V61 He-Ne laser

Abstract

This experiment gives an overview of the characteristics of an He-Ne Laser (**L**ight **a**mplification of **s**timulated **e**mission of **r**adiation). To do this the He-Ne laser is adjusted and the properties of the laser radiation are measured (i.e. wavelength, intensity distribution, polarisation and mode spectrum). The influence of the resonator length and type of mirrors on the stable function of the laser is also checked.

References

[1] W. Demtröder, *Laser Spectroscopy 1: Basic principles*, Springer (2014)

[2] H. J. Eichler, J. Eichler and O. Lux, *Lasers (Basics, Advances and Application)*, Springer (2018)

[3] B. E. A. Saleh and M. C. Teich, *Fundamentals of Photonics*, Wiley (2008)

Preparation

For sucessful processing of the experiment, it is necessary to know the elementary basics of lasers. You should be able to answer the following guiding questions.

- What are the three basic components of the laser? What defines the wavelength of a laser?
- Discuss the most important processes in the active medium (absorption, stimulated emission and spontaneous emission). Discuss the relationship between the amplification of the light and the population inversion in the active medium.
- Why is a two-level laser not possible? Which transition is responsible for the red line of the He-Ne laser? How is the population inversion achieved?
- Calculate the stability parameter $g_1 \cdot g_2$ as a function of the resonator length L for at least two resonator configurations and plot the result. The available mirror configurations can be found in Table 1. What is the maximum resonator length that can be achieved?
- Describe the intensity curve in the plane perpendicular to the propagation direction for TEM_{00} and TEM_{01} modes. Explain the term “intracavity aperture for mode selection”. What is the difference between longitudinal and transversal modes?
- Describe the broadening of the optical transition in gas due to the Doppler effect. How large is the spectral broadening for the optical transition in Ne gas at room temperatur? Describe the mode spectrum (frequency spectrum) for the laser with typical resonator length $L = 1.5\ m$. How does mode selection work with the help of a Fabry-Perot etalon?

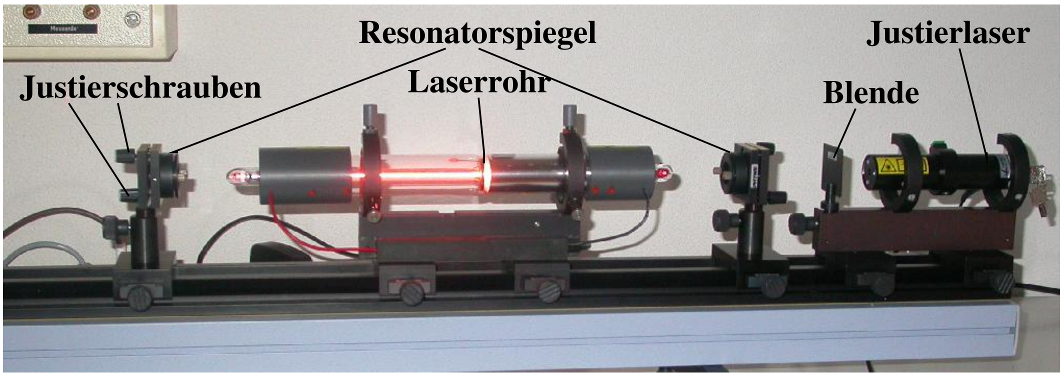

Figure 1: Experimental setup

- The laser under investigation is equipped with Brewster windows fitted to the end of the laser tubes. What is the role of the Brewster windows? What is the resulting polarisation of the laser?

Attention! Class 3B laser!
Do not look into the laser beam!
Wear protective glasses!

Experimental setup and Alignment

The experimental setup is shown in Figure 1. An auxiliary alignment laser ($\lambda = 532\ nm$, $P_{max} = 1\ mW$) with a reduced laser power[1] of $P_{green} = 0.2\ W$. To set up and adjust the He-Ne laser, the aligment laser beam must first properly adjusted. For this purpose, a target screen with the hole marked with cross can be positioned directly behind the alignment laser and at the end of the optical bench. If the auxiliary laser meets the holes of the target screens and positioned in the center of the crosses, then its beam coincidences with the optical axis of the main He-Ne laser, the green He-Ne laser is aligned with the optical axis. The actual He-Ne laser consists of a laser tube and two highly reflective mirrors that form the laser resonator. The laser tube (length $l = 408\ mm$ and diameter $d_{HeNe} = 1.1\ mm$) is filled within a He-Ne gas mixture and equipped with electrodes so that an inversion can take place by means of discharge. Brewster windows are located at the ends of the laser tube to achieve a defined polarisation direction with as little loss as possible. Four different mirrors (diameter $D_{mirror} = 12.7\ mm$) are available as resonator mirrors with which you can construct an optical resonator.

To measure the laser properties (e.g. polarisation, beam diameter or wavelength), various components are available (e.g. photodiode, powermeter, gratings, slit, micrometer screw or polariser) that you can place in the beam path of the laser.

[1] To obtain full power, you must press the green button on the laser. However, the reduced power is quite sufficient for adjustment.

Mirror	Design	Surface
plan	flat/flat	HR (high reflectivity) $R \geq 99\%$
concave	$r = 1000\ mm$/flat	HR (high reflectivity) $R \geq 99\%$
concave	$r = 1400\ mm$/flat	HR (high reflectivity) $R \geq 99\%$
concave	$r = 1400\ mm$/flat	OC (out coupling) $T = 1.5\%, ..., 1.8\%$

Table 1: Description of the available mirrors

Measurements and analysis

- **Alignment of the He-Ne laser:** Place the alignment laser with the two diffraction diaphragms on the optical rail so that the diaphragms are the maximum distance apart. Adjust the alignment laser with the 6 screws so that the beam meets the holes of the target screens and positioned in the center of the crosses. Now place the resonator mirrors (see Figure 2a,2b) and the laser tube (see Fig. 2c) on the optical rail one after the other and make sure the proper alignment for each component individually, i.e. the back reflections of the alignment laser from each of the mirrors hits the target screens in the center of the cross, while for the laser tube the alignment laser passes without any distortions. (Note: Use the opposite aperture as well. A good pre-alignment is important in order to be able to use the laser afterwards!) Place all components (gas tube and resonator mirrors) on the optical bench and switch off the alignment laser (see Figure 2d). Set the current of the high voltage to $I = 6.5\ mA$. The laser tube will glow red due to the discharge. Normally, however, no laser activity stats yet. To do this, you must **carefully** readjust the adjustment screws of the resonator mirrors. When the laser starts to work, you will see a red beam between the Brewster window and the resonator mirrors. If this is not the case even after some time, you did not worked carefully enough during the pre-adjustment and you have to start the whole procedure again from the beginning.

- **Check the stability condition:** Adjust the laser to the maximum power using a photodiode. Set the maximum possible resonator distance. To do this, increase the distance between the two laser mirrors while the laser is running; do not forget to readjust the laser power. With good adjustment, they should almost reach the theoretical value from the stability condition. Repeat the measurement for another resonator. Consider the reason for the loss of stability.

- **Observing TEM modes:** Try to **observe** as many **TEM modes** as possible. Stabilise and identify different modes. To stabilise the modes, a thin tungsten wire ($d = 0.005\ mm$) is placed between the resonator mirror and the laser tube and shift in such a way that different modes can be identified on an optical screen. To recognise the modes you have to enlarge the beam diameter of the laser with the help of a scattering lens. What is the function of the wire? Replace the optical screen with a photodiode and measure the intensity distribution of at least two modes. Plot the measured intensity distributions in a diagram and fit the theoretical distribution to the experimental data.

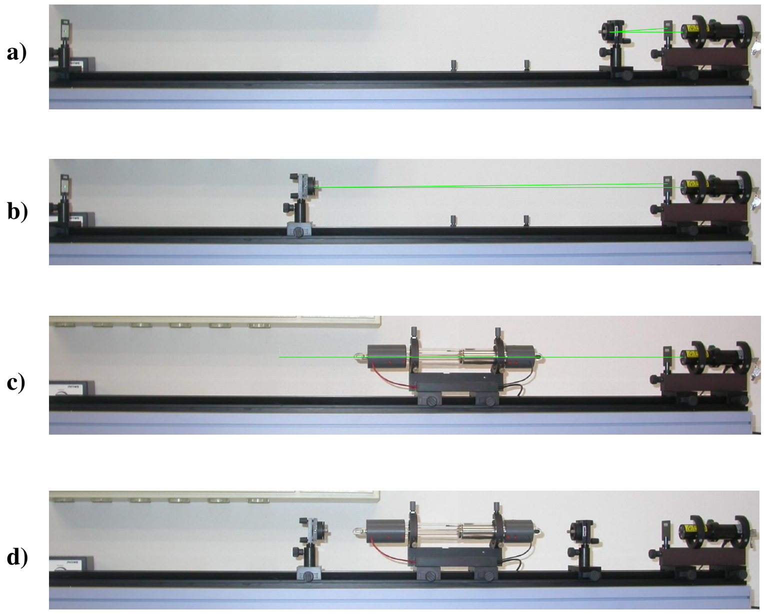

Figure 2: Alignment of the He-Ne laser.

- **Determining the polarisation:** Place a polariser behind the outcoupling mirror and measure the intensity with a photodiode as a function of the polarisation direction. Explain why Brewster windows lead to polarised laser emission and compare the measured intensity distribution with the theoretically calculated one. What influence do the resonator mirrors have on the polarisation of the laser?

- **Multimode operation and frequency spectrum of the laser:** Without Fabry-Perot etalon, the laser runs in multimode operation. This means that there are several longitudinal modes that lead to beating in the temporal dependence of the laser intensity. To measure these beat frequencies, take a fast photodiode (bandwidth up to 1 GHz) and measure the Fourier spectra for different resonator lengths L with the help of the spectrum analyser. In the protocol, compare the spread of the neon transition with the distance between the longitudinal modes. Justify the multimode operation. Describe the dependence of the beat frequency on the resonator length.

- **Determining the wavelength:** Determine the wavelength of the He-Ne laser from the diffraction maxima and diffraction minima of a slit and a grating, respectively.