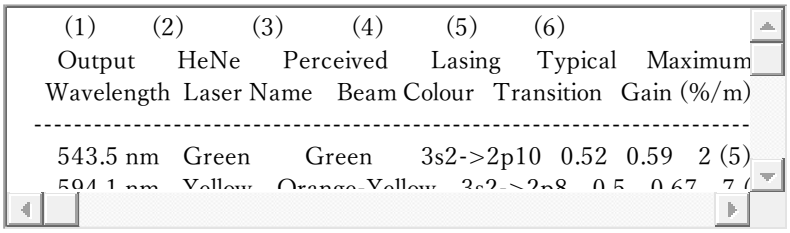
②Practical Wavelength

“Various IR lines will lase in pure neon, and even the 632.8 nm line will lase, but it takes a different pressure and a much longer tube. 632.8 nm also shows up with neon-argon, neon-oxygen, and other mixtures. Just about everything on the periodic table will lase, given the right excitation. See “The CRC Handbook of Lasers” or one of the many compendiums of lasing lines available in larger libraries. These are usually 4 volume sets of books the size of a big phone book just full of every published journal article on lasing action observed. It’s a shame that out of these many thousands and thousands of lasing lines, only 7 different types of lasers are under mainstream use.

There are many possible transitions in neon from the excited state to a lower energy state that can result in laser action. (Only the three found most commonly in commercial He-Ne lasers are shown in the diagram, above.) The most important (from our perspective) are listed below:



	(1) Output Wavelength	(2) HeNe Laser Name	(3) Perceived Beam Colour	(4) Lasing Transition	(5) Typical Gain (%/m)	(6) Maximum Power (mW)
1	543.5 nm	Green	Green	3s2->2p10	0.52	0.59 2 (5)
2	594.1 nm	Yellow	Orange-Yellow	3s2->2p8	0.5	0.67 7 (10)
3	604.6 nm		Orange	3s2->2p7	0.6	1.0 3
4	611.9 nm	Orange	Red-Orange	3s2->2p6	1.7	2.0 7
5	629.4 nm		Orange-Red	3s2->2p5	1.9	2.0
6	632.8 nm	Red	" "	3s2->2p4	10.0	10.0 75 (200)
7	635.2 nm		" "	3s2->2p3	1.0	1.25
8	640.1 nm		Red	3s2->2p2	4.3	2.0 2
9	730.5 nm		Border Infra-Red	3s2->2p1	1.2	1.25 0.3
10	886.5 nm		" "	2s2->2p10	1.2	1.25 0.3
11	1,029.8 nm	Near-IR	Invisible	2s2->2p8	???	
12	1,062.3 nm	" "	" "	2s2->2p7	???	
13	1,079.8 nm	" "	" "	2s3->2p7	???	
14	1,084.4 nm	" "	" "	2s2->2p6	???	
15	1,140.9 nm	" "	" "	2s2->2p5	???	
16	1,152.3 nm	" "	" "	2s2->2p4	???	1.5
17	1,161.4 nm	" "	" "	2s3->2p5	???	
18	1,176.7 nm	" "	" "	2s2->2p2	???	
19	1,198.5 nm	" "	" "	2s3->2p2	???	
20	1,395.0 nm	" "	" "	2s2->2p?	???	0.5
21	1,523.1 nm	" "	" "	2s2->2p1	???	1.0
22	3,391.3 nm	Mid-IR	" "	3s2->3p4	???	440.0 24

Notes:

Output Wavelength is approximate. In addition to slight variations due to actual lasing conditions (single mode, multimode, doppler broadening, etc.), some references don't even agree on some of these values to the 4 or 5 significant digits shown.

He-Ne Laser Name is what would be likely to be found in a catalogue or spec. sheet. All those that have an entry in this column are readily available commercially.

Perceived Beam Colour is how it would appear when spread out and projected onto a white screen. Of course, depending on the revision level of your eyeballs, this may vary someone from individual to individual.

Lasing Transition uses the so-called "Paschen Notation" and indicates the electron shells of the neon atom energy states between which the stimulated emission takes place.

Typical Gain (%/m) shows the percent increase in light intensity due to stimulated emission at this wavelength inside the laser tube's bore. This is the single pass gain and will be affected by tube construction, gas fill ratio and pressure, discharge current, and other factors. The first column is from various sources. The second column is from Hecht, "The Laser Guide Book". However, a newer text: Mark Csele, "Fundamentals of light sources and lasers" (ISBN 0-471-47660-9, Wiley-Interscience, 2004) lists the typical gain as 1.2 to 1.5 at 633 nm. And measurements by myself and others seem to show that this slightly higher value may be more accurate, at least under some conditions.

Gain at 1,523 nm may be similar to that of 543.5 nm – about 0.5%/m. Gain at 3,391 nm is by far the highest of any – possibly more than 100%/m. I know of one particular He-Ne laser operating at this wavelength that used an OC with a reflectivity of only 60% with a bore less than 0.4m long. Yet, the output power of the largest 3,391 nm commercial He-Ne laser is still only a fraction of that at 632.8 nm.

Maximum Power shows the highest output power lasers commercially available in a TEM00 beam for each wavelength. The first number is rated power while the number in () is achieved output power for a particularly lively tube. Lasers operating with multiple (spatial) modes (non-TEM00) may have somewhat higher output power.

The most common and least expensive He-Ne laser by far is the one called 'red' at 632.8 nm. However, all the others with named 'colours' are readily available with green probably being second in popularity due to its increased visibility near the peak of the of the human eye's response curve (555 nm). And, with some He-Ne lasers with insufficiently narrow-band mirrors, you may see 640 nm red as a weak output along with the normal 632.8 nm red because of its relatively high gain. There are even tunable He-Ne lasers capable of outputting any one of up to 5 or more wavelengths by turning a knob. While we normally don't think of a He-Ne laser as producing an infra-red (and invisible) beam, the IR spectral lines are quite strong – in some cases more so than the visible lines – and He-Ne lasers at all of these wavelengths (and others) are commercially available.

The first gas laser developed in the early 1960s was an HeNe laser operated at 1,152.3 nm. In fact, the IR line at 3,391.3 is so strong that a HeNe laser operating in 'superradiant' mode – without mirrors – can be built for this wavelength and commercial 3,391.3 nm HeNe lasers may use an output mirror with a reflectivity of less than 50 percent. Contrast this to the most common 632.8 nm (red) He-Ne laser which requires very high reflectivity mirrors (often over 99 percent) and extreme care to minimize losses or it won't function at all.