THERMAL GRADIENT EXPERIMENTS ON THE CHARGE-DENSITY-WAVE CONDUCTION NOISE SPECTRUM.

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The firmest evidence supporting theories\textsuperscript{1,2} which ascribe the voltage oscillations (narrow-band noise) to phase-slippage at the ends of the sample come from experiments performed with the sample in a thermal gradient\textsuperscript{3,4}. In this short note we will review three classes of experiments which clarify different aspects of the problem. All experiments are done on high purity (RRR > 100) NbSe\textsubscript{3} in two-probe configuration, except otherwise indicated. Where appropriate we will stress experimental details and difficulties. See K. Maki, these proceedings, for theoretical details.

1.) MONOTONIC GRADIENT ON LONG SAMPLES. In these studies\textsuperscript{3} one of the sample ends A is held at a fixed temperature $T_A$ while the other B is incrementally scanned from $T_A$ to a higher value, usually exceeding the transition temperature $T_c \approx 59$ K. The sample lengths exceed 2 mm. When $\Delta T = T_B - T_A$ increases from zero the single fundamental frequency splits into two frequencies $f_1$ and $f_2$. If $T_A$ is well regulated then $f_1$ remains stationary while $f_2$ moves as $T_B$ is raised (Fig. 1.) Eventually as $T_B$ crosses $T_c$, $f_2$ decreases rapidly to zero, leaving $f_1$ as the sole frequency (Fig. 2.) In our studies a run was abandoned if the sample displays more than one fundamental frequency at zero $\Delta T$. In samples with poor contacts (or ones that have undergone numerous thermal cycling) several fundamentals are often seen even in nominally zero $\Delta T$. These are likely due to weakly-connected current paths near the contacts.

(Recall that the sample frays easily at the cut ends and that slightly different electric fields $E$ can induce different frequencies in independent fibers\textsuperscript{5}.) The different fundamentals clearly have nothing to do with behavior in a gradient.
Very often the spectrum can be cleaned up by applying fresh paint and cooling down again. Some clean samples will show a single fundamental at low current $I$ which then splits into two closely spaced frequencies at higher $I$ (in zero gradient.) These, again, are unrelated to the gradient results. The important point is that in a gradient one set of frequencies is static while a second set moves according to the hot end $T$. In particular, the second set decreases to zero when $T_B$ exceeds $T_c$. No frequencies with behavior different from these two sets are observed.

2) MONOTONIC GRADIENT ON SHORT SAMPLES. In these studies the samples (between 0.8 and 0.3 mm in length) were attached to copper wires which were anchored to sapphire substrates. Separate diode sensors and heaters on the two substrates enabled $T_A$ and $T_B$ to be independently regulated so that the sign of $\Delta T$ as well as its magnitude could be changed. (This was desirable because of the observation of frequency-locking in short samples.) Furthermore, because of the surprisingly large thermal conductance of short samples we had to attach secondary sensors made of NbSe$_3$ samples to the copper support wires. We found that a large fraction of the imposed $\Delta T$ occurs along the support wires so that $\Delta T$ across the sample itself is greatly overestimated without using the secondary sensors. Figure 3 shows an example of frequency-locking in a 0.6 mm sample. With end A clamped at 40 K the two frequencies $f_1$ and $f_2$ merge continuously as $T_B$ warms towards $T_A$. They stay locked until $\Delta T$ exceeds 2 K. Unlocking proceeds by a first-order jump. Such abrupt jumps are rare. We observed them in 2 out of 10 short samples examined. The linewidth narrows noticeably during the locking interval $\Delta T_L$ (Fig.4.) A sample displaying locking over a 10 K range is shown in Fig. 5. (Note that in this run in which secondary sensors were not utilised the hot end $T$ is badly overestimated.) In all 10 samples unlocking invariably occurs when the hot end exceeds 50 K, because the