⑨ Testing of Stabilized HeNe Lasers

Whether dealing with a commercial stabilized laser, or one cobbled together from eBay parts, relatively simple tests can be done to determine how well it is working. Here's a fairly exhaustive list of tests, though for most applications, measurements on only a few of these will be necessary. Some of these may only be applicable once the laser has locked:

- **Output power:** This can be measured with a laser power meter having a silicon sensor or a power meter can be assembled that is suitable for most stabilized HeNe lasers for under $5. Thermal power meters are generally not sensitive or stable enough for low power measurements.
- **Beam parameters:** These include diameter, divergence, profile, M^2, pointing stability. A beam profiler is required for quantitative measurements, but for most purposes, a smooth symmetric profile by eye will suffice.
- **Polarization:** Orientation and purity. Most stabilized lasers produce either 1 linearly polarized component, or 2 that are orthogonal to one-another. A linear polarizer and SFPI can be used to determine the orientation(s) and confirm single frequency (purity). Where two orthogonal components are present, their optical frequency will differ by the longitudinal modes spacing. (Stabilized lasers that output only a single component will have blocked the other one internally). Since the mode spacing is determined by the laser tube cavity length, it's not usually necessary to measure it. But it would typically be done with an RF/microwave spectrum analyzer by beating (heterodyning) them together using a high speed photodiode behind a linear polarizer at 45 degrees to the polarization axes.

  For axial Zeeman lasers, there should be two orthogonal components each of which is single frequency, but differ by the split frequency. Since the split frequency is never higher than around 8 MHz, this can be checked with a fast photodiode behind a linear polarizer at 45 degrees to the polarization axes and an oscilloscope or frequency counter.

- **Longitudinal mode position and mode balance:** For two mode or axial Zeeman lasers, the modes should normally be equal. An SFPI can be used to these if one isn't blocked internally. The two modes should generally be equal in amplitude so they straddle NGC in non-Zeeman frequency stabilized lasers.

  For axial Zeeman lasers, they will be two close together to resolve with most SFPIs, but by using a linear polarizer to selectively block one or the other, their amplitudes can be tested.

- **Spatial mode (TEM00) purity:** Only HeNe laser tubes spec'd to be TEM00 will generally be used. However, the manufacturers' specifications often allow for a small percentage of higher order spatial modes (e.g., up to 5 percent), though it is rare to see anything significant.

- **Optical frequency purity:** This can be checking using an SFPI once the laser locks. There should be only a single peak present on an SFPI display of a non-Zeeman stabilized laser. For an axial Zeeman laser, the appearance on most SFPIs will be similar they typically cannot resolve optical frequency components closer than 20 MHz or so. In either case, there should be no other "rogue" or "runt" modes present in the display. For single frequency lasers, such a mode may simply be due to the output polarizer not being adjusted properly.
- **Optical frequency stability (fixed conditions):** While most of us do not have the facilities to actually measure the optical frequency directly, its slow variation can be inferred from the variation in amplitude by estimating the rate of change of optical frequency versus amplitude based on mode position. The time scale for this can be from microseconds to years.

  The relevant parameters will be the longitudinal mode spacing, maximum amplitude of the a single mode (isolated with a linear polarizer if necessary), and the estimated shape and width of the NGC. An SFPI can be used to determine the lock point and the NGC parameters. An estimate of the slope at the lock point can then be made and used to calculate change in optical frequency versus amplitude. Depending on the time scale of interest, either a laser power meter or biased photodiode and DMM, oscilloscope, or data acquisition system can be used to make the measurements.

- **Optical frequency stability (variable conditions):** The most important variables would be HeNe laser power supply input voltage (which affects the tube current) and ambient temperature (which may affect the lock point). Ambient pressure and humidity are not generally important (though they - along with temperature - do affect the wavelength for metrology applications).
- **Amplitude ripple and noise:** These will result both from the lasing process itself and ripple and noise in the tube current from the HeNe laser power supply. Testing would typically be done using a fast photodiode and oscilloscope or signal analyzer.
- **Susceptibility to back-reflections:** Most of these lasers are very sensitive to even a very low power beam returned directly to the laser tube. In some cases, even just placing a piece of transparent tape in the beam may be enough to return enough scatter to destabilize the laser. There's not much one can do to the laser to change this, but it will impact how the experimental setup is designed, possibly requiring one or even two Faraday isolators if back-reflections cannot be eliminated by orienting optics to be offset or at an angle.