2.1.3. HeNe Laser Overview

A helium-neon laser, typically called a HeNe laser, is a small gas laser with many industrial and scientific uses. The primary wavelength they are used at is 632.8 nm, in the red portion of the visible spectrum.

The gain medium of the laser is a mixture of helium and neon gases in a 5:1 to 20:1 ratio that is contained at low pressure in a sealed glass tube. The excitation source for these lasers is a high-voltage electrical discharge through an anode and cathode at each end of the glass tube. The optical cavity of the laser consists of a flat, high-reflecting mirror at one end of the laser tube and an output coupler mirror with approximately 1% transmission at the other end.

### HeNe Applications

- Metrology
- Cleanroom Monitoring Equipment
- Food Sorting
- Flow Cytometry
- Confocal Microscopy
- Imaging and Medical Equipment
- Opacity Monitoring
- Alignment
- Maritime Visual Guidance Systems

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#### Figure 1 Optical Resonator Cavity

![Optical Resonator Cavity Diagram](image)

**Typical HeNe Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Diameter (D)</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cavity Length (L)</td>
<td>0.15 m (0.5 mW) to 1 m (50 mW)</td>
</tr>
<tr>
<td>Reflectivity at High Reflector (HR)</td>
<td>&gt;99.99%</td>
</tr>
<tr>
<td>Transmission at Output Coupler (OC)</td>
<td>~1%</td>
</tr>
</tbody>
</table>

HeNe lasers tend to be small, with cavity lengths of around 15 cm up to 0.5 m and optical output powers ranging from 1 mW to 100 mW. Thorlabs offers output powers up to 22.5 mW.

2.1.4. HeNe Linewidth

A red HeNe laser wavelength is 632.816 nm in air, though it is often reported as either 632 nm or 633 nm. The wavelength gain curve is actually made of several longitudinal modes that fluctuate within the range due to thermal expansion of the cavity and other external factors.

The linewidth of a HeNe laser is specific to the application. The axial mode structure of the HeNe laser is characterized by the number of modes, the free spectral range (FSR), and the Doppler width (see Figure 2 on page 7). The linewidth of individual axial modes is usually small (~kHz) and is primarily determined by external factors and measurement timescales rather than fundamental laser parameters. In most interferometric applications, the most relevant parameter is the coherence length, which is determined by the axial modes that are furthest apart. For a red HeNe laser, the coherence length is approximately 30 cm.
The laser process in a HeNe laser starts with the collision of electrons from the electrical discharge with the helium atoms in the gas. This excites helium from the ground state to a long-lived, metastable excited state. Collision of excited helium atoms with ground-state neon atoms results in excited neon electrons.

The number of neon atoms entering the excited states builds up until population inversion is achieved. Spontaneous and stimulated emission between the states results in emission of 632.82 nm light along with other emission wavelengths. From these states, the electrons quickly decay to the ground state. The HeNe laser’s power output is limited because the neon upper level saturates with higher current, while the lower level varies linearly with current.
The laser cavity can be designed with the correct mirrors and length to promote other wavelengths of laser emission. There are infrared transitions at 3.39 µm and 1.15 µm wavelengths, and a variety of visible transitions, including a green (543.365 nm, sometimes called GreeNe laser), a yellow (593.932 nm), a yellow-orange (604.613 nm), and an orange (611.802 nm) transition. The typical red, 633 nm wavelength output of a HeNe laser actually has a much lower gain compared to other wavelengths, such as the 1.15 µm and 3.39 µm lines.

**HeNe Visible Laser Lines**

![HeNe Visible Laser Lines](image)

**Figure 4 HeNe Visible Laser Lines**

### 2.1.5. HeNe Polarization

**Unpolarized (Randomly Polarized) Beam**

The output of an unpolarized HeNe laser consists of a rapidly fluctuating, linearly polarized beam whose polarization orientation changes on a nanosecond time scale. Unpolarized lasers are ideal for applications where there are no polarizing elements in the beam path. Depending on the time scale of an application, large power fluctuations are possible.

**Linear Polarized Beam**

The state of polarization in a polarized HeNe laser beam is linear, making these lasers ideal for polarization-sensitive applications.