23: Number of Longitudinal Modes at Other HeNe Wavelengths

As described above, the gain bandwidth of neon is roughly inversely proportional to the wavelength (or proportion to the frequency) of the lasing transition. However, this assumes that the lasing threshold is at the same location relative to the peak of the neon gain curve, often specified as the Full Width Half Maximum or FWHM. At 632.8 nm, this turns out (not coincidentally!) to be reasonable and results in the expected number of lasing modes and mode sweep plots to go along with them.

For very low gain wavelengths like green (543.5 nm) and yellow (594.1 nm) – which may have 1/10th the gain or less compared to the common red (632.8 nm) wavelength, the lasing threshold will be far higher on the roughly Gaussian shaped gain curve, where it is narrower. So, while the FWHM of the neon gain curve may be slightly wider at these wavelengths, fewer modes will be oscillating because of the narrowing due to the higher lasing threshold. However, until the lasing threshold approaches the peak of the gain curve, the reduction in number of modes won't be that dramatic. And every effort is made to eliminate losses inside the cavity for these low gain lasers, so in fact, the lasing threshold may not even get that high relative to the peak during the expected life of the laser.

For very high gain wavelengths, the reverse will happen. There's really only one – the mid-IR transition at 3,391 nm which behaves more like a solid state laser with a gain over 40 times that of 632.8 nm. The lasing threshold will be much lower on the gain curve extending the useful region well out into the tails of the distribution. In this situation, many more modes could end up oscillating than would be accounted for by the much narrower FWHM of the neon gain curve of 315 MHz – roughly 1/5th the width compared to 632.8 nm. If calculations based solely on this small gain bandwidth were valid, a 75 cm 3,391 nm laser would have a similar number of longitudinal modes to a 14 cm 632.8 nm HeNe where there are only 1 or 2 active modes at any given time. Since 3,391 nm lasers much shorter than 75 cm are commercially available and don't have dramatic variations in output power with mode sweep, this must not be the case. For example, REO has one with a cavity length of less than 50 cm and maximum power variation of 5 percent, which implies that there are several longitudinal modes always present.

Here are results so far:

- **543.5 nm (green):** TBD.
- **594.1 nm (yellow):** TBD.
- **604.6 nm (orange):** TBD.
- **611.9 nm (orange):** TBD.
- **632.8 nm (red):** See other info below and in the sections starting with Inexpensive Home-Built Frequency or Intensity Stabilized HeNe Laser.
- **1,152 nm (near-IR):** TBD. Other than my rebuilt SP-119 laser head, a sample of one of these may be difficult to find. The only thing that can be said about the IR SP-119 is that it is short enough that lasing ceases entirely for a portion of the mode sweep.
- **1,523 nm (near-IR):** Initial testing of a Melles Griot 05-LIR-150 with a cavity length of 34.2 cm and a strategically placed magnet seem to show that its behavior is similar to that of a 632.8 nm laser with a cavity length of 20 or 25 cm. But, the amplitude of the two polarizations are not

equal implying that it is probably operating at least in part as a transverse Zeeman laser, which isn't that surprising given the magnet. However, with 3 strategically placed magnets, the behavior reverts back to what would be expected of a 633 nm tube of 20 or 25 cm with two pure orthogonally polarized modes separated by the longitudinal mode spacing of the tube are present for most of mode sweep with just a hint of a third mode when one is near the center of the neon gain curve. So, it would look like Longitudinal Modes of Random Polarized 1 mW IR (1,523 nm) HeNe Laser, which is the same diagram as Longitudinal Modes of Typical Random Polarized 1 mW HeNe Laser with different numbers.) See the section: Sam's Stabilized IR (1,523 nm) HeNe Laser for more on stabilizing this laser.

With my $2 SFPI modified for 1,5XX nm operation (replaced PD with cut-open germanium transistor photodiode), I have confirmed that the modes of the 05-LIR-151 are also similar in number and appearance to those of a 20 to 25 cm 632.8 nm laser. There are 2 modes most of the time with 3 appearing briefly when a mode is close to the center of the gain curve.

- **3,391 nm (mid-IR):** TBD, maybe.