We started with the circuit and board layout from the Vuletic group; Vladan tells us that the circuit was originally designed by Brent Young in the Chu group at Stanford. A known feature of the Young circuit is that operation above 85% of the maximum current set by the I_max trimmer results in noisy behavior. At first unaware of this feature and the known workaround of operating well away from I_max, we traced the frequency noise to a voltage resonance at 10-30 kHz on the LM317 output. The upside of our troubleshooting is that our improved circuit, even operating much closer to I_max, eliminates the 10-30 kHz noise. For our current laser this improvement corresponds to a frequency noise reduction from 70 kHz (operating well away from I_max) to 20 kHz (even operating very near I_max). Details below.

Our important modifications are:

- LM317 section:
  - Added a 22 uF bypass capacitor over the I_max trimmer as recommended in the LM317 datasheet.
  - Added a 5 Ohm, 22 uF tantalum low pass filter on the LM317 section output as in the original Libbrecht-Hall circuit.
  - Routed the low pass filter's output directly to R_sense as in the original Libbrecht-Hall circuit.
- Added ground planes. This reduced the broad noise from 10 kHz-100 kHz.

Other modifications and comments:

- The modulation section's resistor values and Mod_Offset limits are changed in order to provide 0-10 V to our particular PZT amplifier.
- We also note that INA217 instrument amplifiers can also be used for higher modulation currents; these amplifiers also have better behavior above 100 kHz.
- We added large capacitors and rectifier diodes to the current-controlling Op Amp’s power inputs as in the original Libbrecht-Hall circuit. Using test loads, we did not observe any signals that would be diode-damaging during power-loss; however, we have not tested power-loss behavior with a laser diode.

On a Scanning Fabry Perot cavity, the linewidth of the 85% of maximum current on the original layout and 95% of maximum current on the improved layout are limited by the SFP's linewidth of 2 MHz. Operating the original layout at 95% of maximum current results in a noticeably poor, non-fittable lineshape on the SFP sweep with features spanning up to 10 MHz.

For testing of the circuit beyond the 2 MHz resolution of the SFP, we used Rb polarization spectroscopy on the 85-Rb, F=3 line with a 400 kHz detection bandwidth. In the attached figures, we do not fully understand the origin of the spectrum analyzer noise-floor profile, but the roll-off behavior between 1-100 kHz is likely due to the SA’s interpretation of white noise injected after its high-pass input filter. Noise peaks below 4 kHz, being from acoustic or mechanical resonances of our ECDL's grating arm, are unimportant in this discussion. The first figure shows the laser frequency noise operating at 95% and 85% of maximum current with the original board layout. The second figure shows the improved design compared with the previous best case. For all scenarios, the transmission signal off resonance was at the noise floor, indicating no observable amplitude noise. Integrating the spectral noise density out to 400 kHz (with the mechanical resonances excluded from the integration) and subtracting off the noise floor in quadrature yields the following estimates on laser frequency noise and corresponding current noise (RMS values):

- Original, 95% of I_max: 470 kHz (890 nA)
- Original, 85% of I_max: 69 kHz (130 nA)
- Improved, 95% of I_max: 19 kHz (37 nA)