28: Stabilized HeNe Lasers at Other Wavelengths

All types of schemes for stabilizing red (633 nm) HeNe lasers have been developed, but most of those that are commonly used in commercial stabilized HeNes are based on monitoring of one or both polarized modes in the output or waste beams and locking their position to the neon gain curve. For well behaved so-called "random polarized" 633 nm HeNe laser tubes, adjacent modes are generally orthogonally polarized. So, to assure a single mode (single frequency) output, the tube simply has to be short enough that at the lock position, either one mode or two polarized modes are present. In the latter case, a polarizer at the output can block the unwanted mode.

While it might be assumed that exactly the same approach could be taken for "other color" lasers, this turns out not usually be the case. The principle reason is that the nice behavior that has been counted on to keep the lasers well mannered may not be present. So while the tube will still have a pair of orthogonal axes of polarization, adjacent longitudinal modes will not necessarily be orthogonal and/or even have a consistent relative polarization - they may flip like a banshee.

So, where it is desired to implement a stabilized HeNe laser at other wavelengths (visible or IR), the polarization may be the primary issue, but there are a number of other complications including differences in the neon gain bandwidth and generally much lower power:

1. **Orthogonal polarization:** For the 633 nm HeNe laser, the Physics has cooperated (or Murphy took a millisecond off) with adjacent modes being orthogonally polarized. Since this is not necessarily true at other wavelengths, the use of a short tube may be required so that only a single mode is permitted at the lock point. For example, to assure that only a single mode can oscillate at 543.5 nm would require a tube less than about 12.5 cm in length, which would have an extremely low output power if it could be made to work at all - probably well under 0.1 mW.
2. **Neon gain bandwidth:** The width of the inhomogeneously-broadened neon gain curve depends on optical frequency and is roughly equal to [633 nm /(Lasing Wavelength) * 1.6 GHz + 100 MHz] where the addition uses the sum of the squares. For most purposes, Doppler broadening dominates and the added 100 MHz term can be ignored since its contribution will be small. Thus, the length of the tube must be selected based on wavelength to assure that only the desired number of longitudinal modes can oscillate. Of course, this may directly conflict with the need for output power! For example, at 633 nm, a tube with a cavity length of 225 mm (667 MHz mode spacing) will allow at most 3 longitudinal modes to oscillate. At 1,523 nm, the gain bandwidth will less than 1/2 of what it is at 633 nm and may be insufficient for even 2 modes to see enough gain, resulting in the output actually going off during part of mode sweep.

   However, FWHM or other definition of the gain bandwidth has to be adjusted depending on the actual gain and losses of the tube. For example, the mid-IR 3,391 nm line has a gain over 40 times that of the 633 nm red line, so the lasing threshold will be much lower effectively widening the gain curve. And the gain at 544 nm (green) is roughly 1/20th of that at 633 nm.

3. **Power output:** The gain and/or efficiency for most of the non-red wavelengths is much lower than for 633 nm. Normally, this can be handled using a longer tube. But that directly conflicts

with (1) for the green (543,5 nm), yellow (594.1 nm), and orange (604.6 or 611.9 nm) wavelengths since these tubes need to be shorter than even for red.

Various tricks may be used to stabilize HeNe lasers at other wavelengths but in general, it's often not as easy! Also see the section: A Stabilized HeNe Laser at 1,523 nm.