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Fiber-Coupled Cryogenic Radiometer with Carbon Nanotube Absorber

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Acknowledgments

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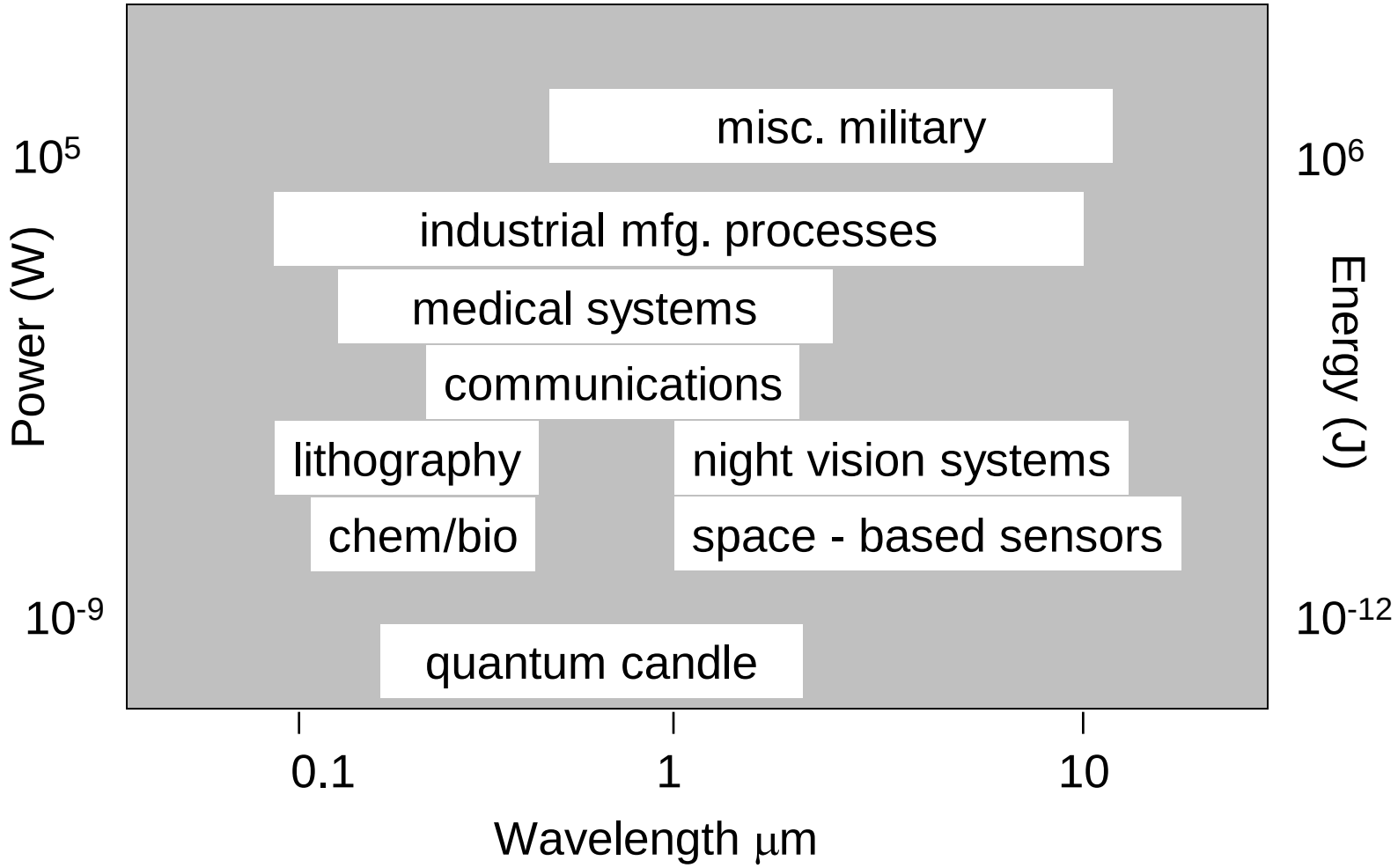
Where

Physical Measurement Laboratory
Quantum Electronics and Photonics Division
Sources and Detectors Group
Laser Radiometry Project (11 people)

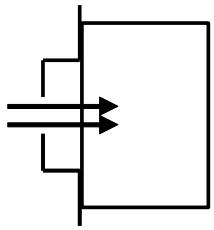
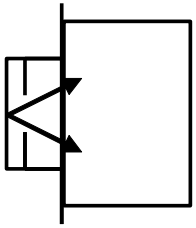
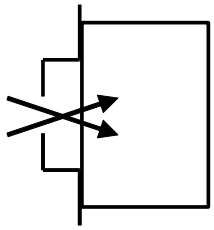
Laser Power Meter Calibration Services (10 % of NIST by income)

Why

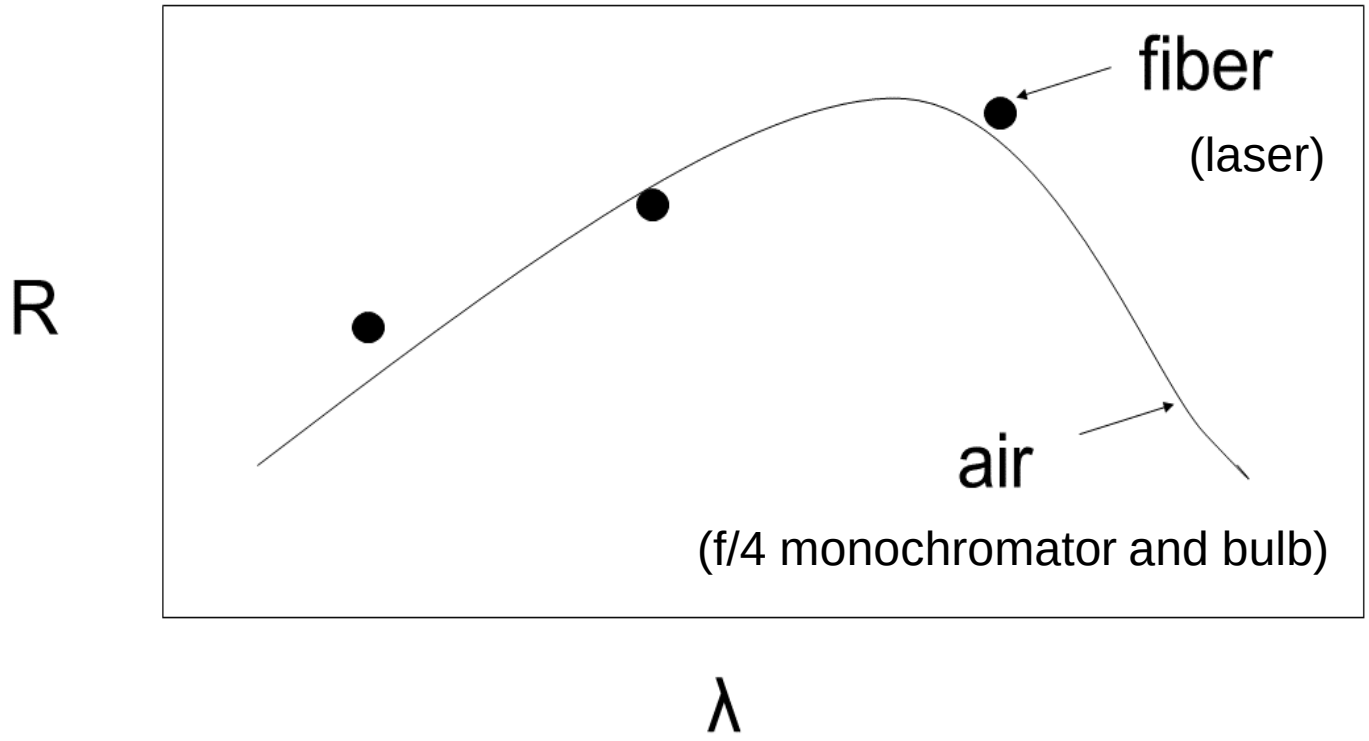
The next generation of detectors for laser power and energy measurements traceable to NIST



Motivation

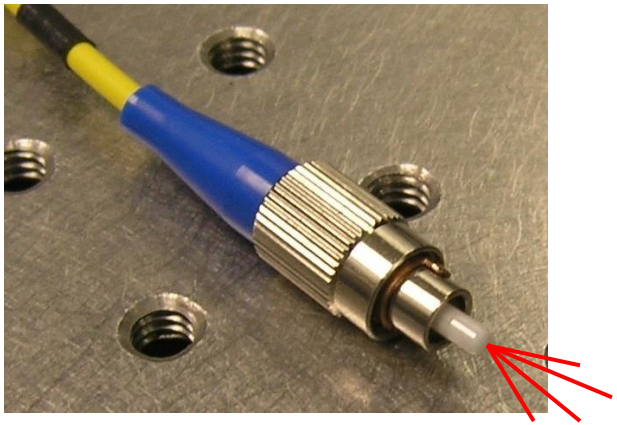
Beam geometry	Detector	Measurement system
Nearly collimated		1. C-series 2. LOCR *Absolute*
Diverging from fiber		3. Fiber-based responsivity with FC connector *(The customer)*
Diverging from monochromator (6 nm bandwidth)		4. Spectral responsivity *“Relative”*

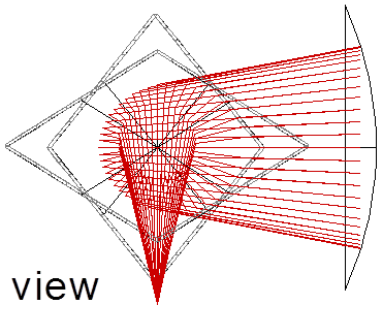
Absolute and Spectral Responsivity

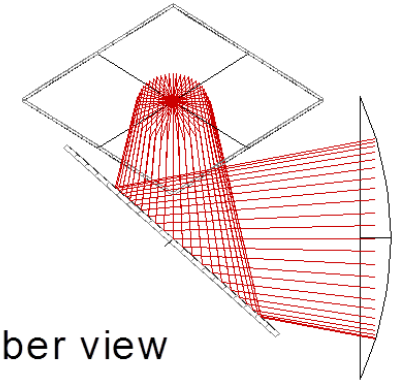


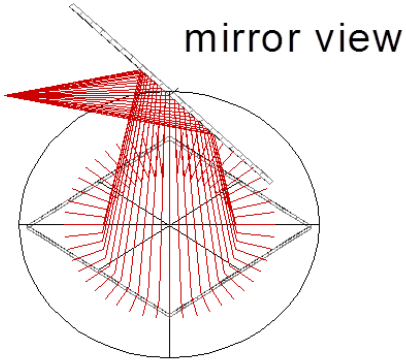
J. H. Lehman, C. M. Wang, M. L. Dowell, and J. A. Hadler, *Journal of Research of the National Institute of Standards and Technology,* **114**, 287-291, 2009.

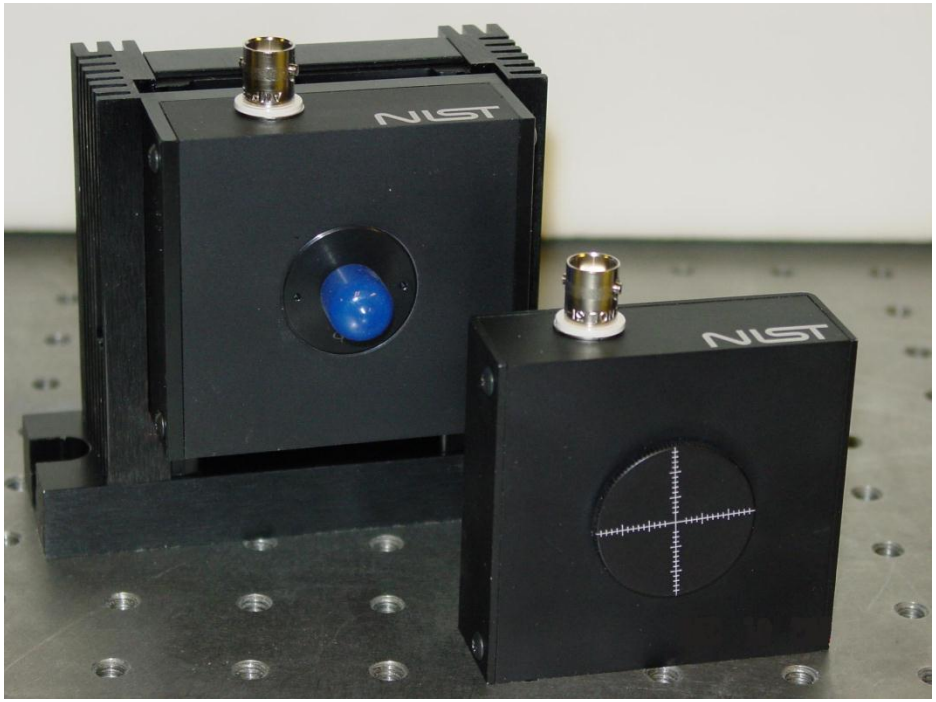
Transfer Standards







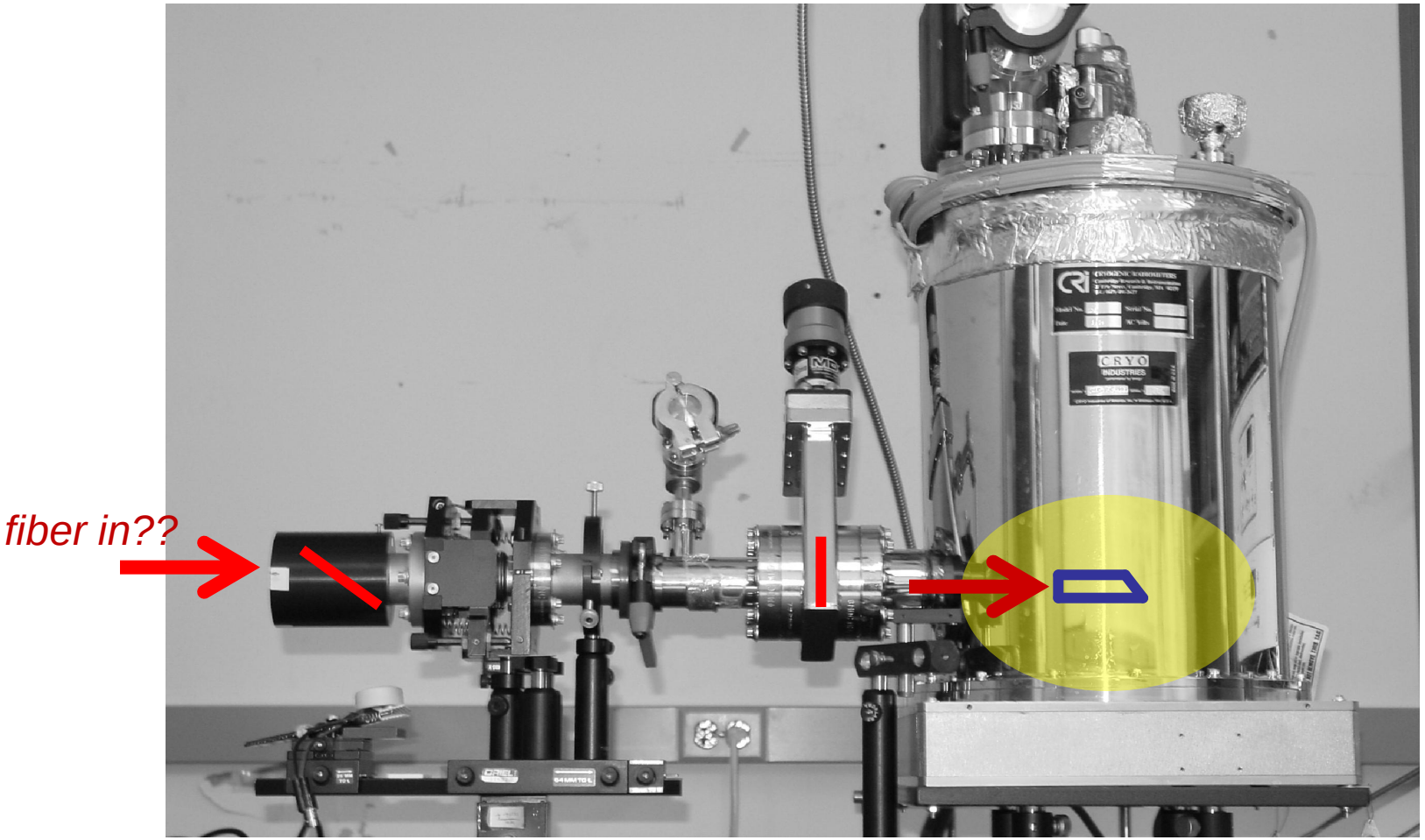




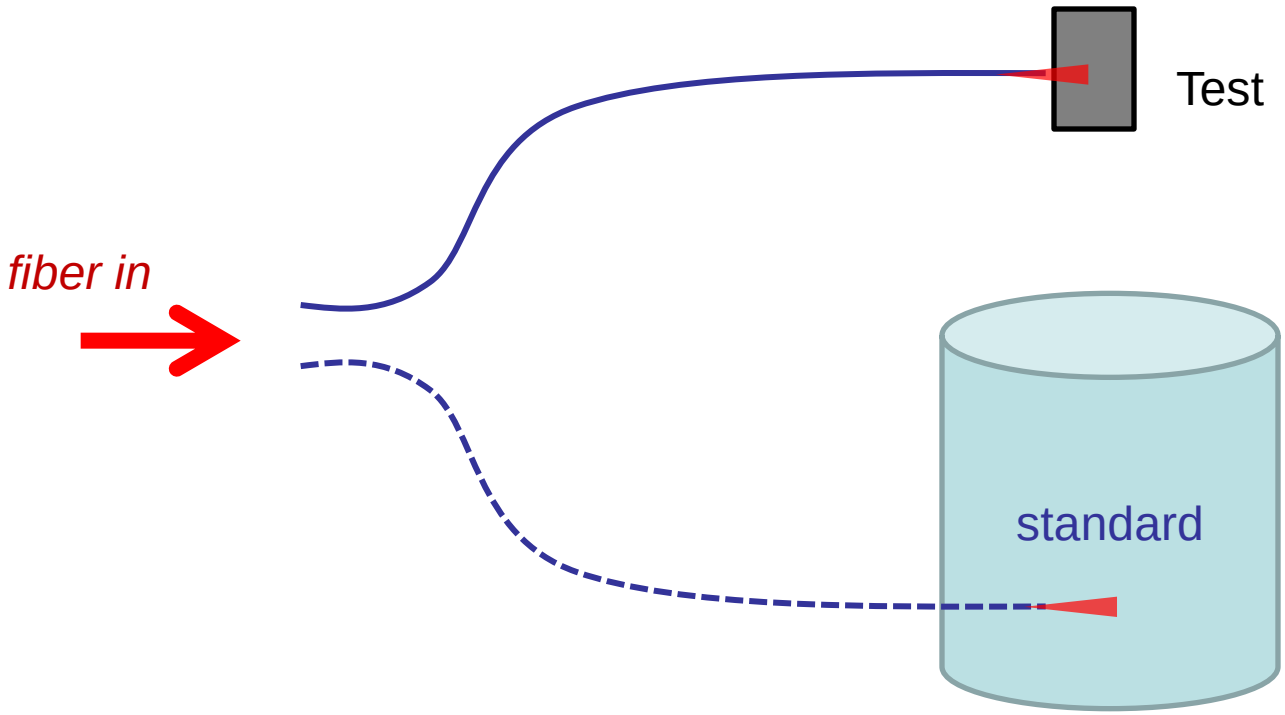
4x Trap detectors

J. H. Lehman and C. L. Cromer, *Appl. Opt.,* **41**, 6531-6536, 2002.

Cryogenic Radiometer

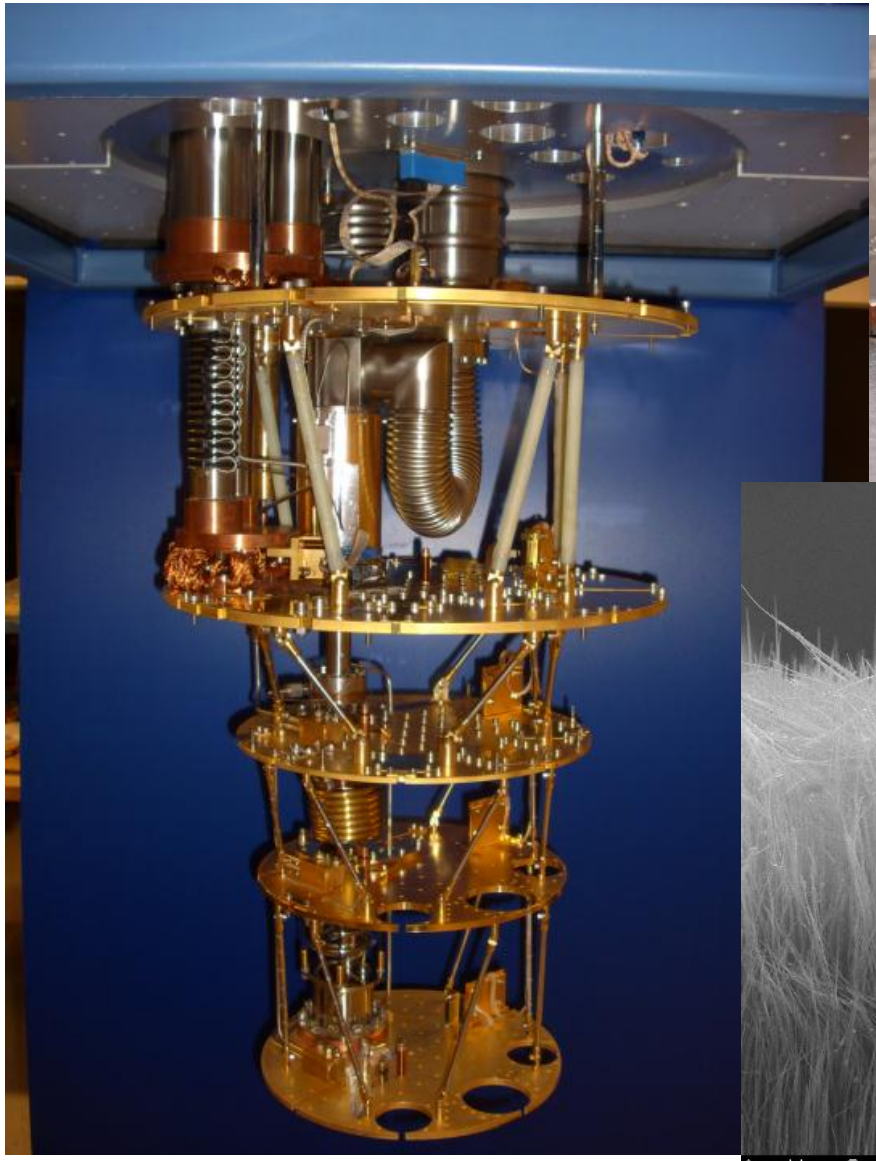


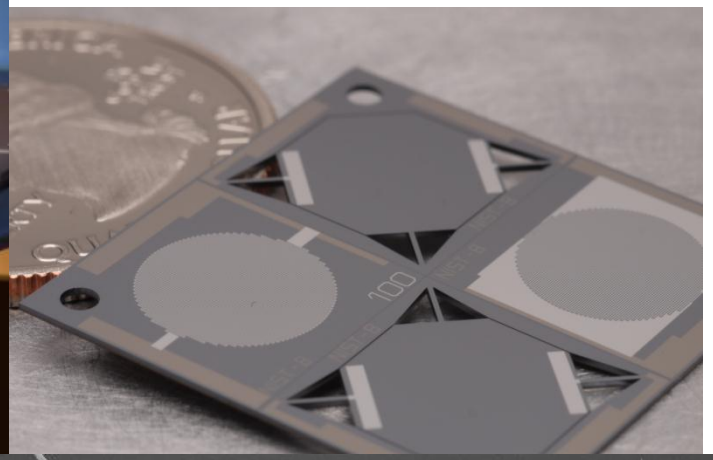
Ideal scenario

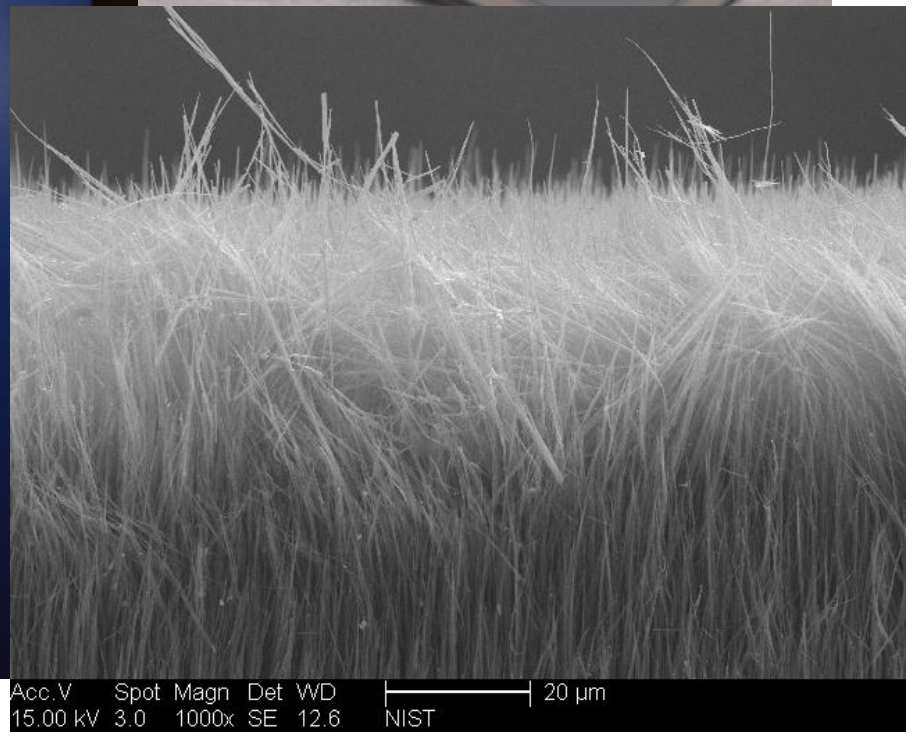


Goal: all-fiber coupling to test and standard detectors

Dilution fridge, micromachining and carbon nanotubes

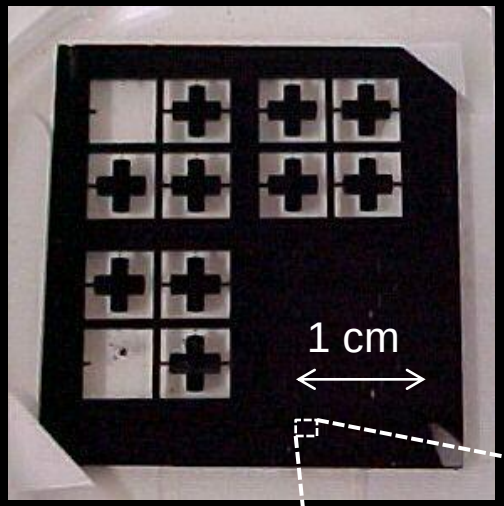


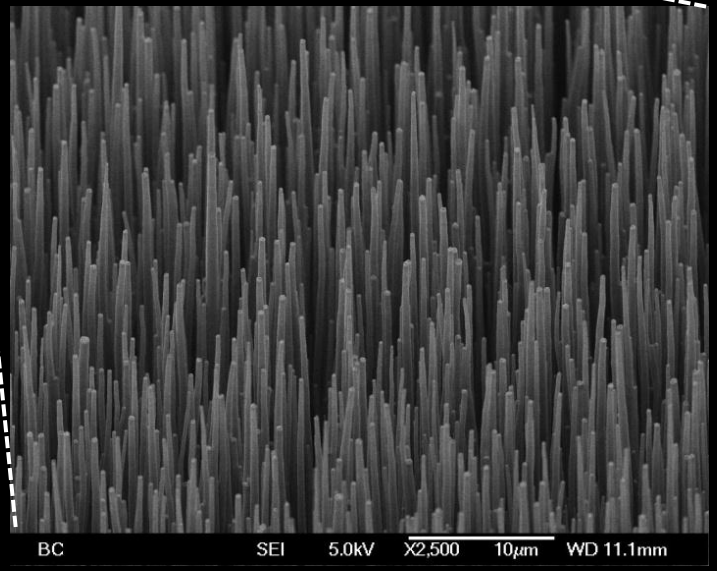




Micromachined components

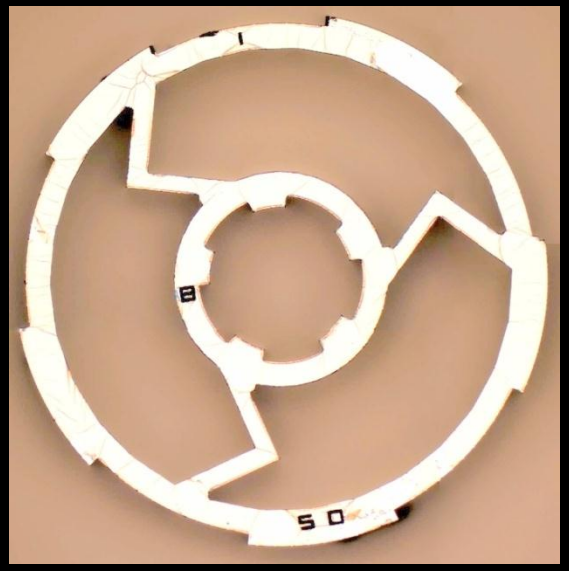
Deep Reactive Ion Etch (DRIE)





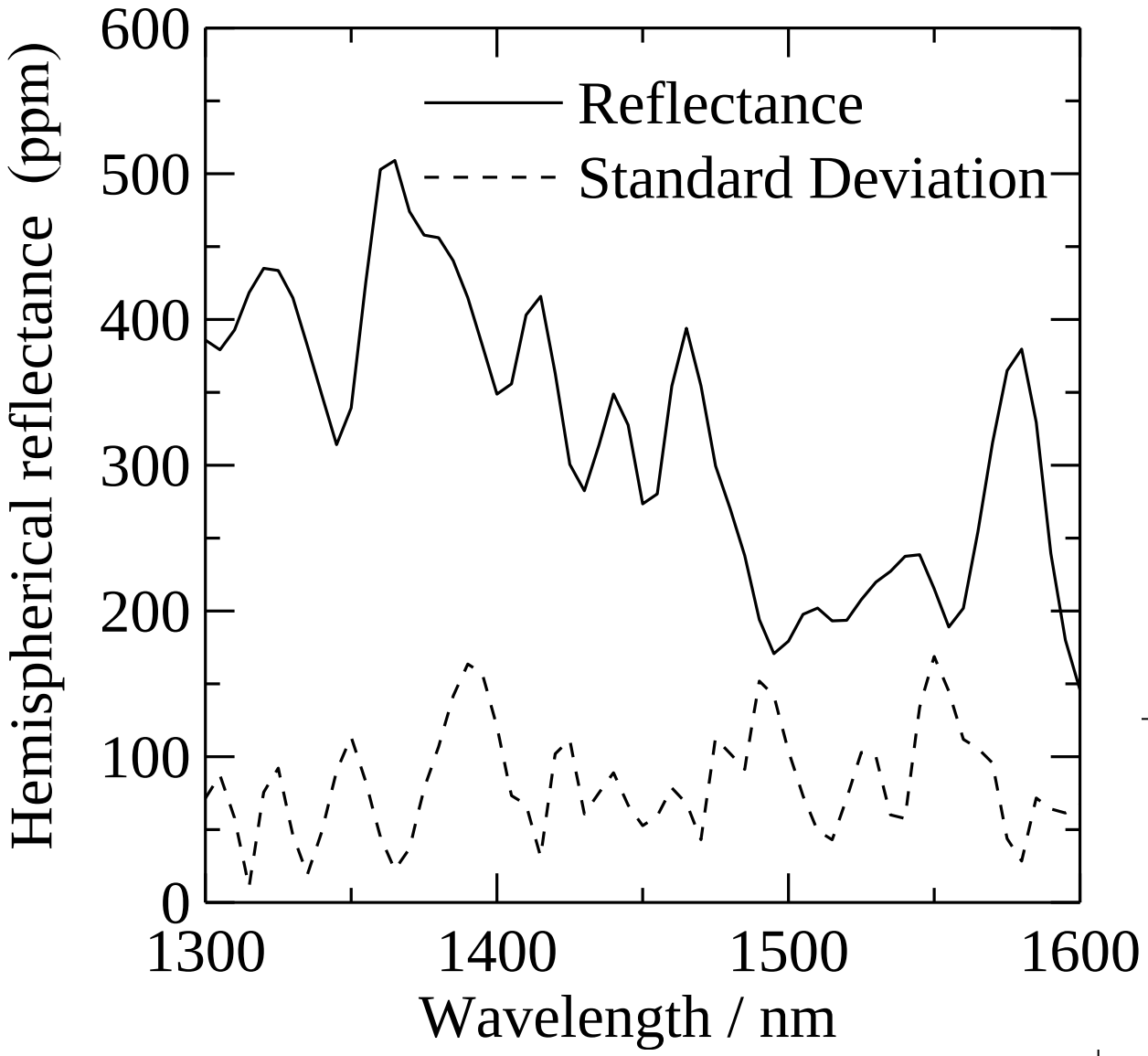
cavity ends and witness

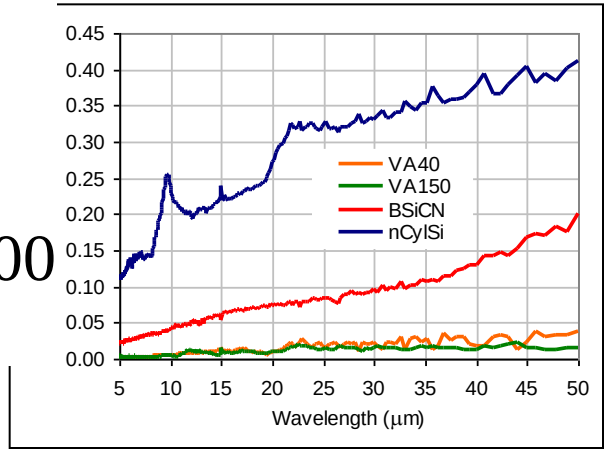
1.4 mm



centering ring
for fiber

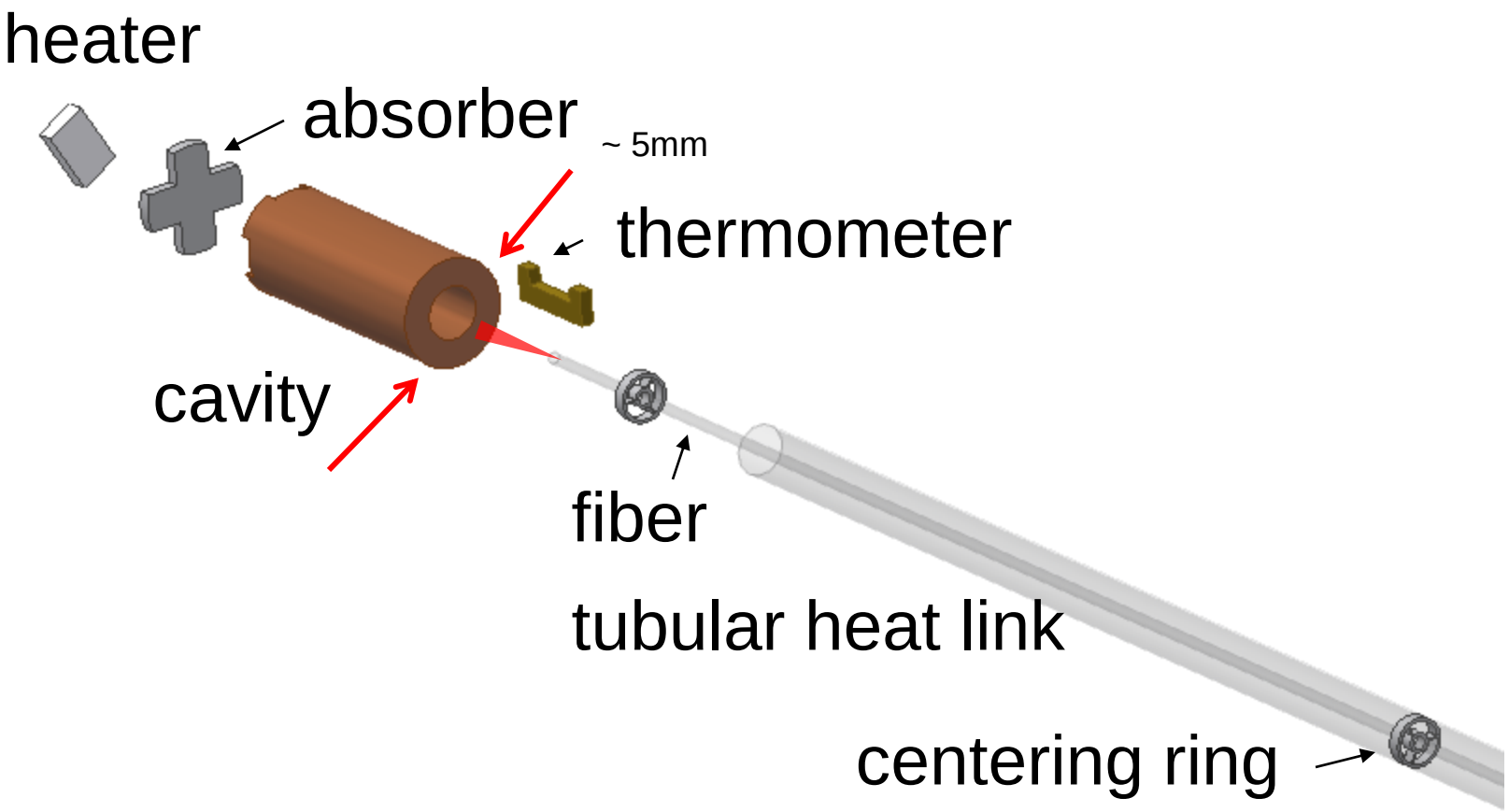
Reflectance Results



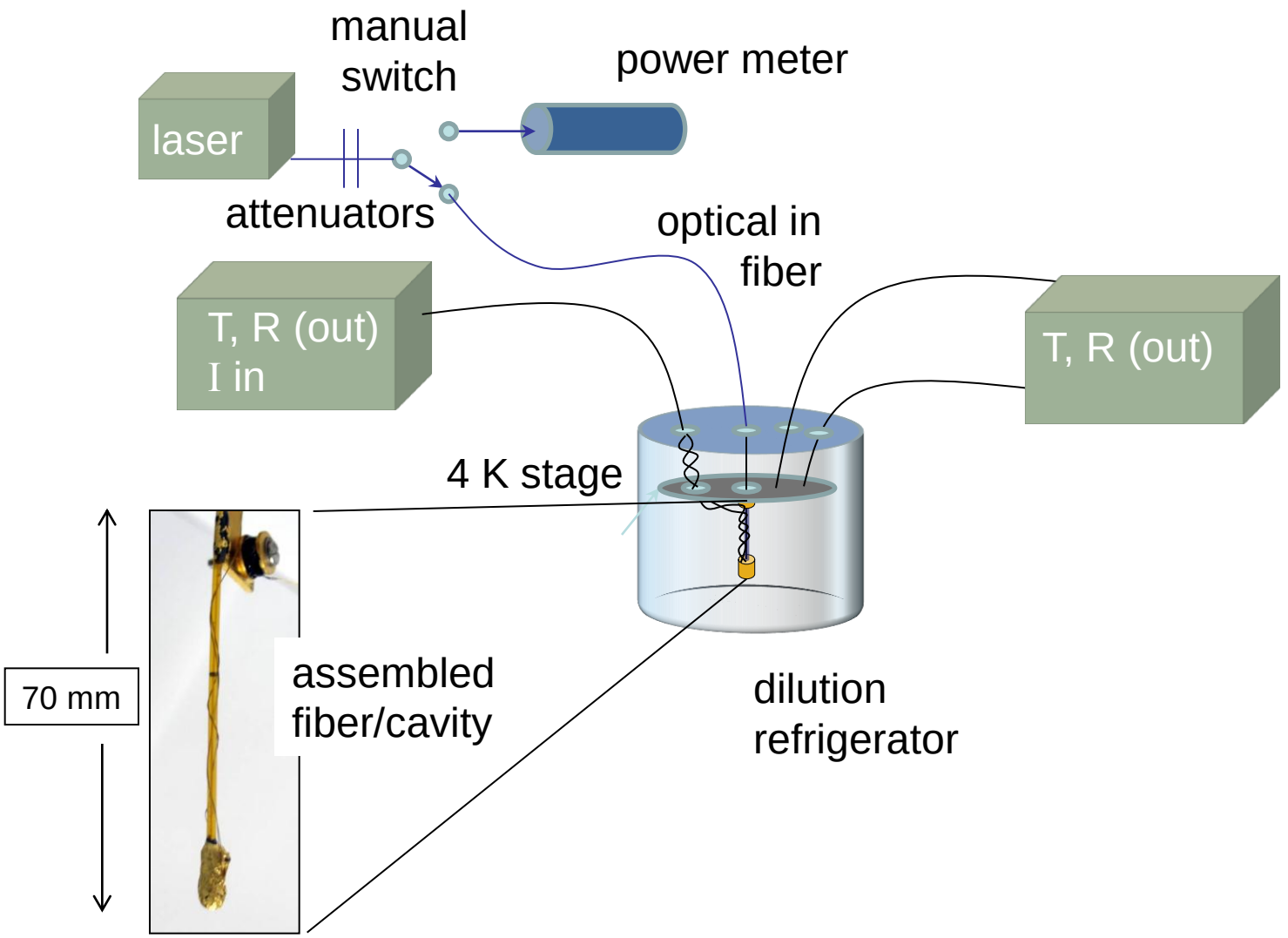


See also OPM_OR_001

Cavity assembly

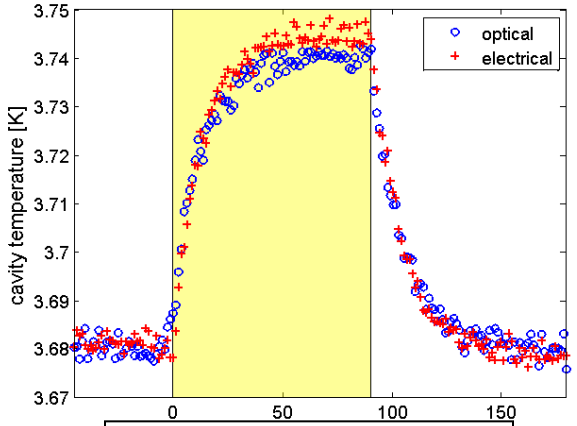


Measurement setup

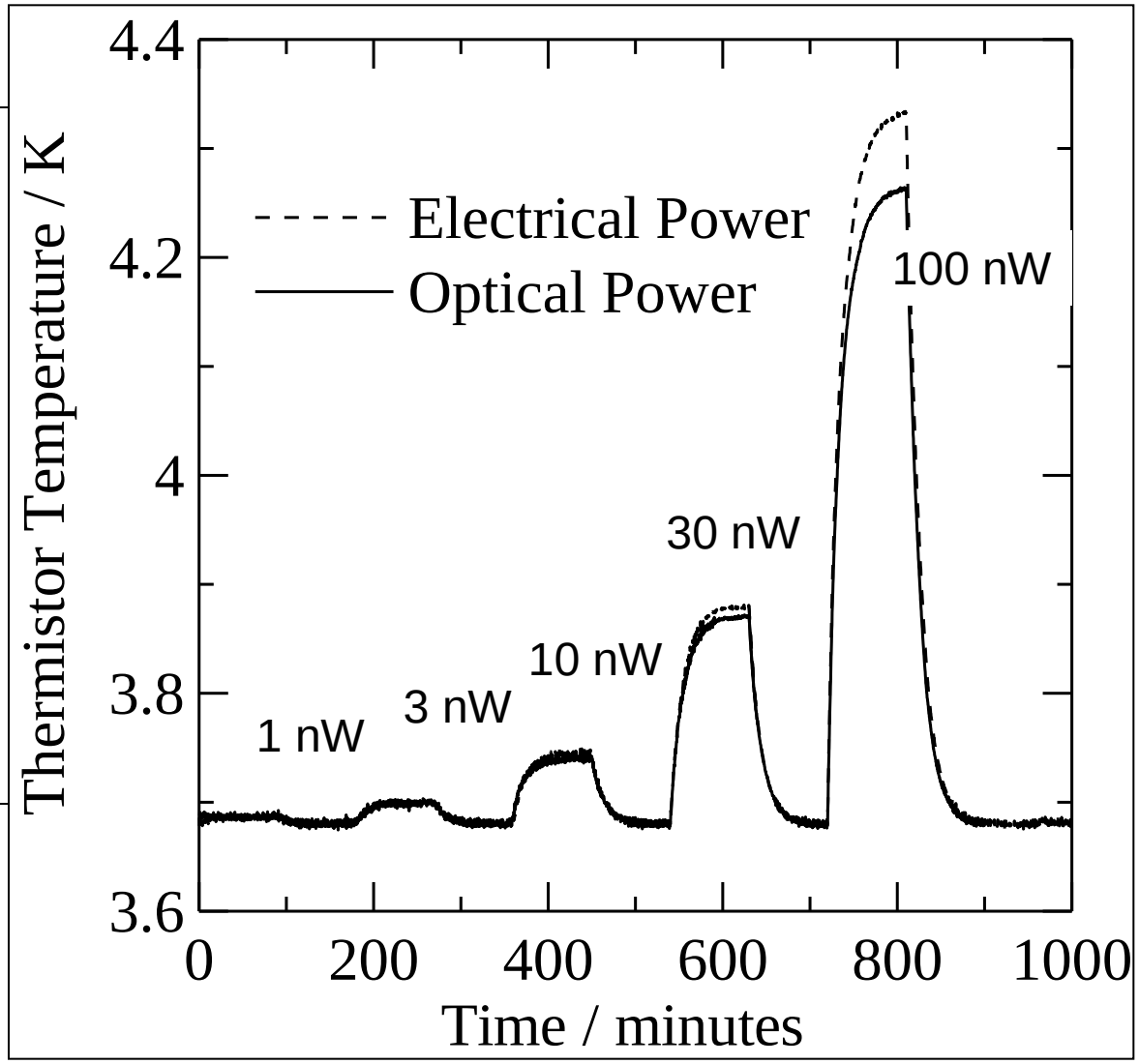


Results

Example measurement at ~ 10 nW

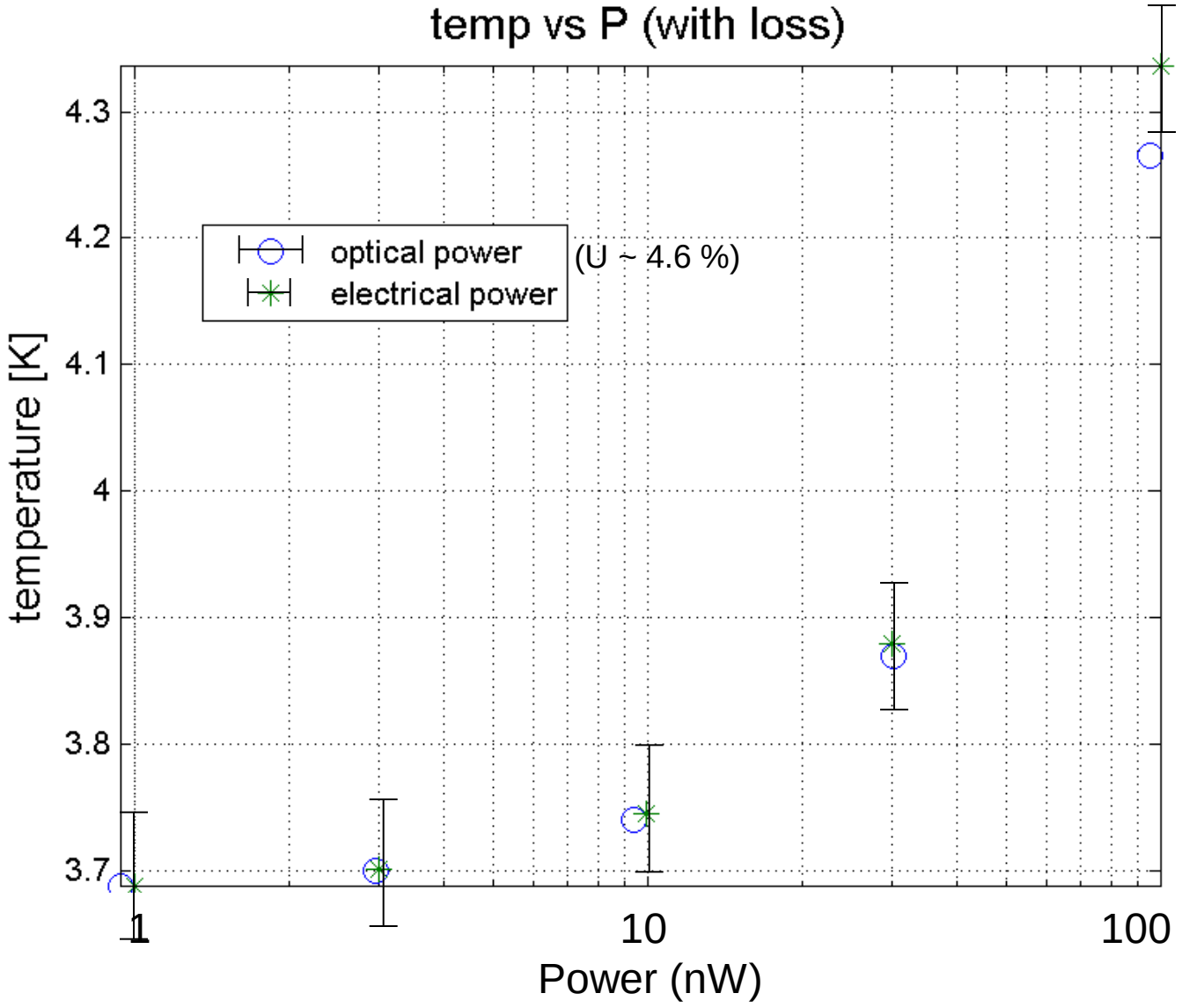


1/e time constant ~ 12 minutes

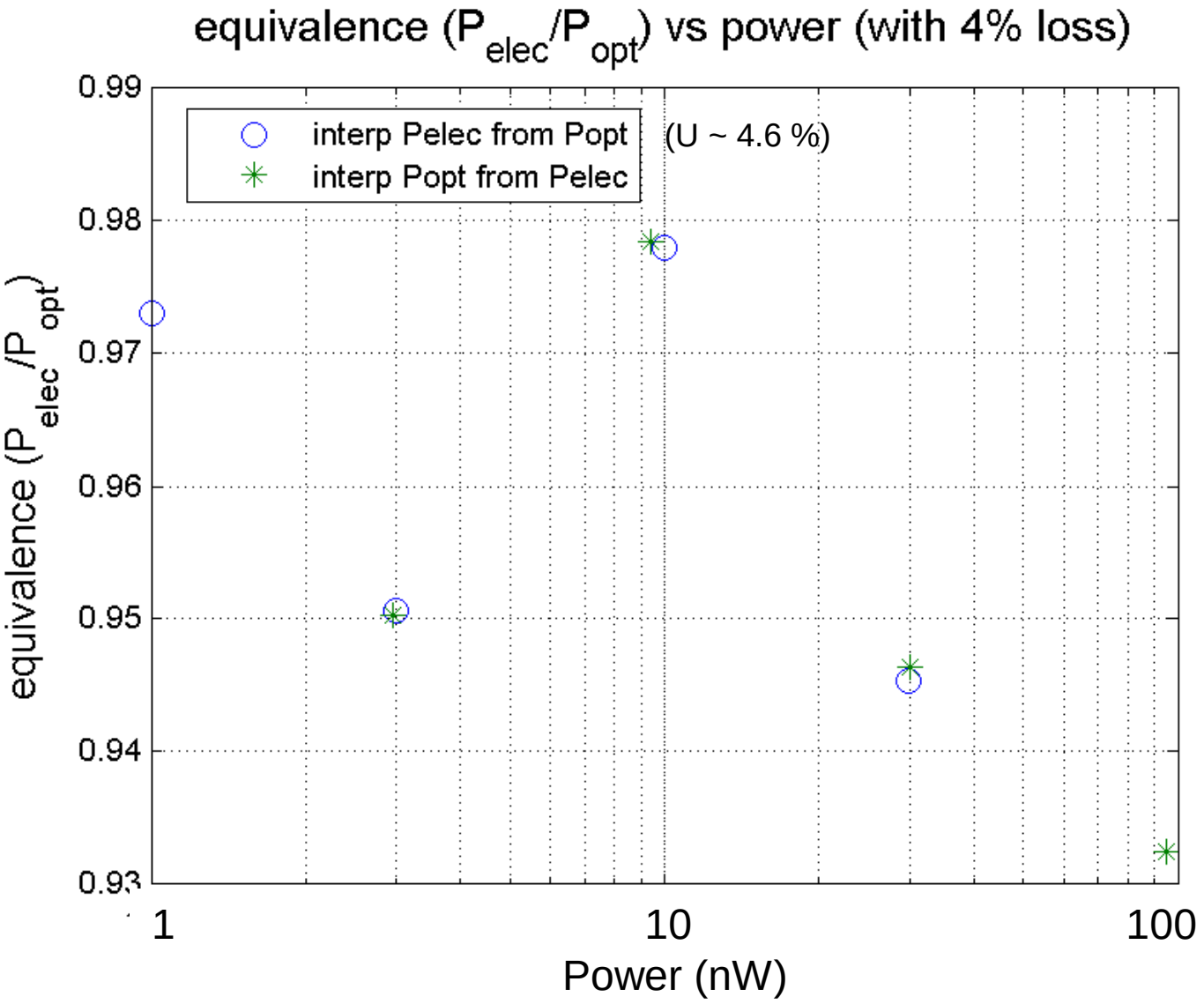


(Values of power shown are nominal)

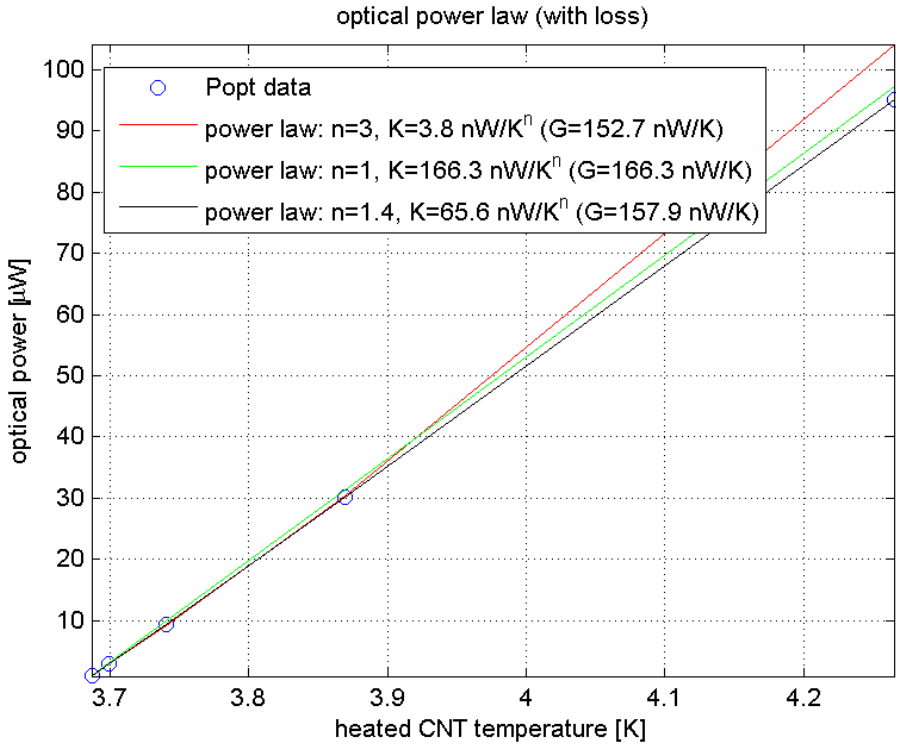
Optical/Electricial Results Summary

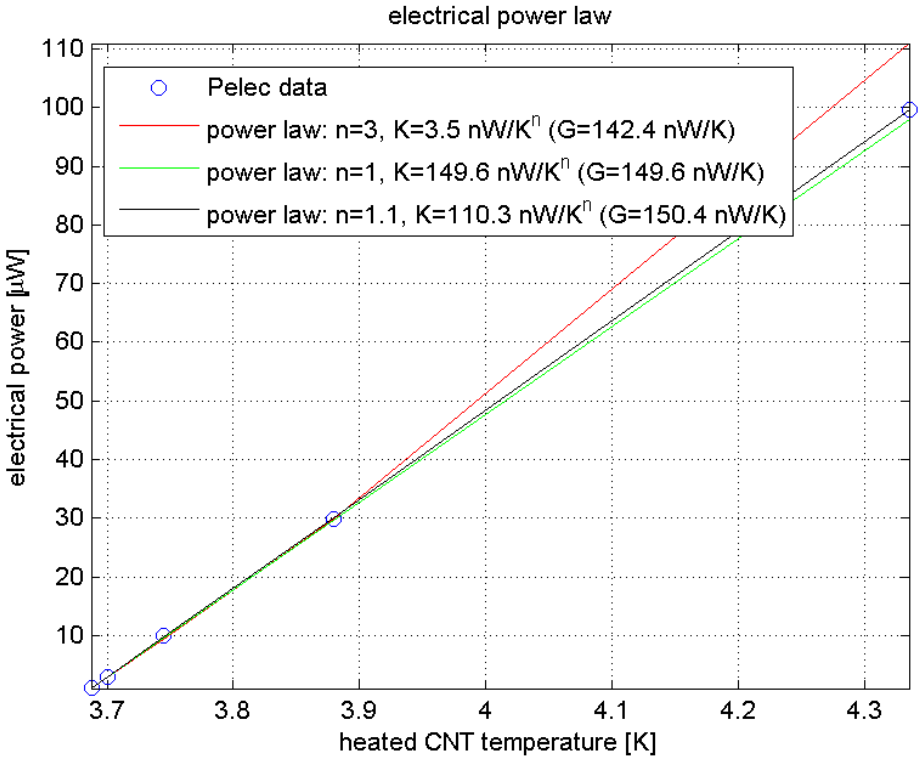


Optical/Electricial Results Summary



Optical/Electricial Results Summary





Power law fits for conductance modes and inequivalence

T^3 insulator (phonon) - no

T^1 metal (electron) -yes

Summary and Future

Demonstrated first nanoWatt Radiometer for Fiber Measurements

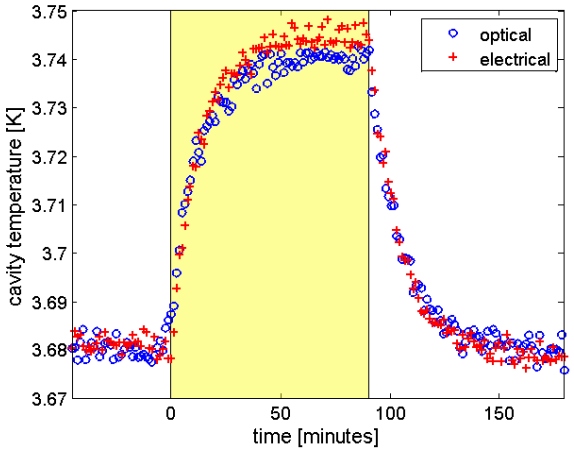
Micromachining and carbon nanotubes

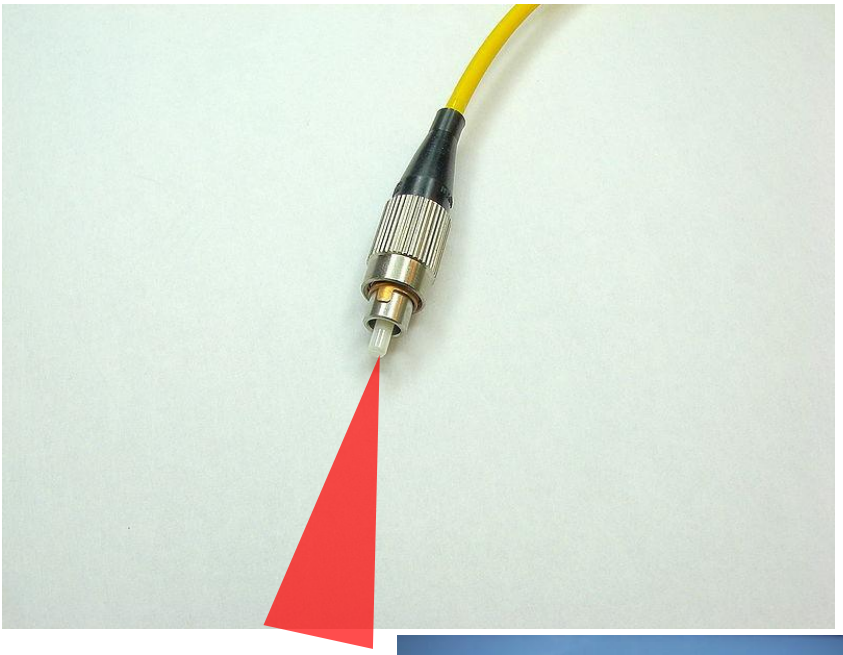
Electrical is slightly more efficient linear (but uncertainties are high)

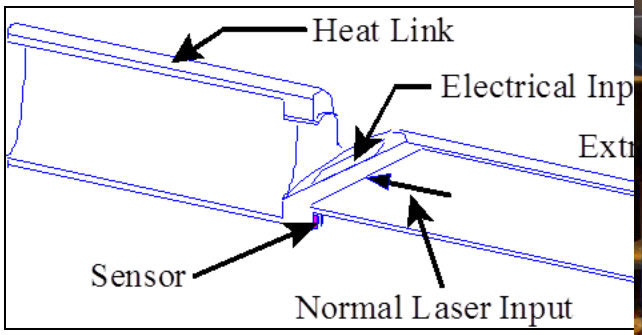
Next iteration, shorter time constant

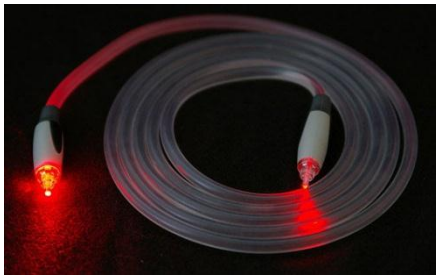
Reduce inequivalence, evaluate uncertainties, improve optical coupling

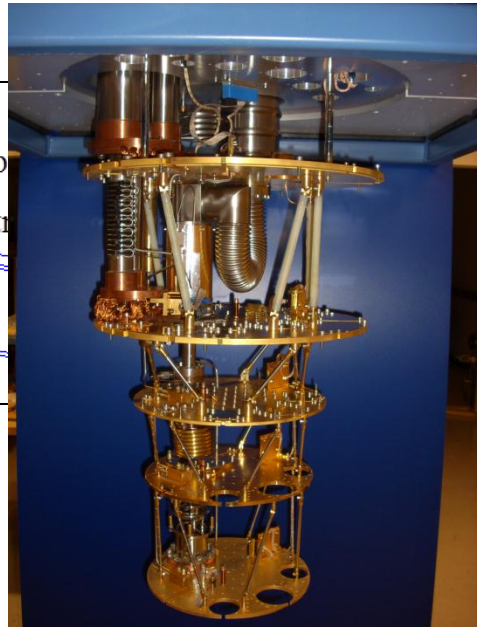
Results

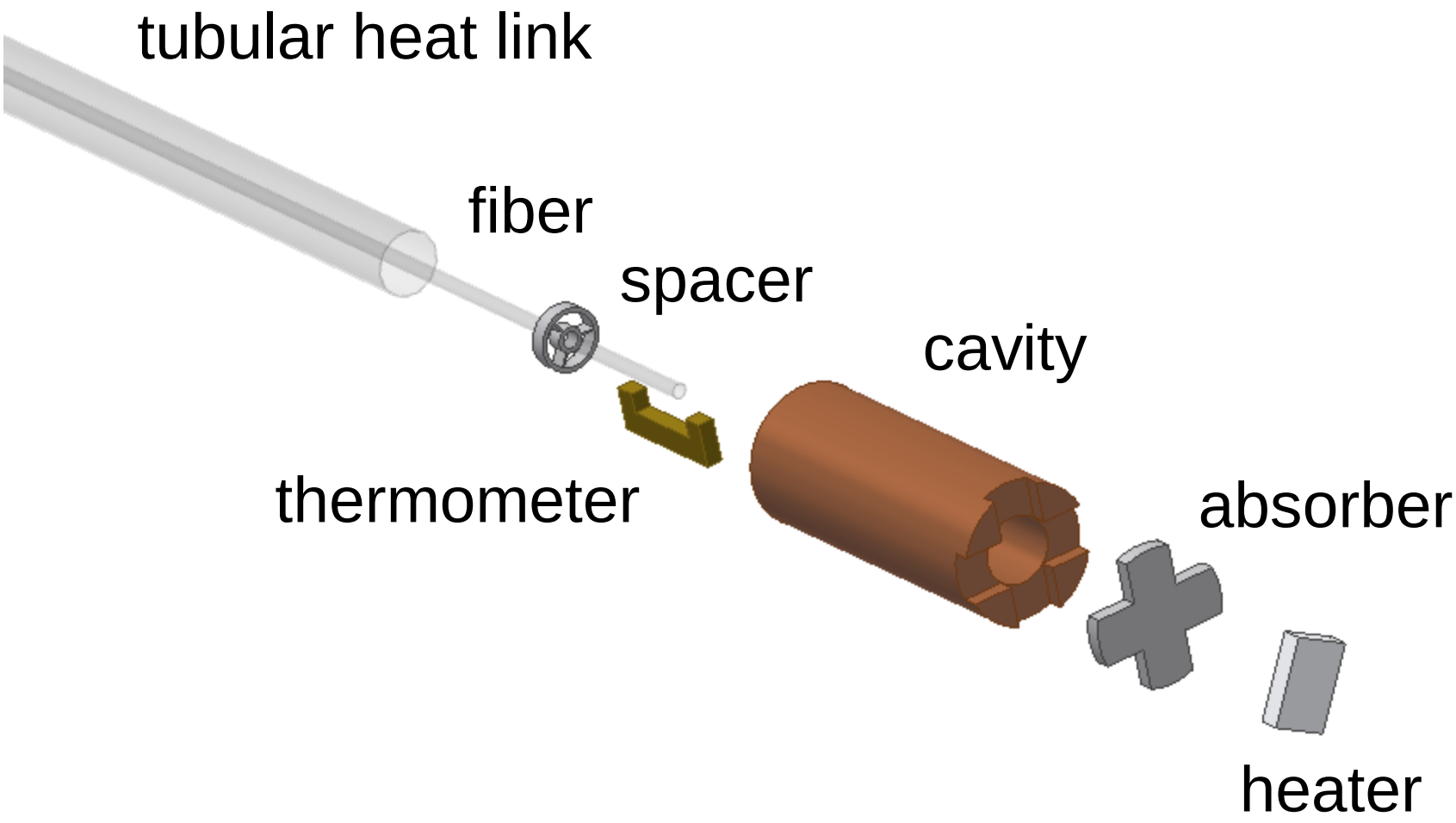

optical
electrical
cavity temperature [K]
time [minutes]
3.75
3.74
3.73
3.72
3.71
3.7
3.69
3.68
3.67
0
50
100
150



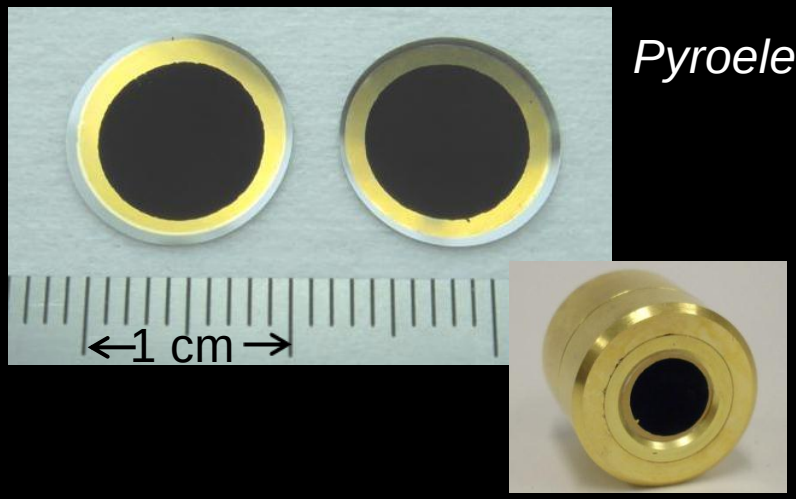

Heat Link
Electrical Inp
Ext
Sensor
Normal Laser Input






tubular heat link
fiber
spacer
cavity
thermometer
absorber
heater

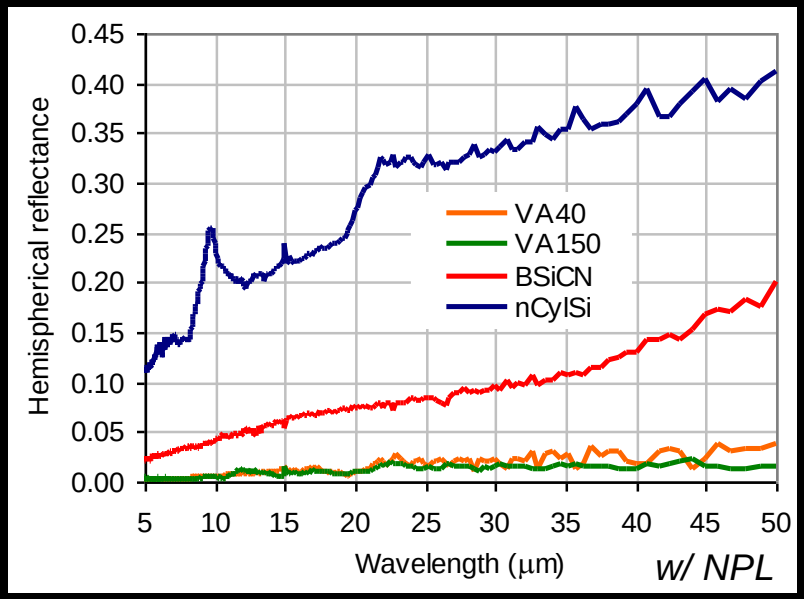
CNTs on detectors



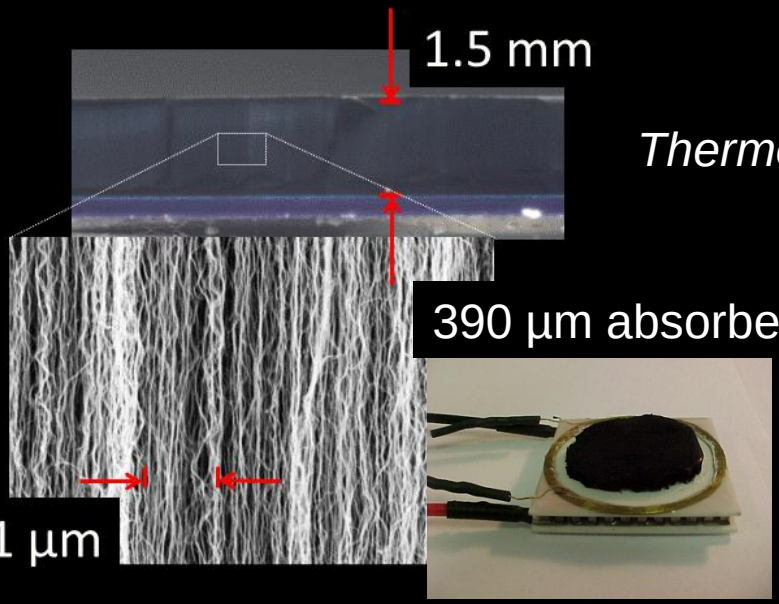
Pyroelectric

w/ NIST-G

'darkest detector'



w/ NPL



Thermopile

w/ E. Grossman

Optical/Electricial Results Summary

Approximate Power (nW)	Optical Power		Electrical Power	
	Responsivity (nW/K)	1/e Time Constant (minutes)	Responsivity (nW/K)	1/e Time Constant (minutes)
1	n/a	n/a	149	12.4
3	154	12.7	149	13.3
10	160	12.1	153	12.9
30	160	13.9	150	13.8
100	164	15	152	15.4

U = 4.55 % (k=2)
(OFPM type B)

U = 3 % (k=2)
(thermistor type B)

Measured responsivity and time constant for optical and electrical power injections. (n/a – not available due to bad curve fit.)