Workshop of Optical Coatings in Precision Measurementの報告

Max-Planck Institute　山元　一広

2008/4/4　重力波研究交流会

会議の趣旨

Optical coating：精密光学実験の要

質の高い光学的性質

高反射率、低損失（吸収、散乱）、小さい形状誤差、などなど

小さい機械的散逸：熱雑音

重力波検出だけでなく周波数安定化、量子光学に波及

Optical coatingだけをkey wordにworkshop開催

会議の概要

場所：California Institute of Technology
日時：3/20（午後）- 21
　　LIGO-VIRGO joint meeting 3/17-20（午前）

日本人参加者（敬称略）：黒田、山本（博）、川村、山元（一）

Organizer：Gregg Harry (MIT)
詳細、スライド、参考文献は
http://www.ligo.mit.edu/~gharry/workshop/workshop.html

Room201 (Bridge)

セッション

Overview
Modeling and theory
Thermal noise
Scatter and optical loss
Absorption and thermal issues

Tours of Caltech labs

Overviewのみ20分（+10分）、他は15分（+5分）

Overview

Ion Beam Sputtering (Ramin Lalezani)

Gravitational Wave Detection (Steve Penn)

Quantum Optics (Markus Aspelmeyer)
　micro mechanical oscillatorとcoatingについて

Laser Frequency Stabilization (Michael Martin)

Modeling and Theory

Interferometer with insensitive to thermal noise

Optimization of coating layer thickness

Larger beam

Laser frequency stabilization

Scattering

Thermal noise

Review(Gregg Harry)

Mechanical loss of silica/alumina coating

Mechanical loss at low temperature

Radiation pressure experiment (MIT)

Optimized coating in Thermal noise interferometer (Caltech)

Thermal noise interferometer with thin disk (Perugia)

Calculation of elasticity of Ta_2O_5

Thermo-optic noise

Mesa beam experiment

Bench 7.0 (software to calculate interferometer sensitivity)

Absorption measurement

Scatter and optical loss
Absorption and thermal issues

Advanced LIGO目指して

Measurement of scatter, absorption, transmittance
(doped coating)

Thermal compensation
Effect of ultraviolet ray irradiation
High power damage

低温におけるcoating mechanical loss

Kazuhiro Yamamoto : Review

Iain Martin (Glasgow) : SiO_2 and Ta_2O_5

Eleanor Chalkley (Glasgow) : HfO_2

2. Studies in Past

2-1. Measurement of coating mechanical loss

3 experiments (in refereed journal)

(1) University of Tokyo
K. Yamamoto et al., Physical Review D 74 (2006) 022002
First measurement

(2) Friedrich-Schiller-University Jena
R. Nawrodt et al., New Journal of Physics 9 (2007) 225
Coating on grating

(3) University of Glasgow
I. Martin et al., Classical and Quantum Gravity 25 (2008) 055005
TiO_2 doping

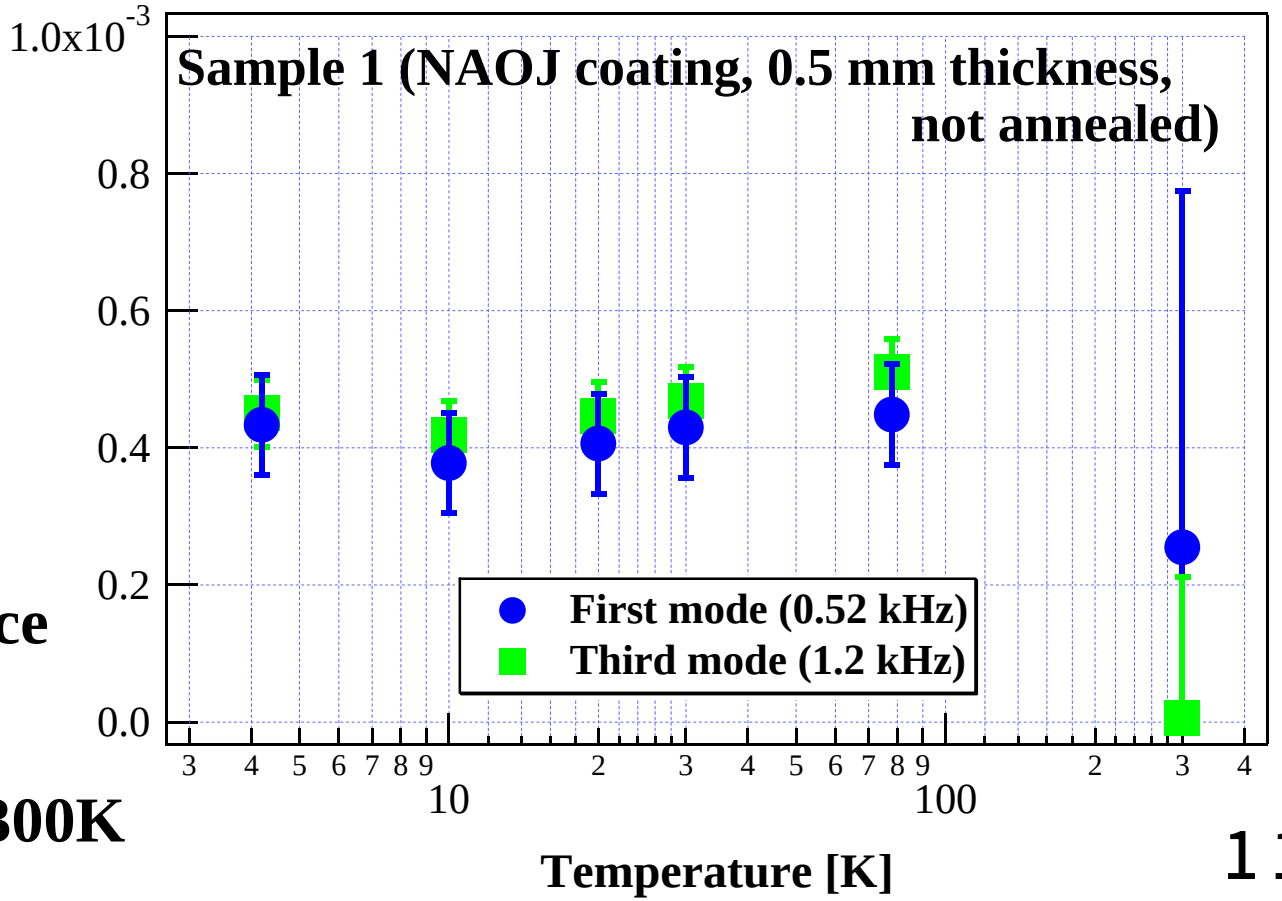
K. Yamamoto's slide

(1)University of Tokyo

K. Yamamoto's slide

K. Yamamoto et al., Physical Review D 74 (2006) 022002

First measurement SiO_2/Ta_2O_5 **coating**



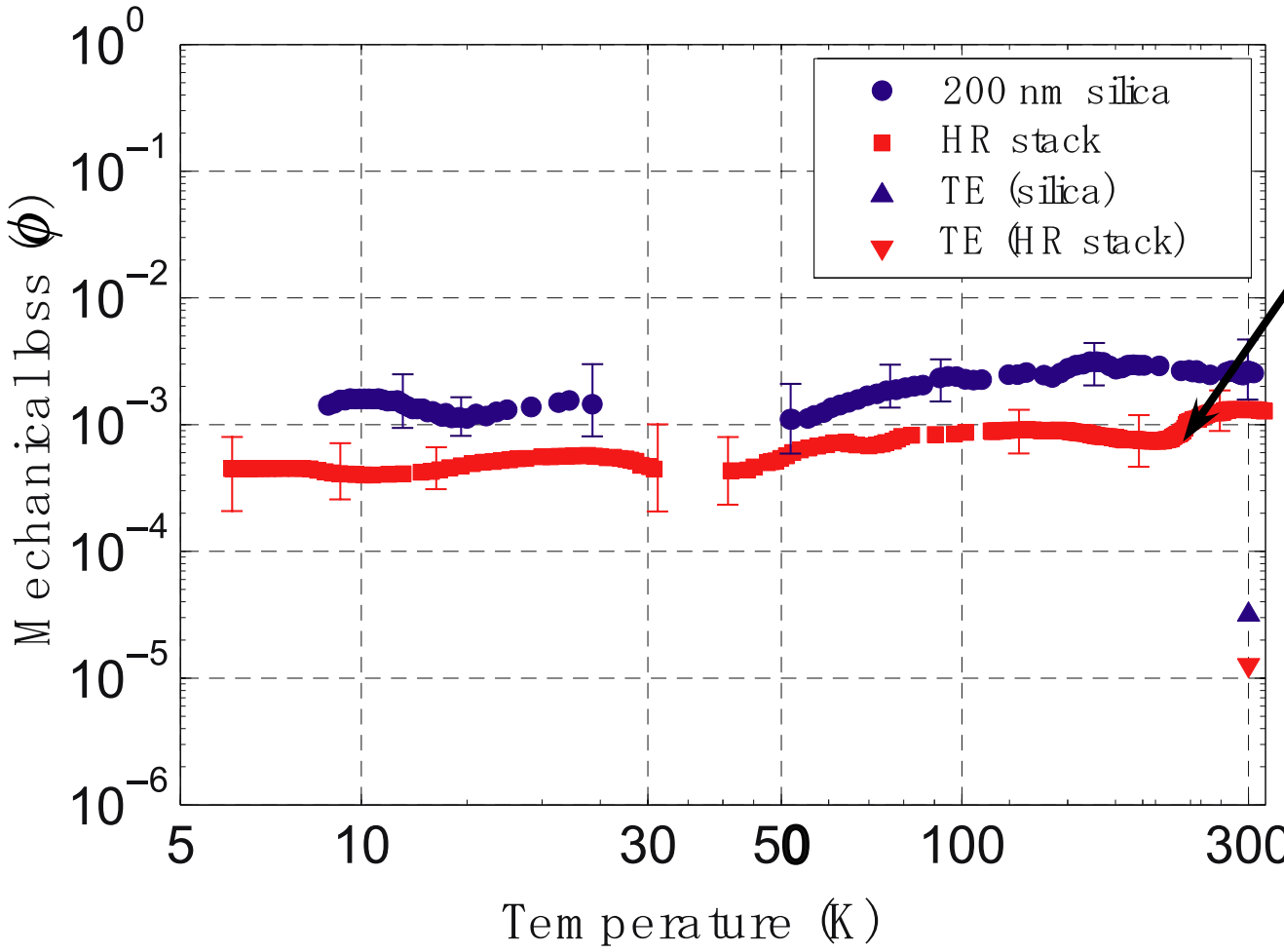
Weak temperature dependence

$\phi = (4 - 6) * 10^{-4}$ **between 4K and 300K**

(2) Friedrich-Schiller-University Jena

R. Nawrodt et al., New Journal of Physics 9 (2007) 225

SiO_2/Ta_2O_5 coating on grating



Red squares
SiO_2/Ta_2O_5 coating loss

Weak temperature dependence

$\phi = 4*10^{-4}$ at 10K

They said that this is comparable to the values reported by (1) University of Tokyo.

K. Yamamoto's slide

(3) University of Glasgow

I. Martin et al., Classical and Quantum Gravity 25 (2008) 055005

Ta_2O_5 doped with TiO_2 **(and his talk)**

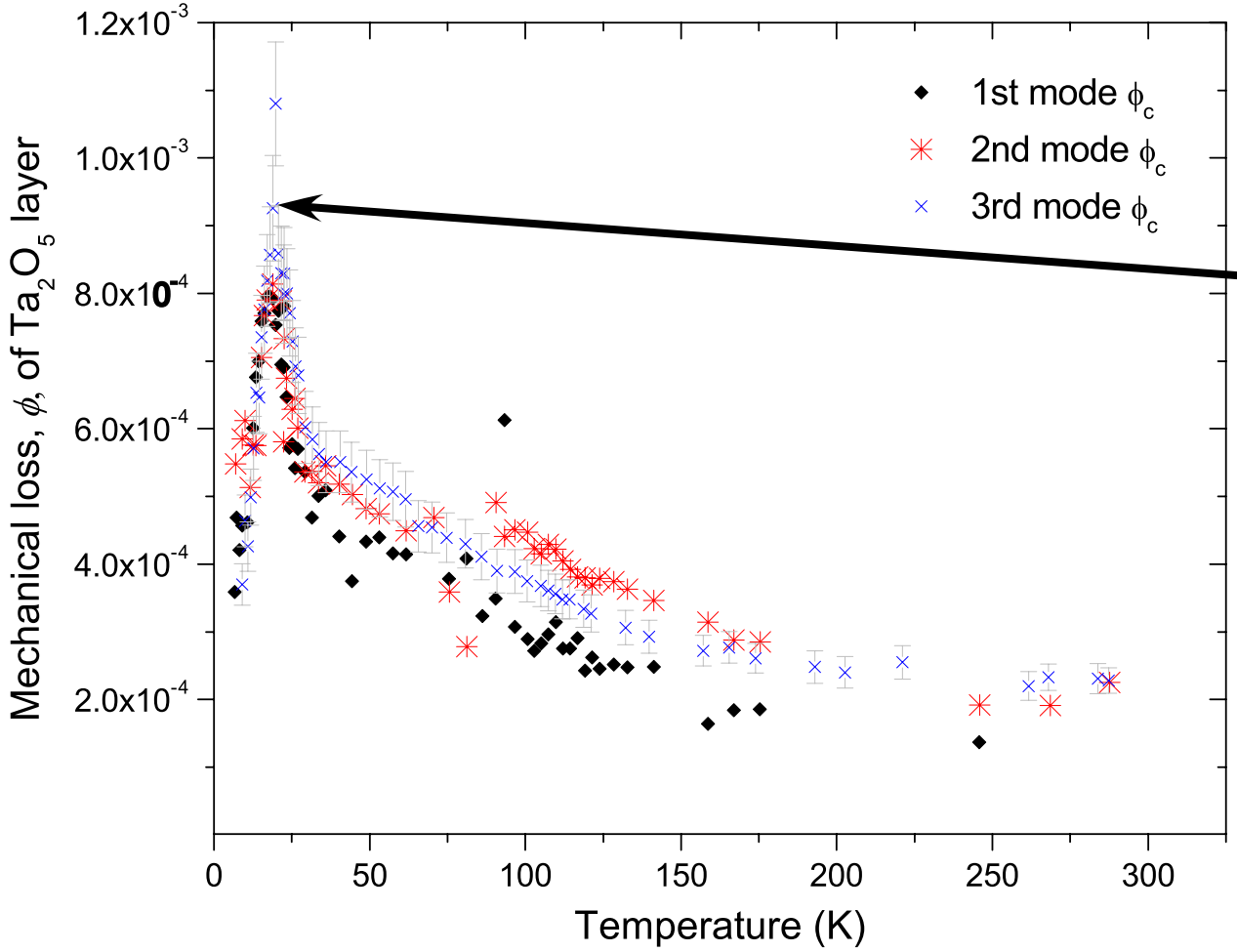


Figure 4. Temperature dependence of the loss of the doped Ta_2O_5 coating.

Peak at 20 K

This peak is comparable to the values reported by (1) University of Tokyo and (2) Friedrich-Schiller-University Jena.

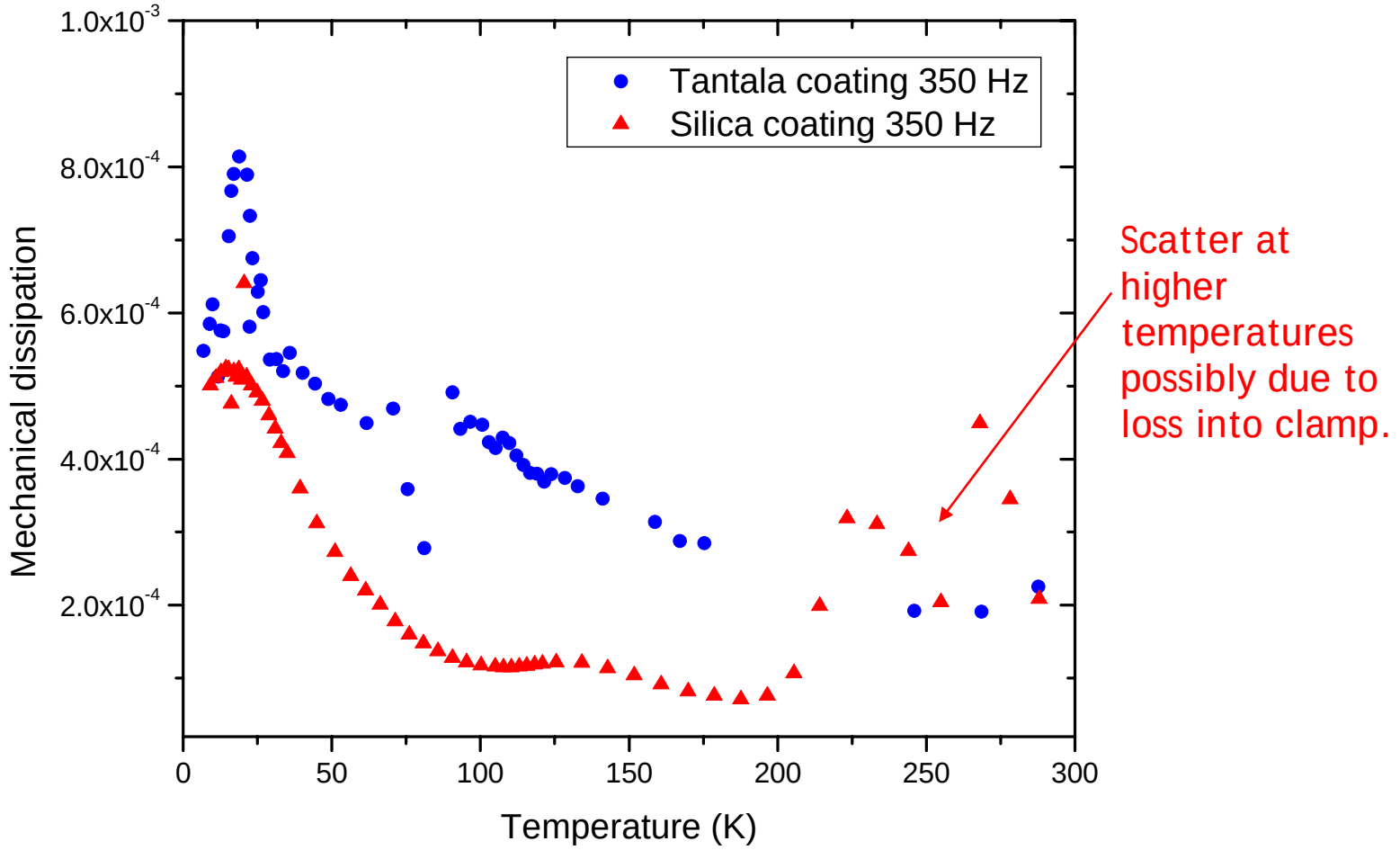
smaller loss than that without doping except for 20K

K. Yamamoto's slide

UNIVERSITY of GLASGOW

SUPA

Comparison of SiO_2 and Ta_2O_5



- Loss of ion beam sputtered SiO_2 is significantly lower than loss of Ta_2O_5 between 10 and 300 K.

I.Martin ' s slide

UNIVERSITY of GLASGOW

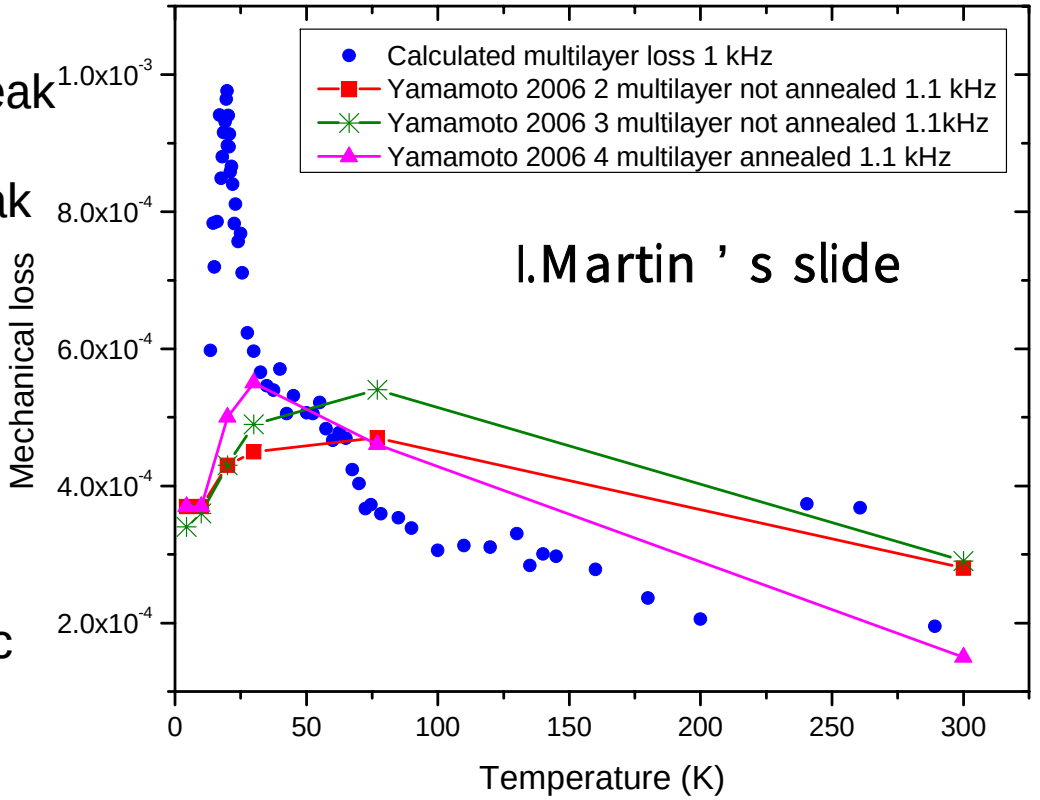
SUPA

Comparison to multilayer results of Yamamoto et al

- Loss of single SiO_2 and Ta_2O_5 layers used to calculate loss in a 31 layer multilayer coating, as measured by Yamamoto et al*

- Yamamoto's results:
  - Show no evidence of a large peak at 20 K
  - Are not inconsistent with a peak at slightly higher T, with T_{peak} possibly lowered by annealing

- Apparent discrepancy in results - could be explained by:
  - Differences in annealing temperature and / or coating layer thickness?
  - Different coating thermoelastic loss between coatings on sapphire and silicon substrates
  - Not enough data for multilayer coating



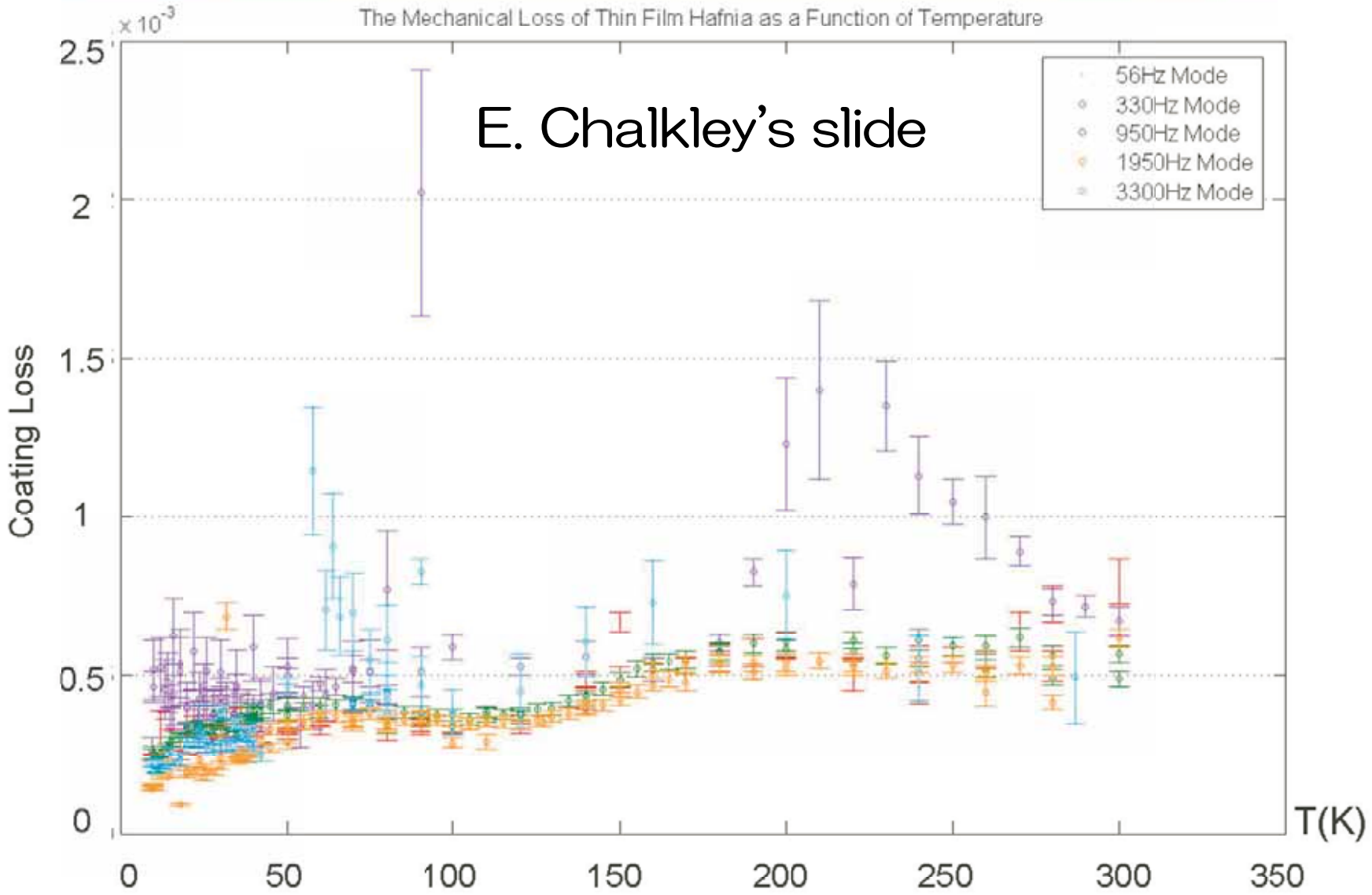
Calculated multilayer coating loss at 1 kHz compared to Yamamoto's measured multilayer loss at 1.1 kHz

*Yamamoto et al., Phys. Rev. D **74,** 022002 (2006)

University of Glasgow

SUPA

Plot showing coating loss for all modes studied



E. Chalkley's slide