AN EMPIRICAL MODEL FOR THE MECHANICAL LOSS IN FUSED SILICA

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Summary: At the March LSC meeting several people who had worked on fused silica (Gregg Harry, Andri Gretarsson, Phil Willems, and I) met in order to postulate a model for the mechanical loss in fused silica. Measurements by the Syracuse group had shown that the minimum loss decreased with the surface-to-volume ratio. For measurements outside the thermoelastic peak the loss would increase with frequency, but the exact dependence was uncertain. On the other hand, measurements by Phil Willems, Kenji Numata, and the Roessler group all showed a clear frequency dependence. However, the data was measured at high frequency and it was unclear whether an extrapolation to low frequencies would agree with the surface loss dependence. Using the collection of data from all Gregg, Andri, Phil, Kenji, myself and Sasha Ageev, I have fit an empirical model of the mechanical loss, including dependencies on both the surface and frequency.

Model: The model includes only terms for the surface loss, the frequency-dependent loss and the thermoelastic loss.

$$\phi(f,\tfrac{V}{S}) = \left(C_1/\tfrac{V}{S}\right) + C_2\, f^{C_3} + C_4\, \phi_{th}$$

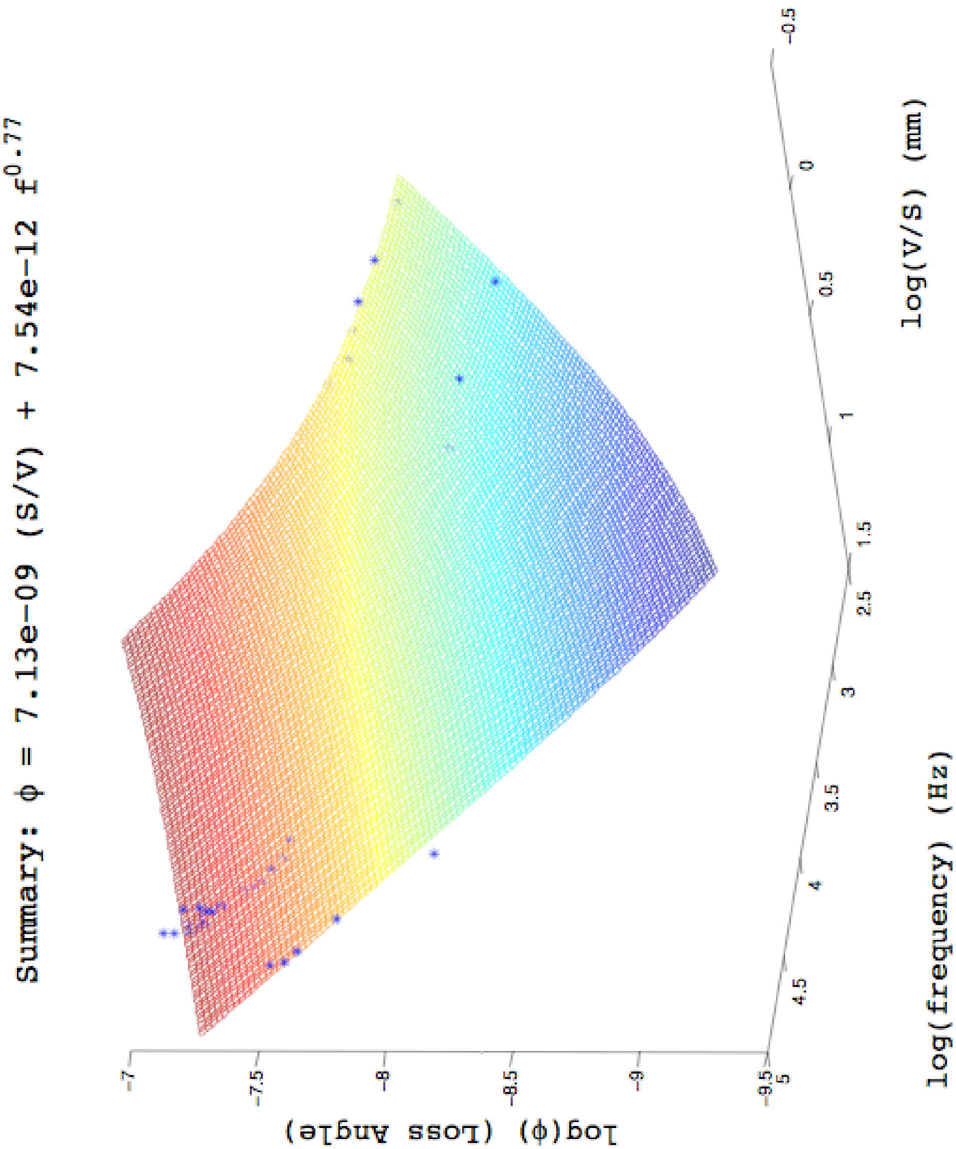
where *V/S* is in mm and *f* is in Hz. The benefits of the model are that it treats the loss as three separate mechanisms, avoiding any convolution of effects. The downside is that most data lie in a regime dominated by one of these loss mechanisms, thus making it difficult to test for variations in the fit coefficients. (For example: In the regime dominated by the frequency dependence the uncertainty in the surface loss coefficient is large.)

Statistics: The distribution of Q data, or phi, is not Gaussian. Systematic errors, which are the dominant error source, almost always reduce the Q. The distribution of measurements is strongly asymmetric and not modeled well by any commonly used parent distribution. Therefore the fitting methods which use Gaussian statistics will not work well in fitting the model for phi. Least-squares fitting and chi-squared minimization will **not** yield the best fit to the data. I am working on a fit method that uses Poisson distribution, which is the distribution that most closely resembles our data. The fits shown still use least squares fitting.

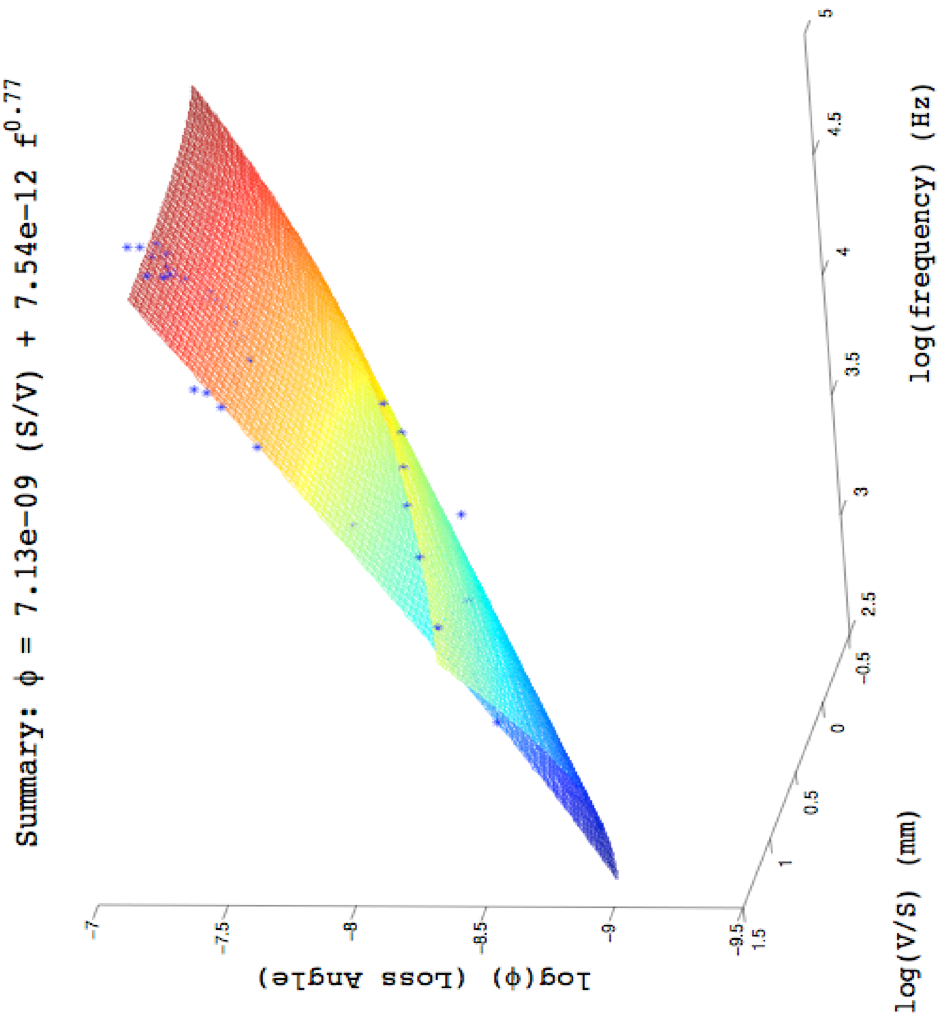
Surface loss mechanism: The surface loss mechanism will depend on the ratio of the energy in the surface to the energy in the volume for each mode. At present I am making the naïve assumption that the ratio is constant and proportional to the surface-to-volume ratio. Gregg has a student performing the FEM calculation of the energy ratio.

Silica Type dependence: The fit parameters depend of the variety of fused silica. Each plot shows only one variety of fused silica.

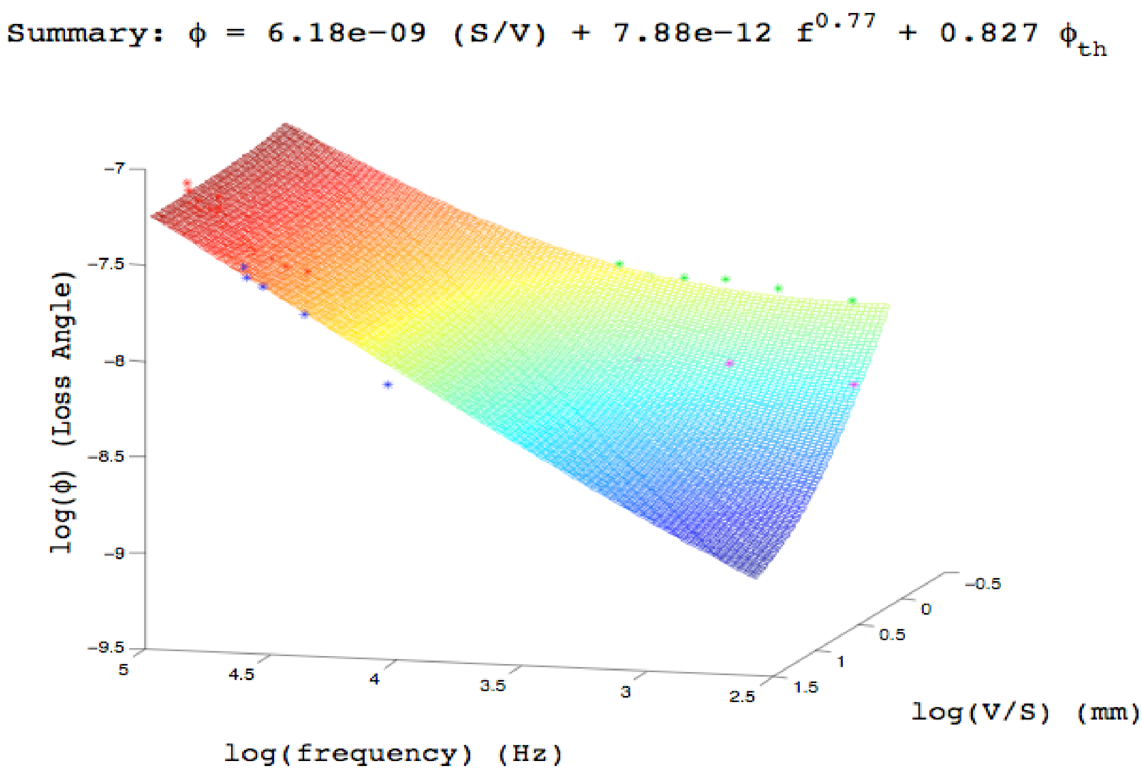
Suprasil 312: View 1



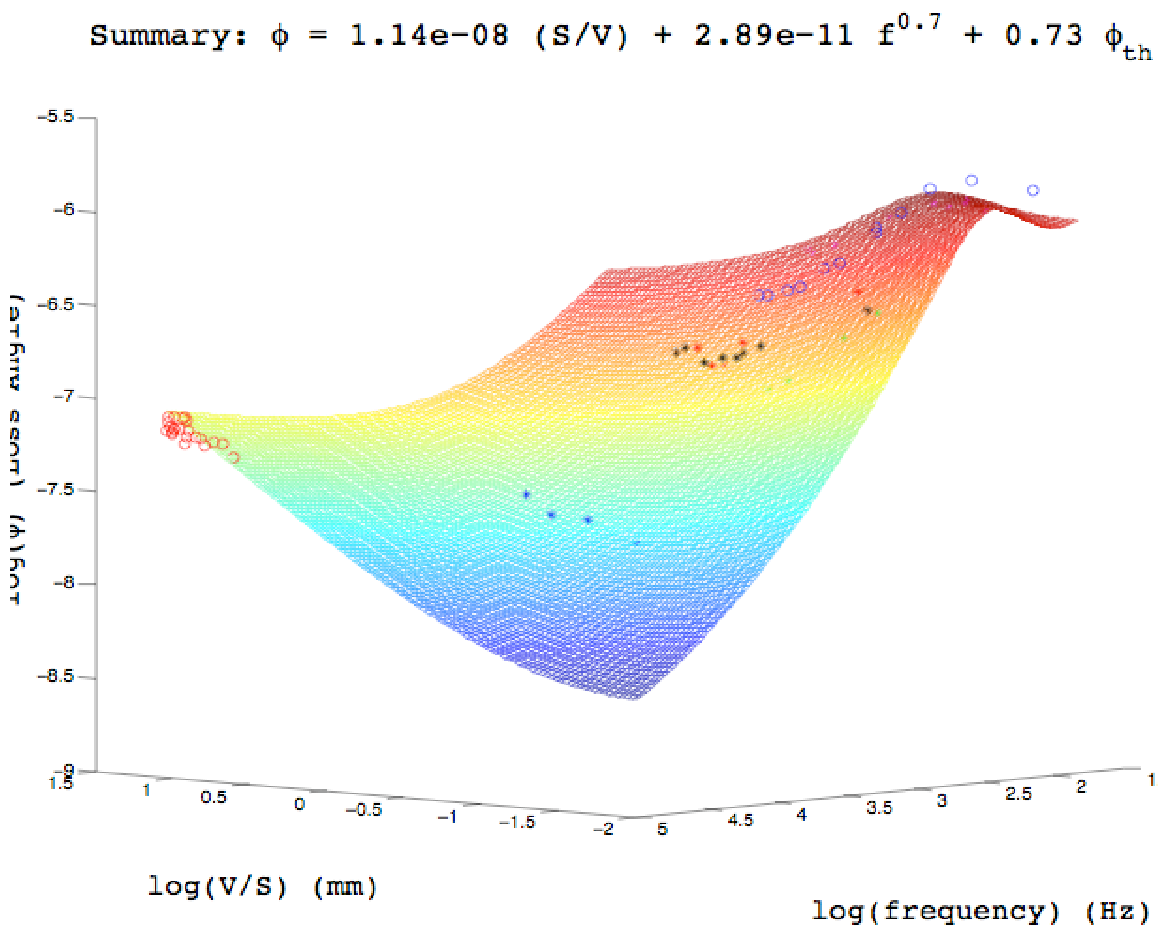
Suprasil 312 View 2



Suprasil312 View 3 with Thermoelastic peak



Suprasil 2


Summary: ϕ = 1.14e−08 (S/V) + 2.89e−11 $f^{0.7}$ + 0.73 ϕ_{th}
−5.5
−6
−6.5
−7
−7.5
−8
−8.5
−9
1.5
1
0.5
0
−0.5
−1
−1.5
−2
5
4.5
4
3.5
3
2.5
2
log(V/S) (mm)
log(frequency) (Hz)