Thermo-optic noise from doped tantala/silica coatings

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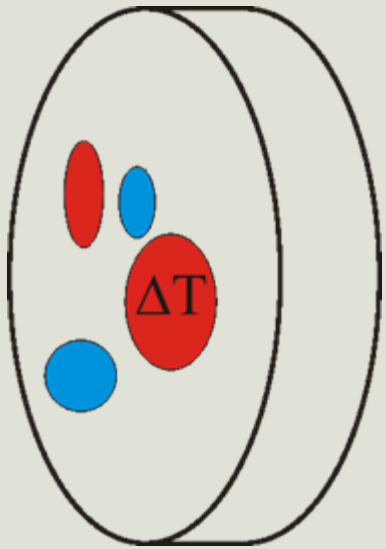
Thermo-optic noise

- Equilibrium heat fluctuations in the test mass surface cause fluctuations in physical parameters of the coating
  - Thermal expansion coefficient, $\alpha \Rightarrow$ Thermoelastic noise.
  - Thermorefractive coeff. $\beta = dn/dT \Rightarrow$ Thermorefractive noise.

Thermo-optic noise

= (coherent) sum of thermoelastic and thermorefractive contributions.



Thermorefractive contribution somewhat higher than thermoelastic contribution but same order of magnitude.

$$S_T(\omega) = \frac{\sqrt{2} k_B T^2}{\pi r_0^2 \sqrt{\omega \kappa \rho C}}$$

$$S_{x,TE}(\omega) = 4\, S_T(\omega)\, \alpha_{eff}^2\, d^2$$

$$S_{x,TR}(\omega) = 4\, S_T(\omega)\, \beta_{eff}^2\, d^2$$

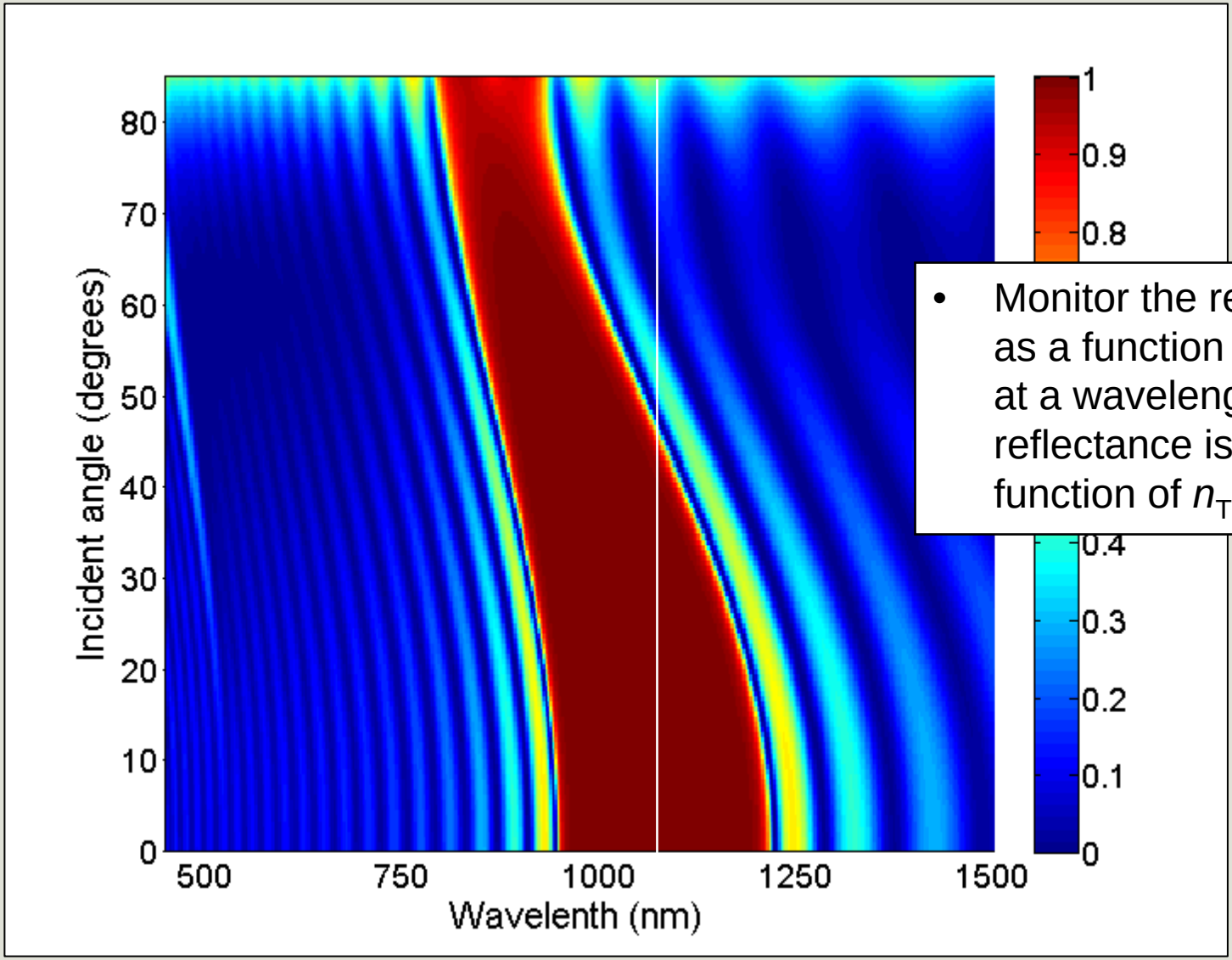
Formulas shown are from Braginsky, Gorodetsky and Vyatchanin (2000).

Independent thermoelastic noise calculation using a different approach due to Fejer et al. (2004) is used in Bench 5.0 .

$$\alpha_{eff} = (1+\nu_{bulk}) \left[\frac{\alpha_1 d_1}{d_1 + d_2} \frac{E_1(1-2\nu_{bulk})}{E_{bulk}(1-2\nu_1)} + \frac{\alpha_2 d_2}{d_1 + d_2} \frac{E_2(1-2\nu_{bulk})}{E_{bulk}(1-2\nu_2)} - \alpha_{bulk} \right]$$

$$\beta_{eff} = \frac{n_2^2 \beta_1 + n_1^2 \beta_2}{8(n_1^2 - n_2^2)} \frac{\lambda}{d}$$

Measuring dn/dT for Ta_2O_5 coating layers



- Monitor the reflectance, *R*, as a function of temperature at a wavelength where the reflectance is a strong function of n_{Ta2O5}.

The setup

Obtain:

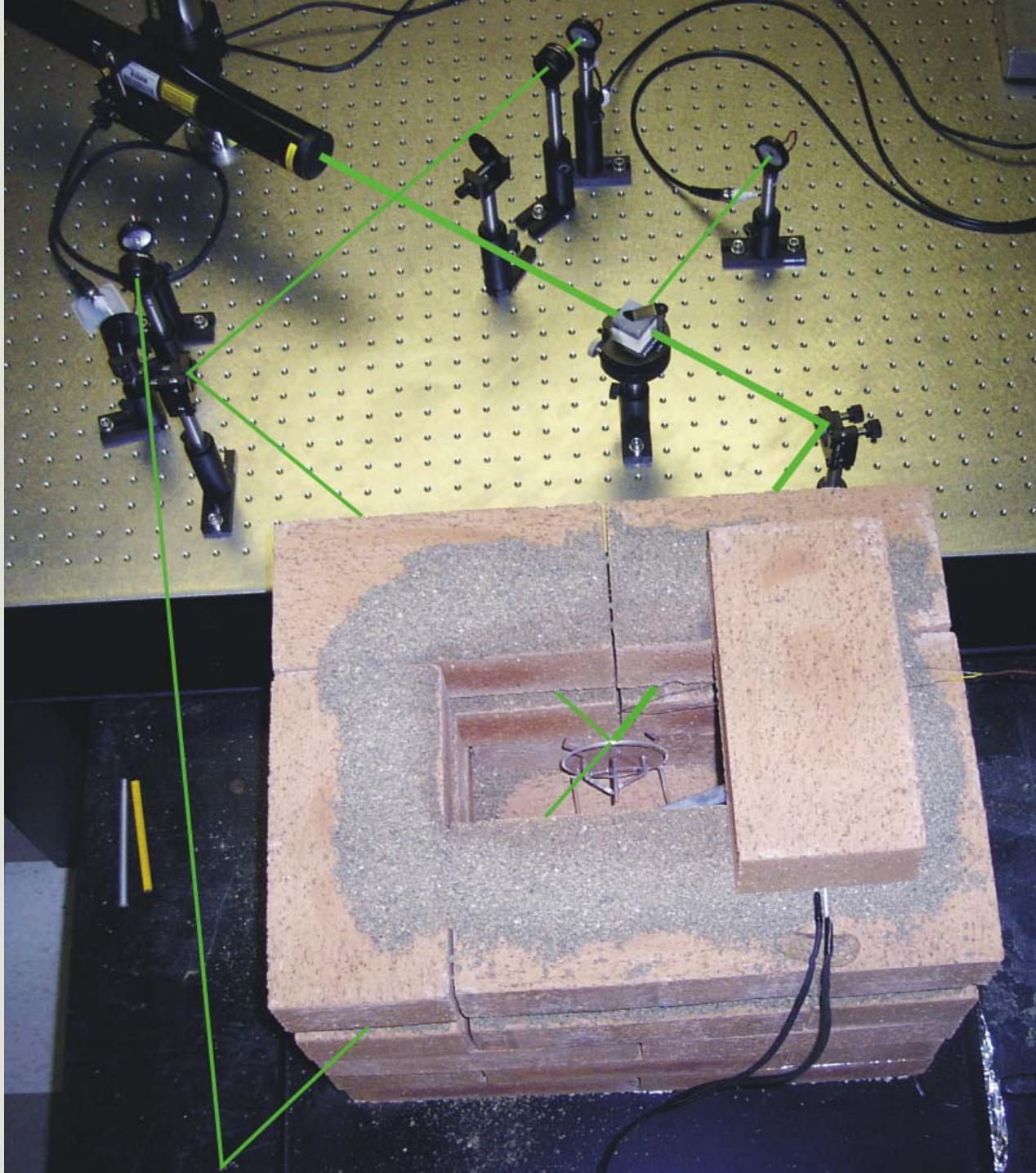
(P_{trans} / P_{input})

And/or

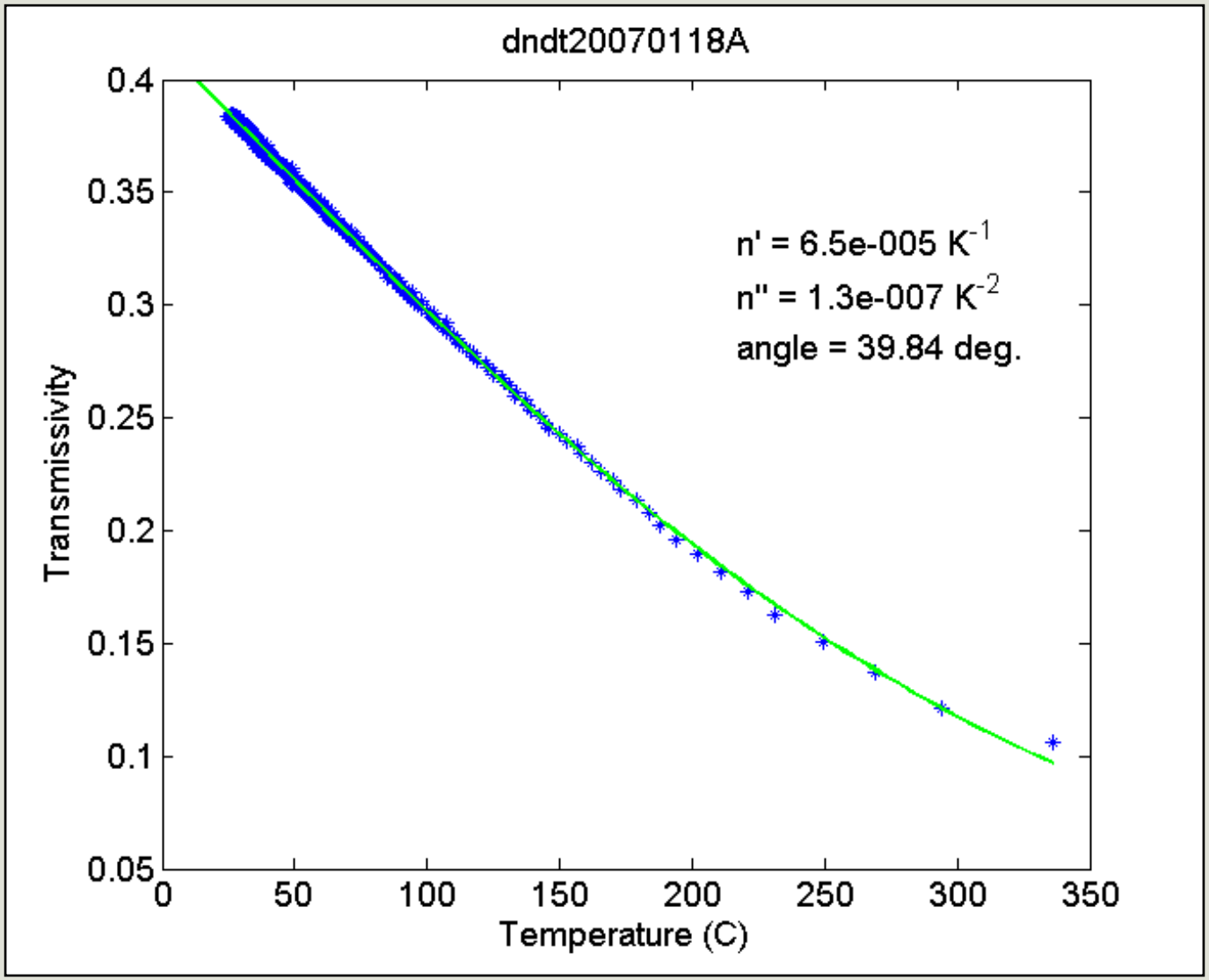
(P_{refl} / P_{input})

versus

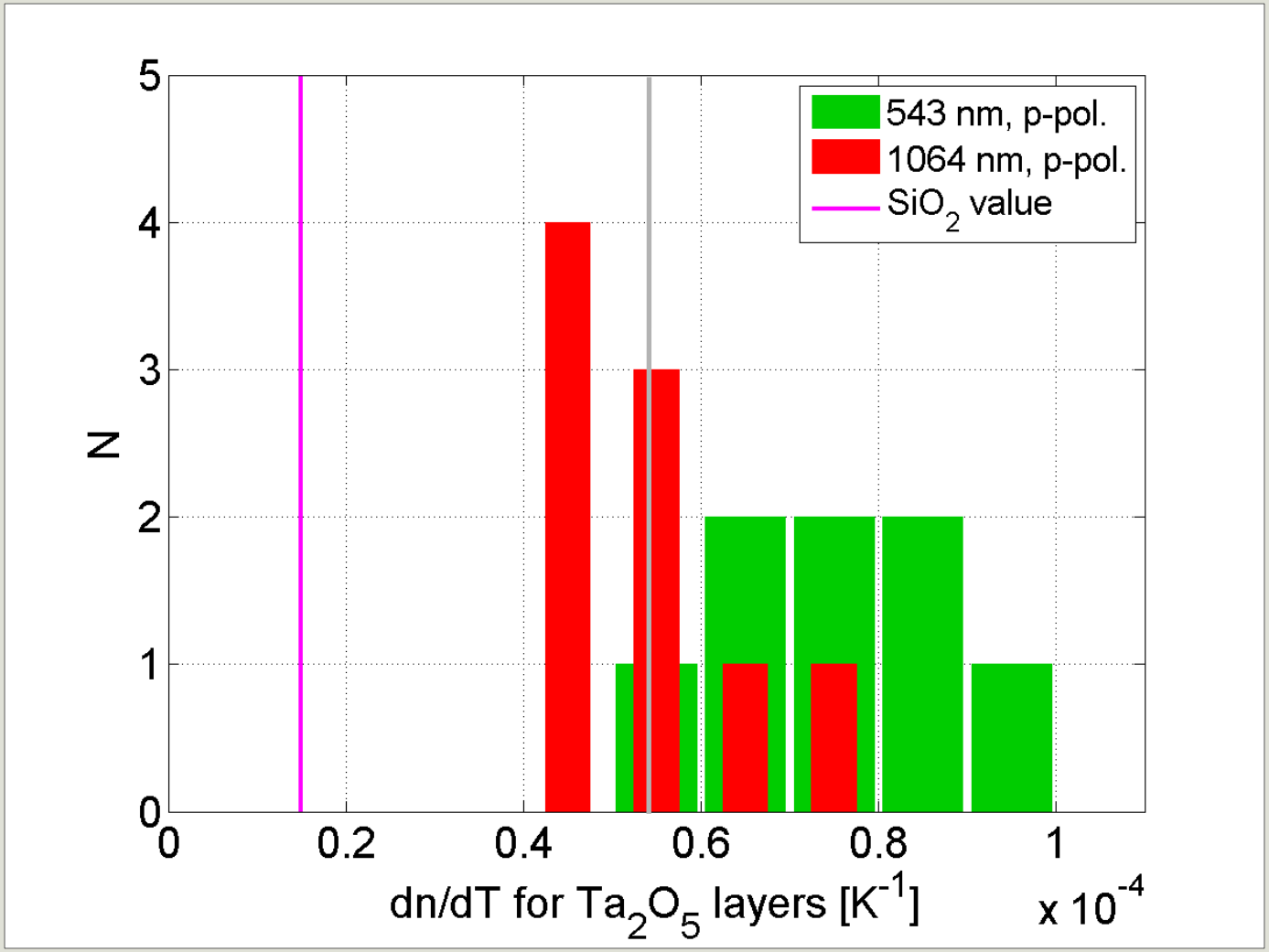
T_{sample}



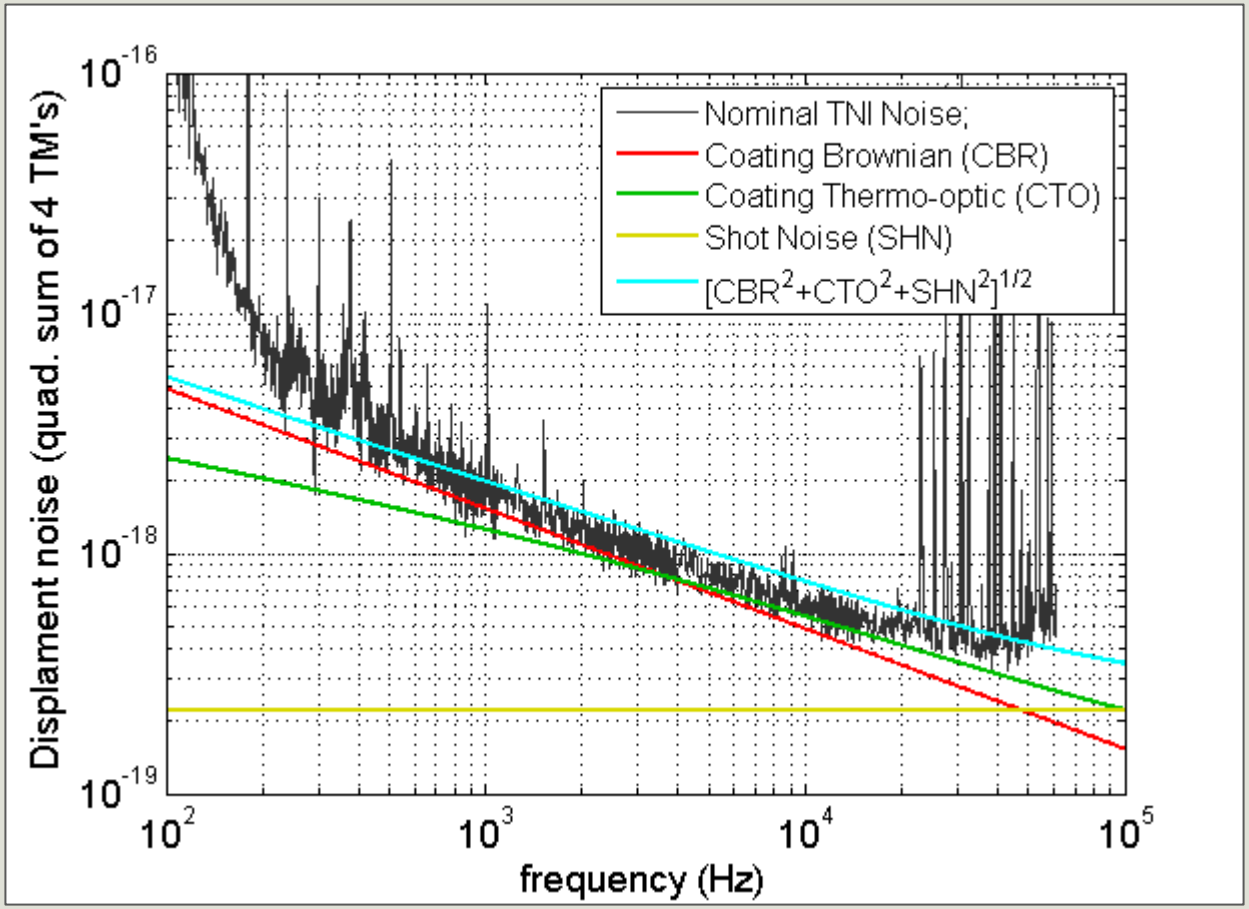
Reflectivity and Transmissivity versus Temperature



Results


543 nm, p-pol.
1064 nm, p-pol.
SiO2 value
N
0
1
2
3
4
5
0
0.2
0.4
0.6
0.8
1
dn/dT for Ta2O5 layers [K-1]
x 10-4

Consistency with Measurements



Consistency with Measurements