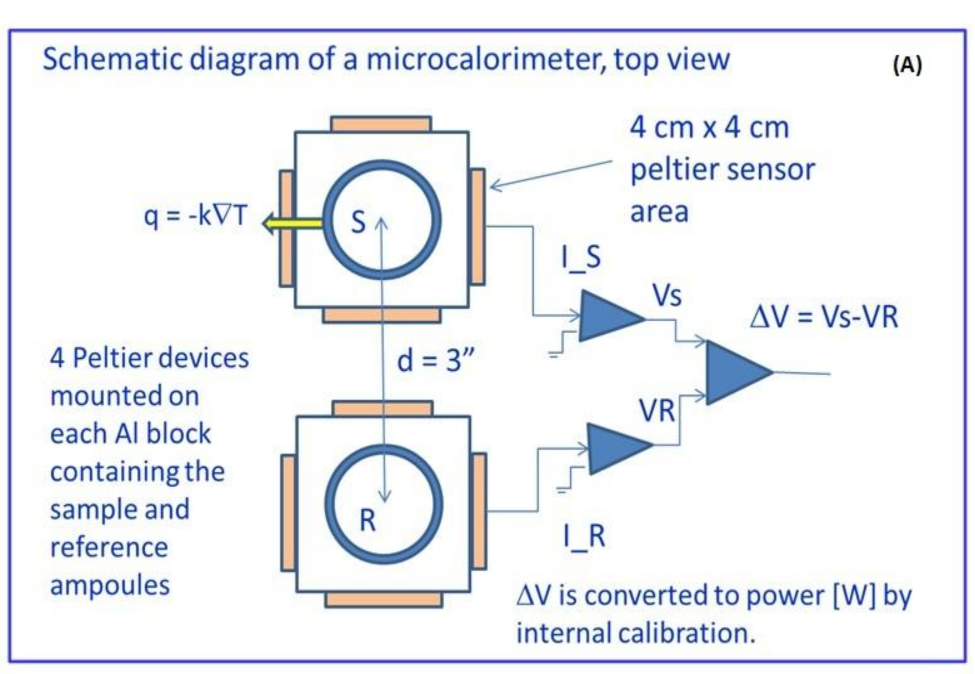
# Phase-sensitive Microcalorimetry for Study of Low-level Radioactive Sources

Heather Chen-Mayer and Ronald E. Tosh
NIST, Gaithersburg, MD 20899

**Introduction**: Microcalorimetry for standardizing activities of radionuclide samples entails measurements of input power heat flow from the sample cell with the radioactive sample present compared to the reference cell under balanced conditions (Fig. 1 A). The heating power from radioactive decays sources is in the μW range (taken as the product of activity and average decay energy, Fig. 1B), requiring high measurement sensitivity and drastic noise reduction, which may be achieved by employing phase-sensitive signal processing methods in the AC response to a periodic insertion of the source into the sample chamber. This study investigates the transfer function of the system at different excitation frequencies.




| Estimated heat power per unit activity (μW·GBq-1) | | | | |
|---|---|---|---|---|
| $^{3}H$ / $^{55}Fe$ | $^{103}Pd$ / $^{125}I$ | $^{32}P$ | $^{90}Sr$-$^{90}Y$ | $^{226}Ra$ |
| 0.9 | 9 | 111 | 181 | 4338 |

(B)

**Figure 1**. Principle of operation of a microcalorimeter (A) and radioactive decay power (B).

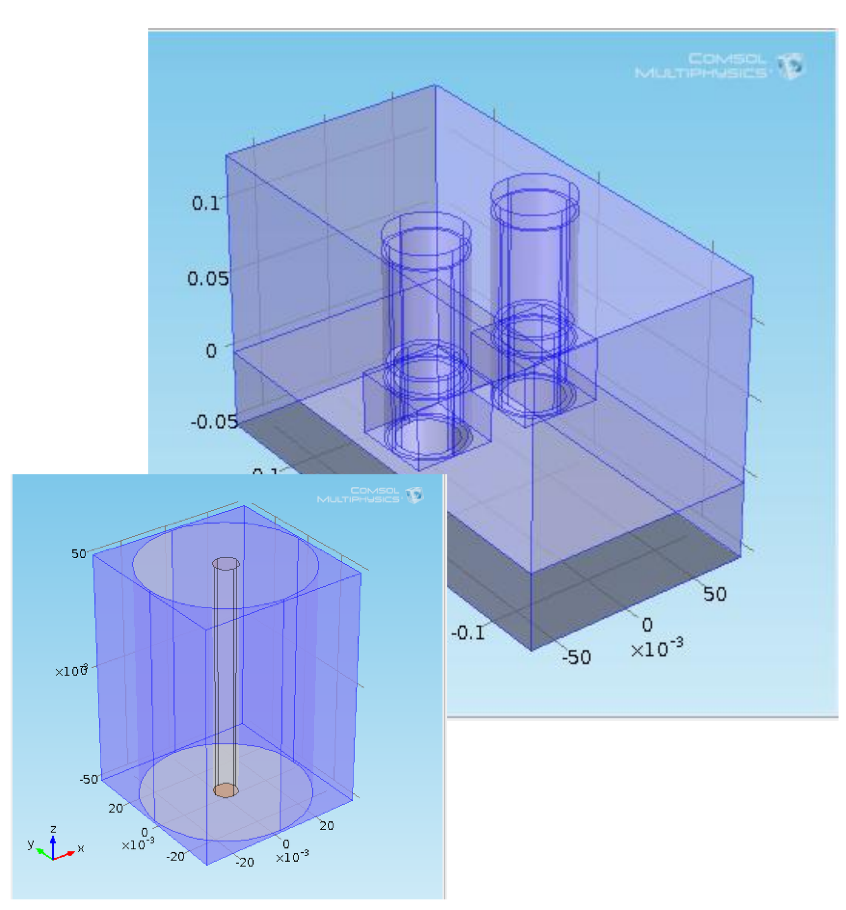
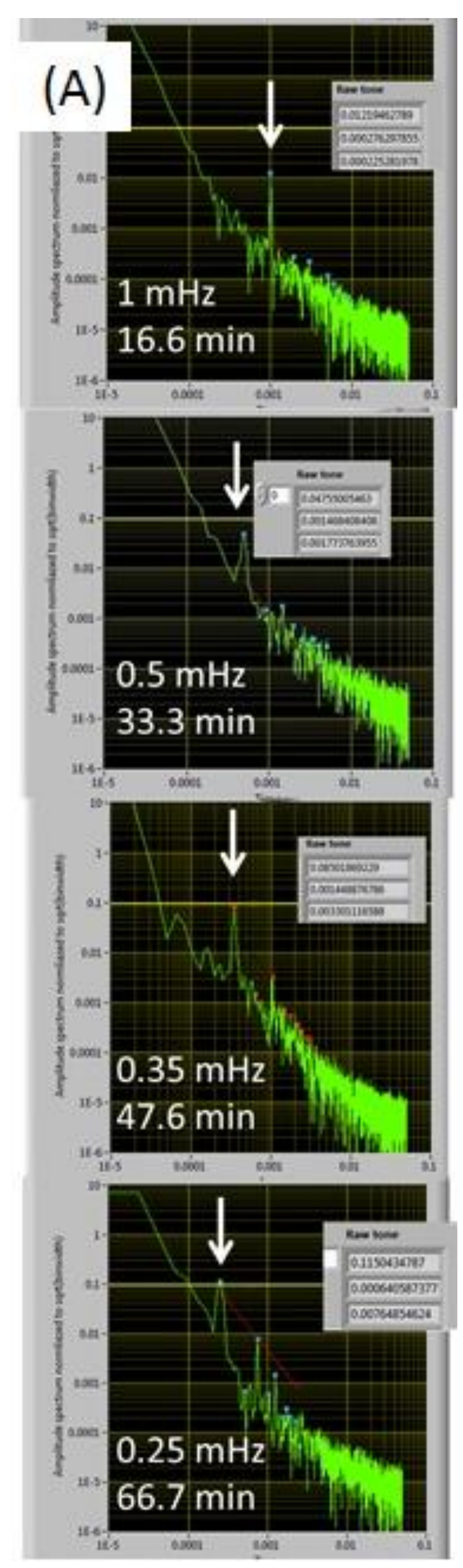


**Figure 2**. The full model based on the microcalorimeter (back) and the simplified section used for this study.

**Computational Methods**: Time dependent heat transfer in solids was simulated in a simplified 3D model (Fig. 2 foreground) of a commercial micro-calorimeter (TA Instruments) modified for the radioactivity applications. The transfer function of the system was experimentally determined previously using periodic electrical heating and frequency analysis (Fig. 3). The simulation attempts to reproduce this transfer function.

**Results**: The thermal transfer function is determined using the ratio of the signal peak amplitude at point of measurement to that at a point directly excited by the input power. Due to the system time constant, this ratio decreases as the frequency increases (or period decreases), as shown in Fig. 3. Also shown for comparison is simulation output that suggests unity gain should be possible to much higher frequency, suggesting poor thermal coupling of heating resistors might be limiting the experimentally observed response.



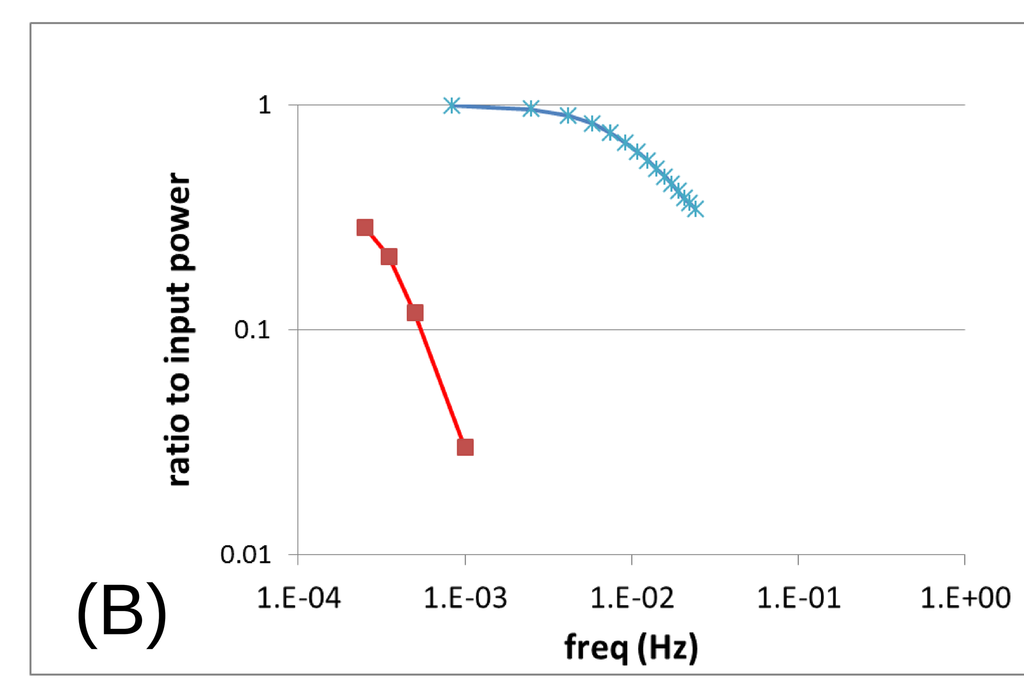




**Figure 3**. By varying the excitation frequency and measuring the instrument response in the Fourier domain (A), the system transfer function was experimentally determined (B red), and modeled for comparison (B blue).

**Conclusions**: Preliminary modeling of the system was carried out in a simplified model to assess the system time and frequency domain response to the heat source. The simulated transfer function will aid the experimental design to improve the instrument sensitivity and to allow precise measurements of radioactivity at very low levels.

***Disclaimer:*** *"Certain commercial equipment, instruments, or materials are identified in this paper in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose."*