Silicon Carbide cryogenic optical test results

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Motivation

- Silicon Carbide for mirror substrate and structural support material
- low density and CTE, high modulus or stiffness and thermal conductivity
- can be polished to < 10Å rms
- more than a dozen SiC manufacturers
- over 70 types of SiC: converted SiC, C-SiC, CVC SiC, CVD SiC, CVD SiC on structural graphite core, hot pressed SiC, monolithic CVD-SiC, reaction bonded SiC, siliconized Carbon, sintered SiC, etc.
- need for vendor independent material properties database

Highly engineered material properties (HEMP)

- **OBJECTIVE**
  - provide test data on materials using consistent test methods
  - vendor independent test data
  - characterize vendor's process and lot uniformity

- **APPROACH**
  - phase I : samples from 2 or more lots from each participating vendors
  - phase 2 : samples from 3 additional processing lots
  - final report and material properties database

Test plan

- **Phase 1**
  - incoming surface roughness evaluation; polish if needed
  - **cryogenic strain tests (from room temperature down to 30° Kelvin)**
  - metallographic analysis/chemical analysis
  - microstructure analysis/X-Ray diffraction
  - density/porosity measurements

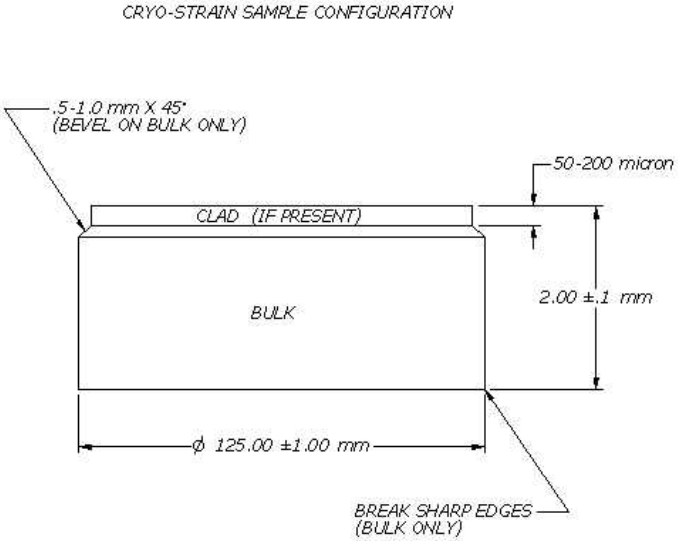
- **Phase 2**
  - CTE
  - thermal conductivity
  - tensile strength and elastic modulus
  - 4-point bending tests
  - fracture toughness
  - Analysis: metallographic, chemical, microstructure, X-Ray diffraction
  - density/porosity measurements

Cryogenic strain test plan

- **Sample Description:** 125 mm plano disk, λ/4 P-V and 100Å rms or best effort. Vendor supply 1 uncapped + 1 capped sample from 2 lots/batches. If uncapped sample is not polishable, then supply 2 capped samples from 2 batches

- **Objective:** measures optical figure changes from room temperature to 30° K. The data output will be figure map, rms value, and power as a function of temperature

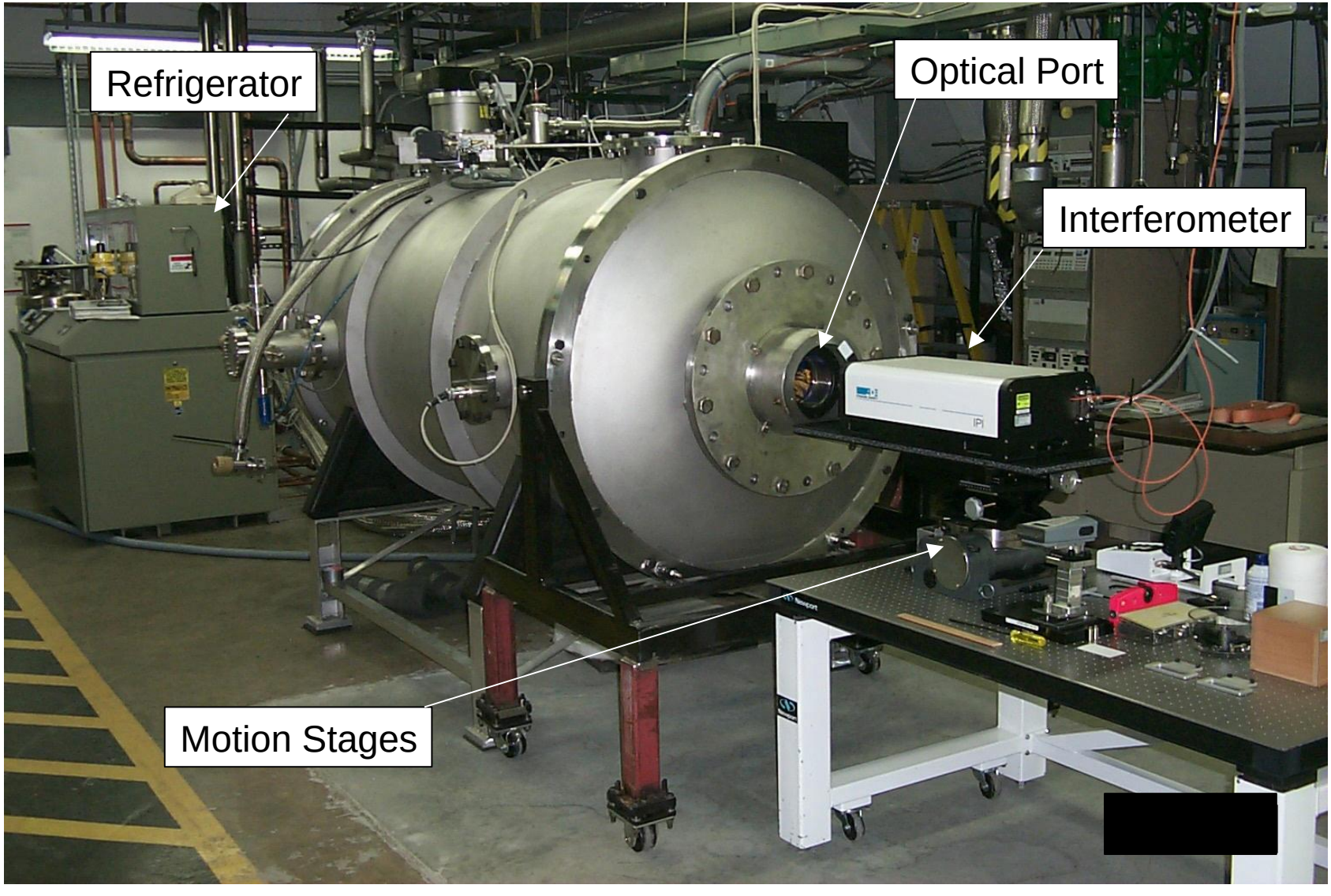
- **Test Method:** interferometric test will be performed under vacuum at room temperature 290°, 200°, 100°, 70°, 50°, 30°, and 290° Kelvin



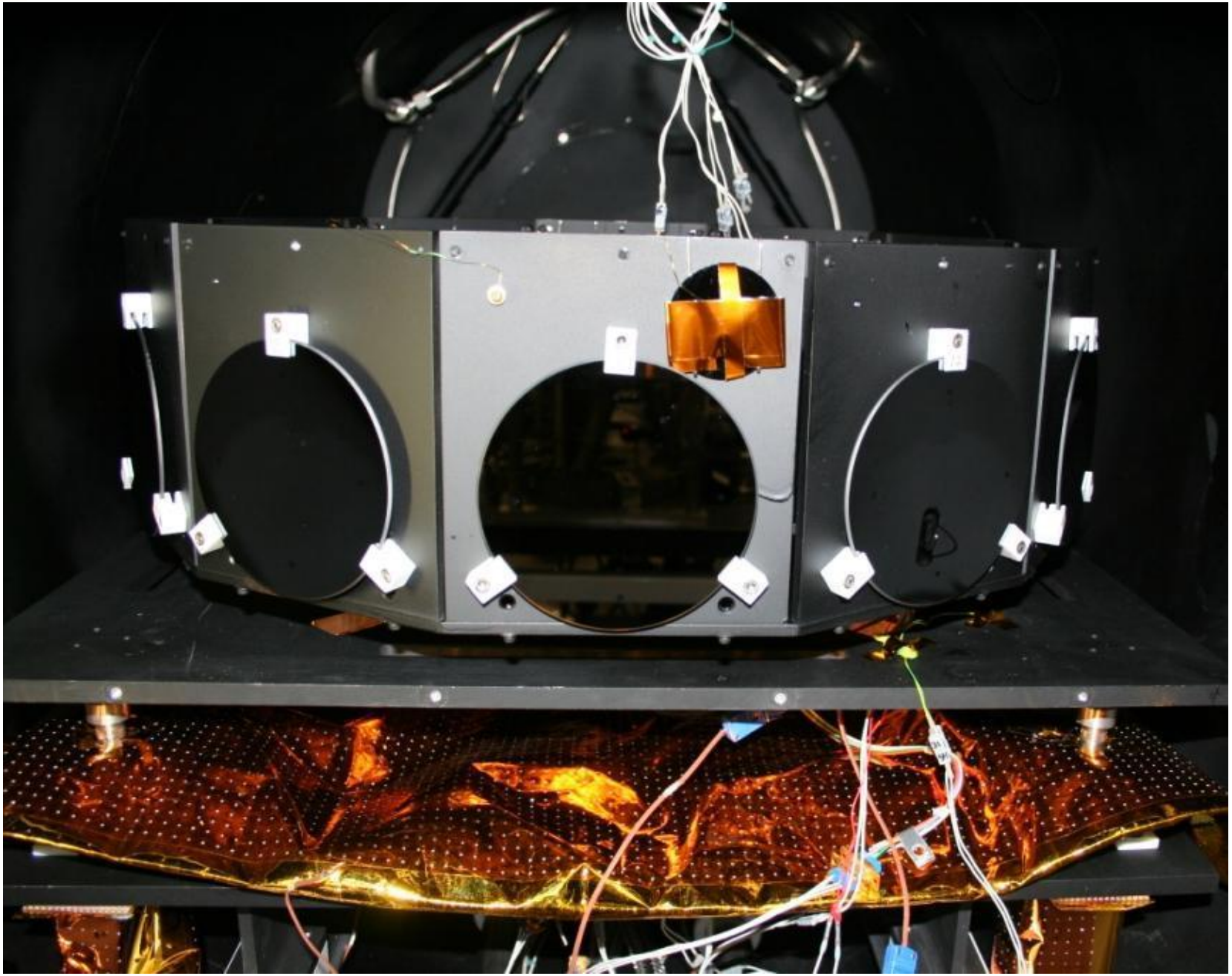
Participating SiC vendors

- Phase 1: tested 46 samples for cryogenic optical strain
  - Boostec S.A.
  - CoorsTek
  - GE Power Systems Composites, LLC / ECM
  - M-Cubed Technologies, Inc.
  - Poco Graphite, Inc.
  - SSG Precision Optronics, Inc.
  - Trex Enterprises Corp.
- Phase 2:
  - CoorsTek
  - Poco Graphite, Inc.
  - SSG Precision Optronics, Inc.
  - Trex Enterprises Corp.

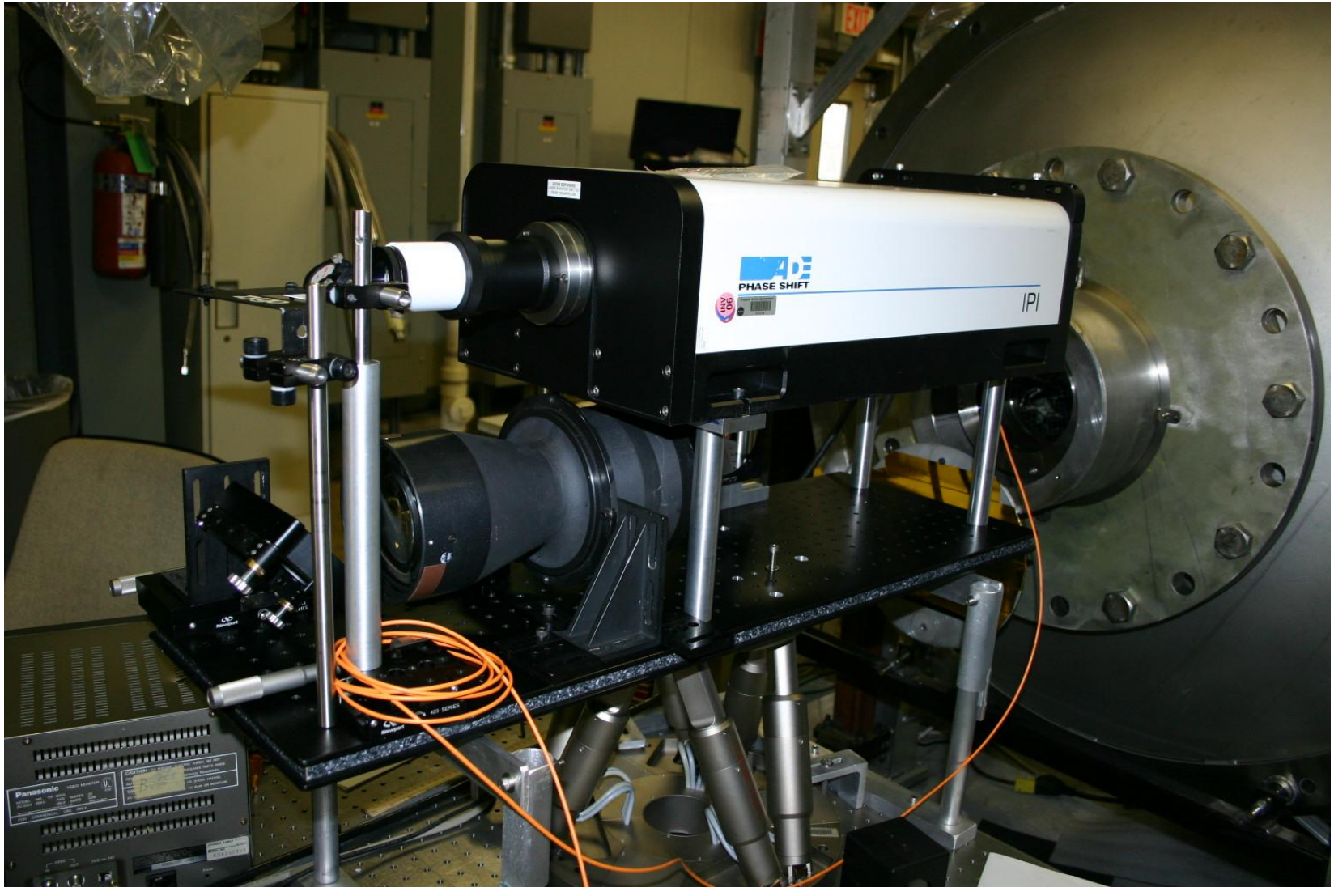
Small chamber for material characterization



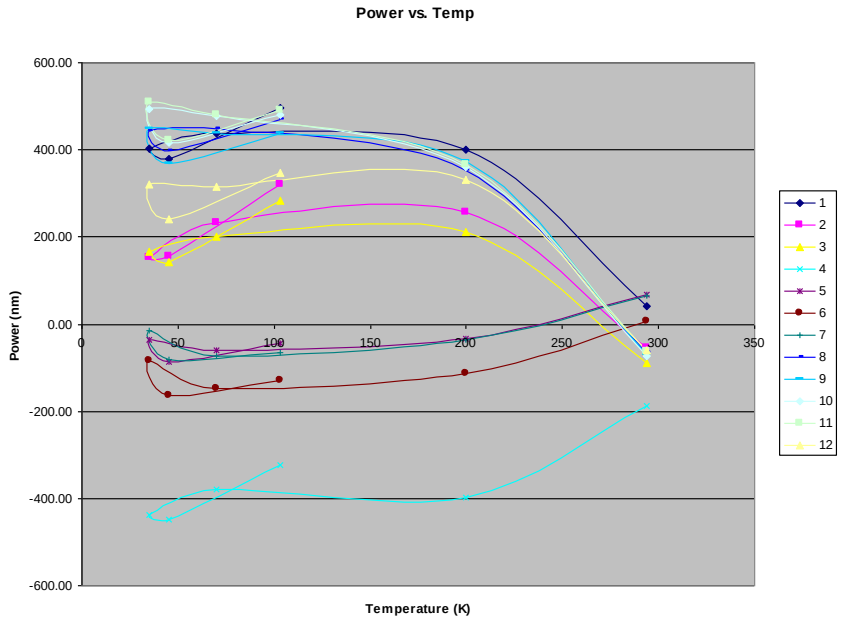
12 SiC samples mounted on carousel

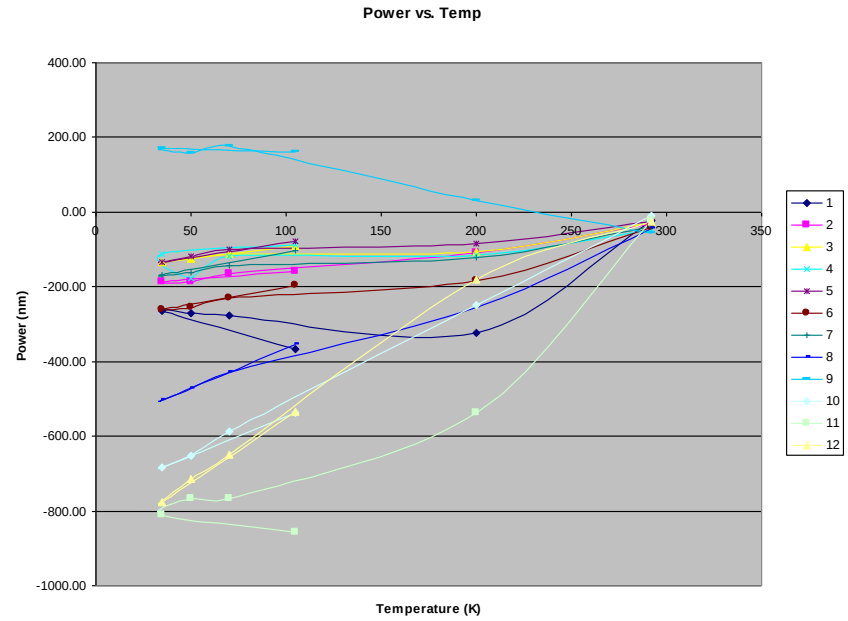


interferometric test setup



Δ power (p-v) vs. temp plots for 46 SiC samples





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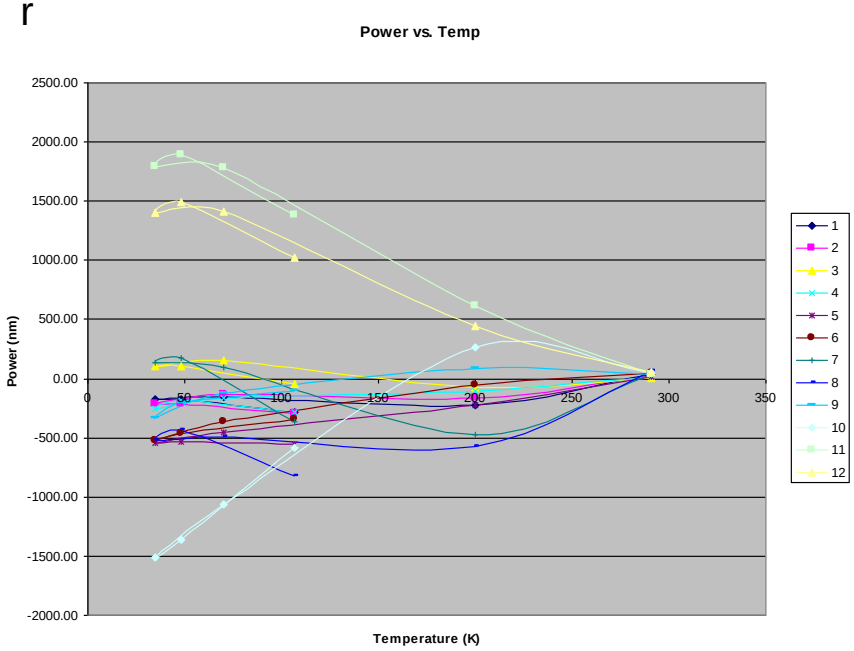
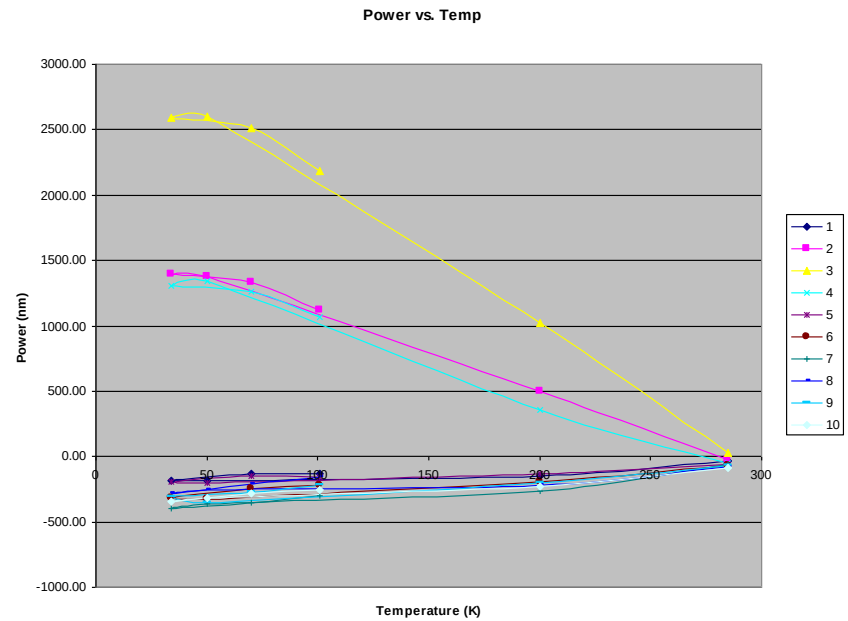
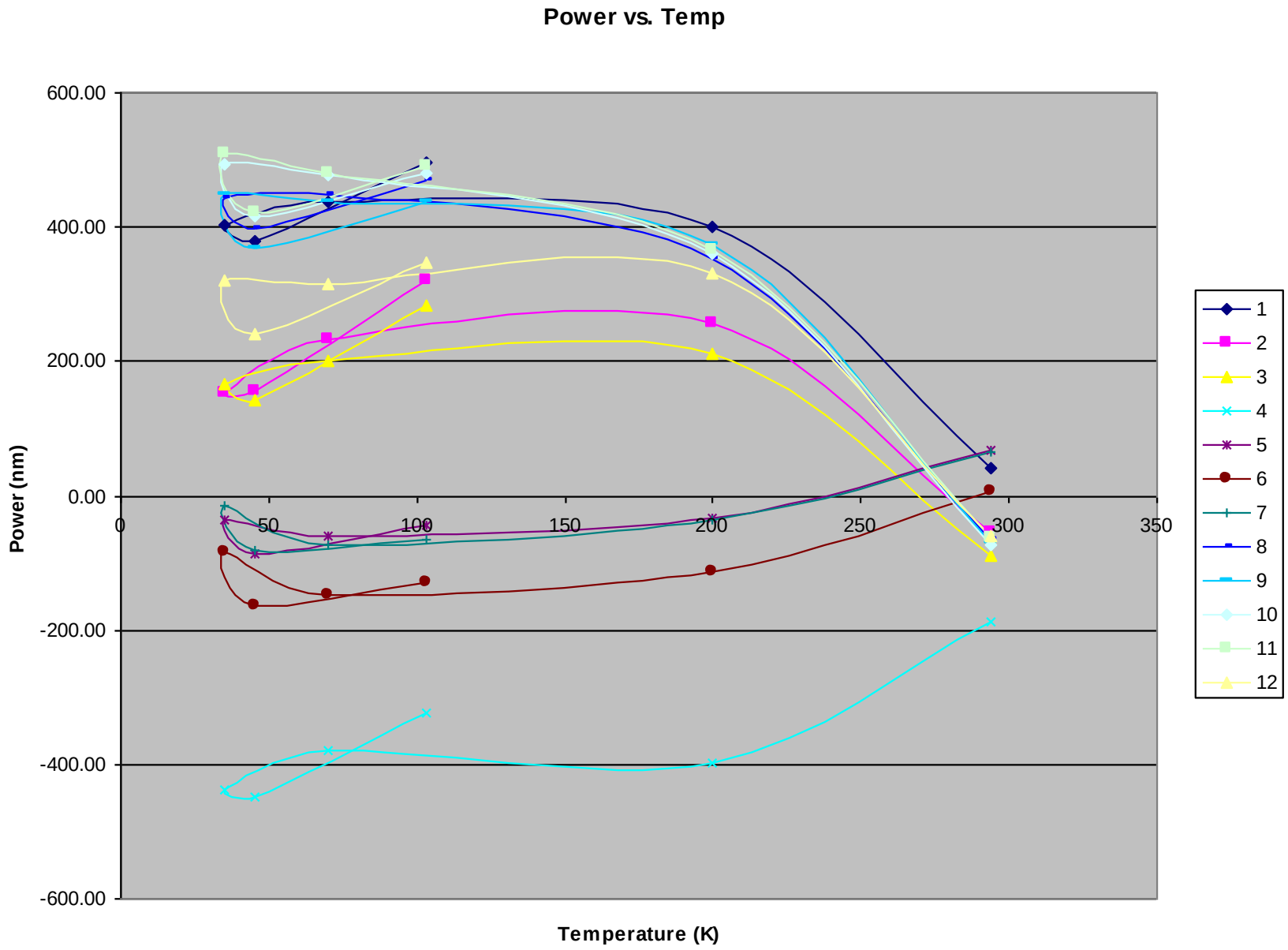
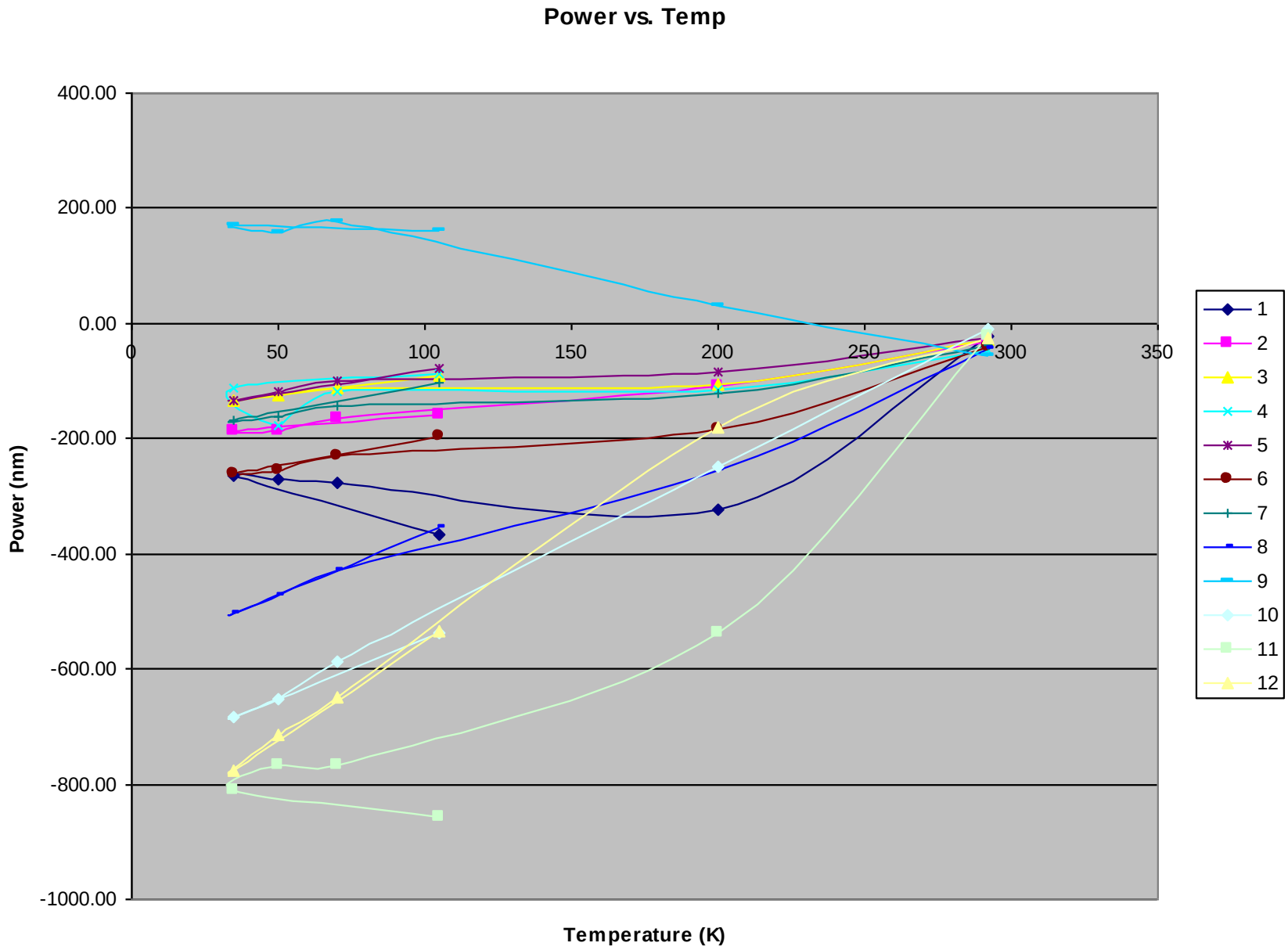




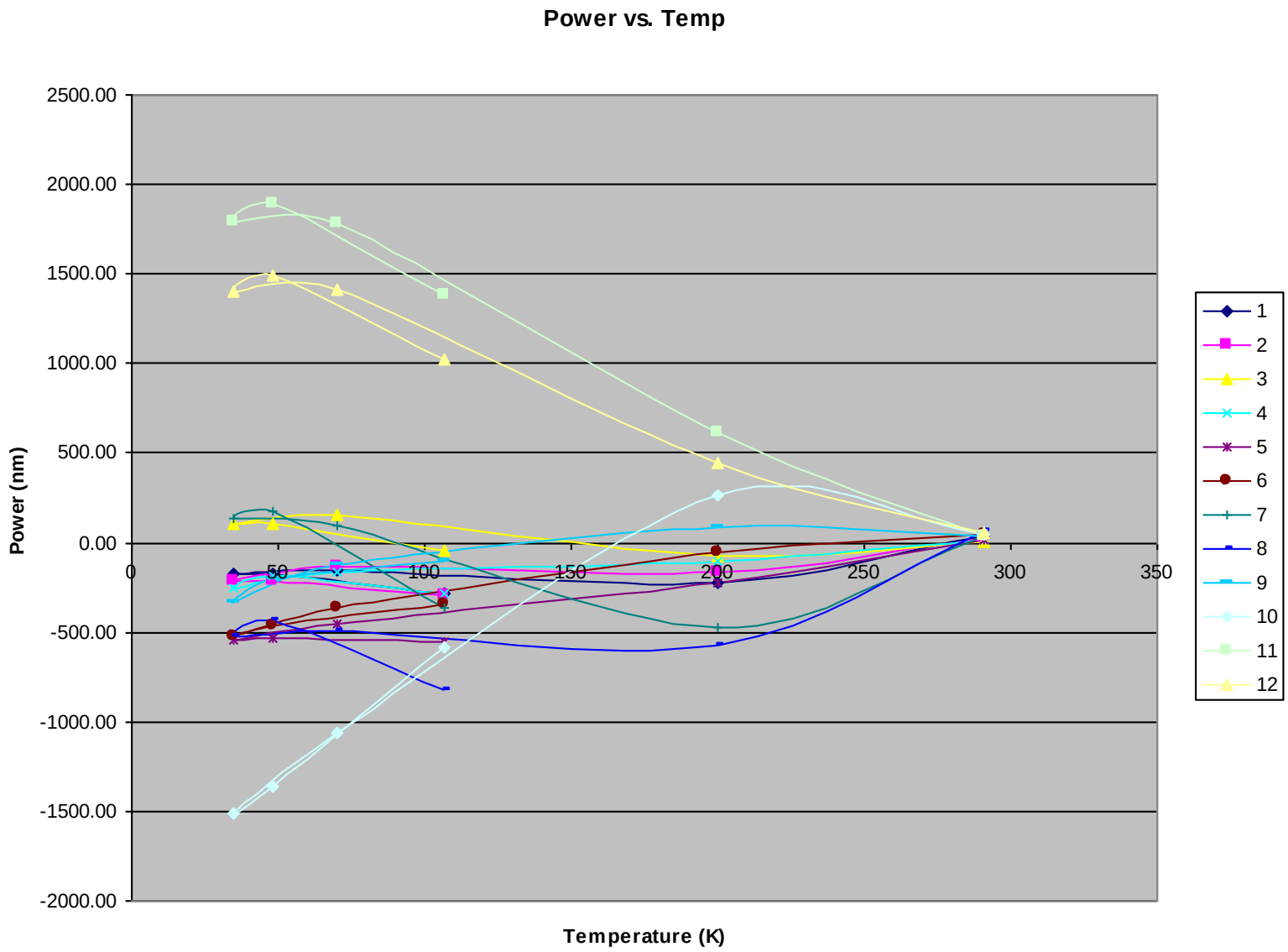
Δ power (P-V) vs temp for batch #1 (12 samples)



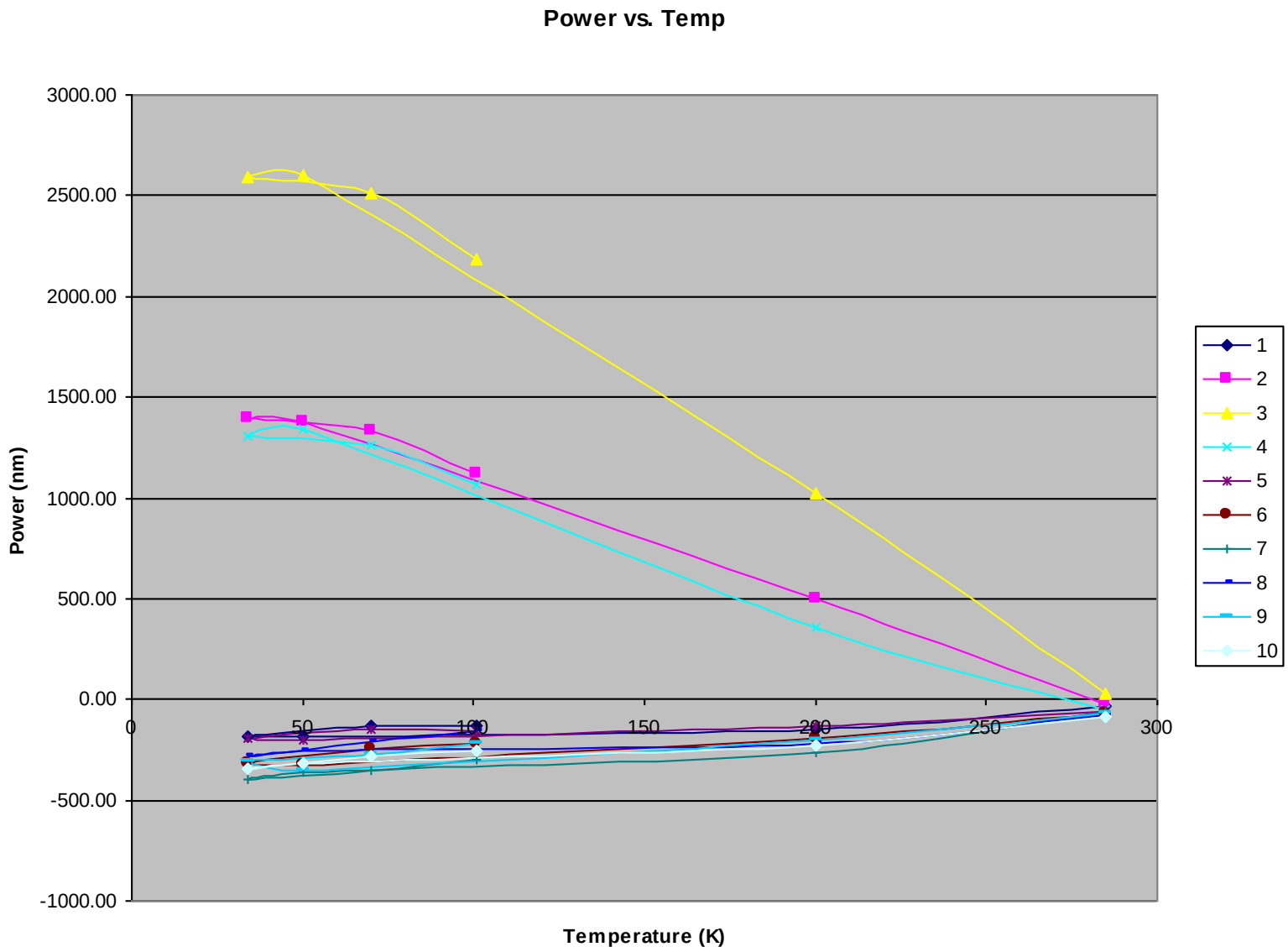
Δ power (P-V) vs temp for batch #2 (12 samples)



Δ power (P-V) vs temp for batch #3 (12 samples)



Δ power (P-V) vs temp for batch #4 (10 samples)



Observations

rank	vendor	sample quantity	min Δ power (nm)	max Δ power (nm)	avg Δ power (nm)	rank
1		8	15	404	202	1
2		6	101	504	237	2
3 (tie)		6	196	397	306	3 (tie)
4 (tie)		8	113	508	308	4 (tie)
5		8	140	1513	511	5
6		3	684	809	756	6
7		7	175	2592	1263	7

Observations

- large variance among each vendor's samples
- SiC cryo strain caused by materials and more importantly, residual stress from polishing
- Test results along with vendor part # will be given to each perspective vendor

Acknowledgment

Phil Stahl, James Carter, Charlie Griffith, Mark Young, SiC vendors, and the XRCF team

JWST mirror segments Al thermal mass test articles

Thank you

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