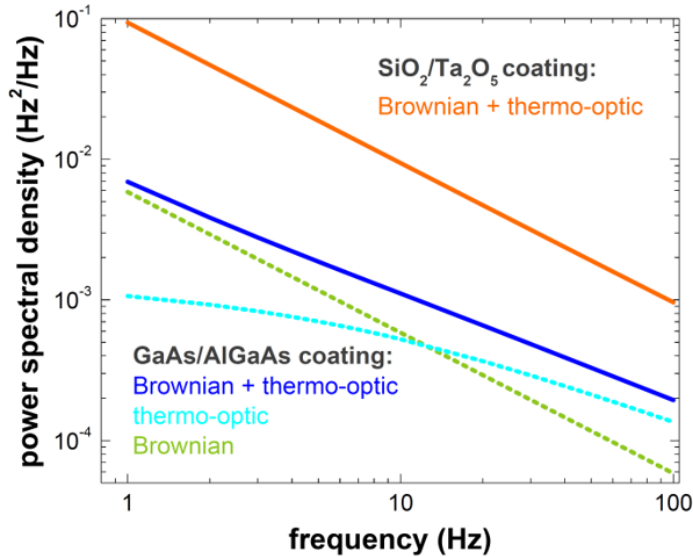


Status of AlGaAs:

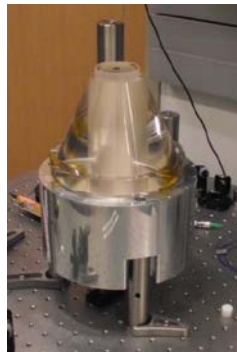
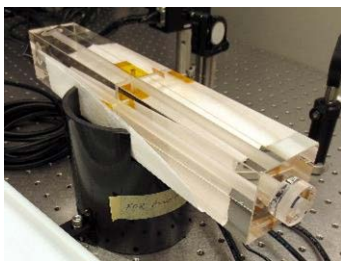
Proven Low Noise via Direct Measurement

Cole et al, Nat. Phot. 2013

MIT Thermal Noise IFO, G2001592



≈ 3 ASD improvement over Si/Ta coating

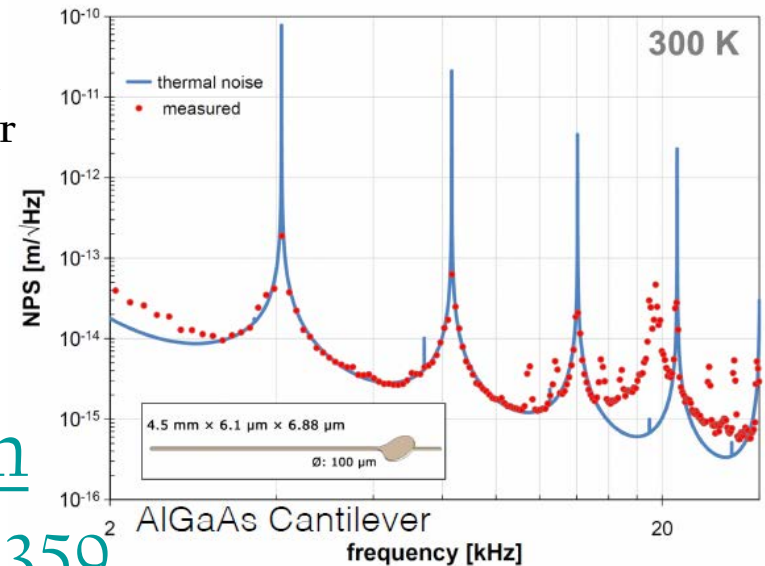


≈ 5 ASD improvement over aLIGO w/ thermo-optic optimization

Probably still limited by other noise than AlGaAs Brownian noise

Status of AlGaAs: Thermal Noise

Shannon Sankar, Thomas Corbitt, and Nergis Mavalvala @ MIT



MIT cantilever data
courtesy of S. Sankar

- Directly measured φ 's

$$\varphi_{11} < 2.3 \times 10^{-4} *$$

$$\varphi_{12} < 5.2 \times 10^{-4} *$$

$$\varphi_{44} < 1 \times 10^{-7}$$

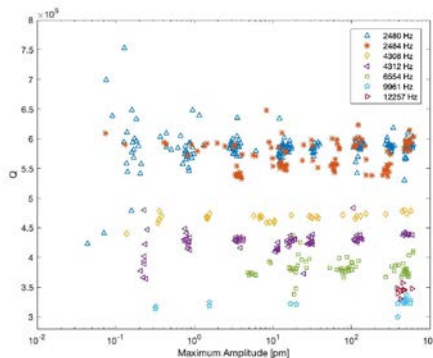
* φ_{11} and φ_{22} TE limited

- Consistent with MIT cantilever data

$$\varphi_{44} \rightarrow 5 \times 10^{-7}$$

$$\varphi_{11} = \varphi_{12} \lesssim 8 \times 10^{-5}$$

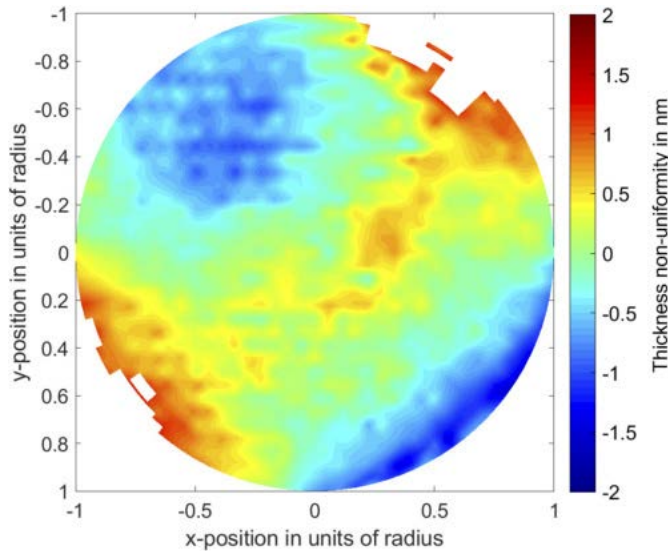
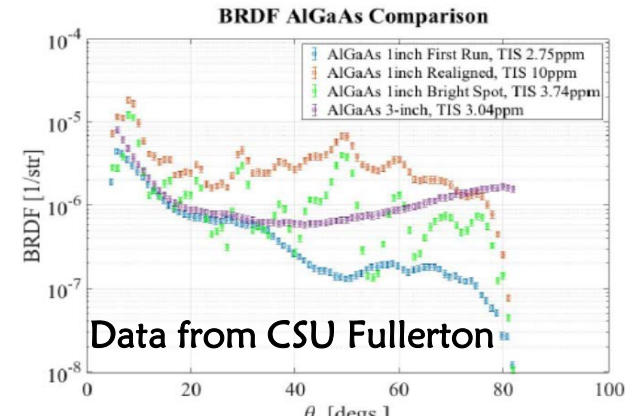
[I. MacMillan](#)
[Thesis P1800359](#)



- No amplitude dependence to mechanical loss (E. Gretarsson thesis)
- Layer optimization, TO noise below Brownian (Tara C. et al Metrologia 53 (2016) 860, P1500054)
- AlGaAs has low thermal noise at all cryogenic temperatures (Sankar et al, 3rd Gordon Conf, 2012)

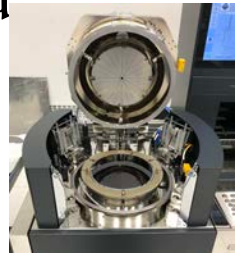
Status of AlGaAs: Optical and Size

- Scatter < 5 ppm (CSU Fullerton)
- Absorption < 1 ppm (Cole 2016)
- Thickness uniformity < 2 nm/5 cm (Koch 2019)



- 20 cm diameter realized
- 10 cm diameter routine
- 30 cm diameter/20 cm thick challenging

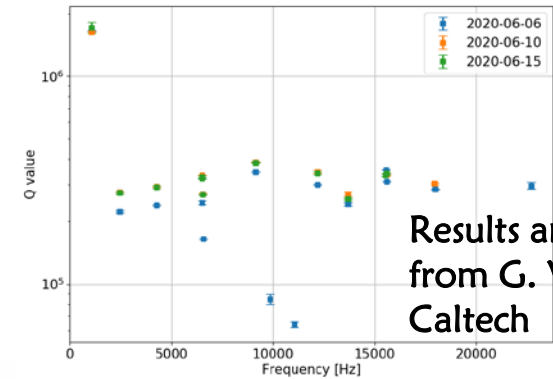
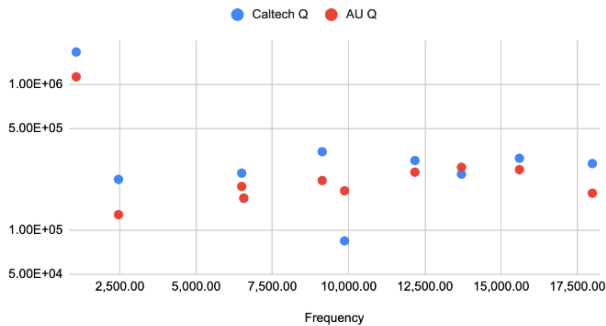
Custom bonding tool,
epitaxy, GaAs wafers



Koch et al. Optics Express 27
(2019) 3673.

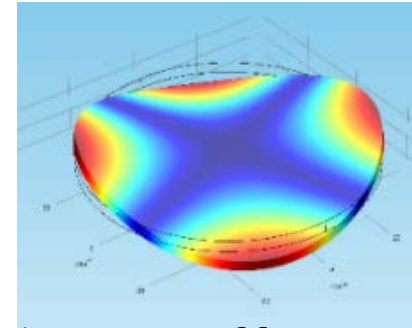
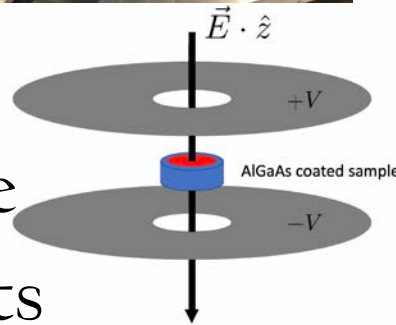
- Single layer GaAs Q at Caltech and American

Quality factors from first suspension



Results and graphic from G. Valente Caltech

- Electro-optic noise experiment at Syracuse
- MIT TNI measurements



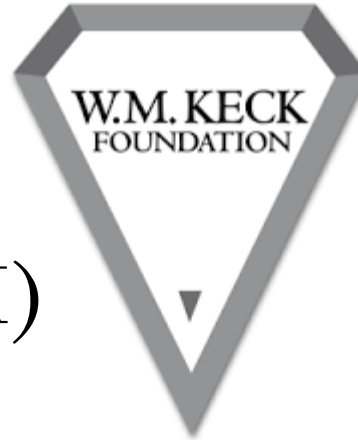
- Multiple locations and spot sizes
- FEA for thermoelastic effect
 - Previous Q's and single layer GaAs
 - Material loss angles; bulk TE limited
 - Thermo-optic noise practical limits⁶
- Birefringence uniformity
- at Embry-Riddle

Timeline and Budget

- Detailed schedule/budget [T2000170](#)
- Engineering plan developed with Freiberger, EV Group, Thorlabs
- Phase 1: Laboratory tests on 10 and 20 cm diameter
 - Summer - fall 2021
 - Paid with existing funding
- Phase 2: 30 cm diameter/20 cm thick development
 - GaAs substrate, custom bonding tool
 - Aim to complete by 2025
 - Estimate US\$20 M
 - Testing in prototype interferometers



- Keck Foundation
- NSF Major Research Instrumentation (MRI)



MAJOR
RESEARCH
INSTRUMENTATION



U.S. DEPARTMENT OF
ENERGY

Office of Science

- Collaboration with Department of Energy groups
- Other private foundations
- Interested in finding non-American collaborators and funding sources

