Setting Up a He-Ne Laser

Experiment Objective

- Setting up a He-Ne laser made out of individual components
- Optimising the laser power by means of a “Beam walk”

Principles

Invented in 1961, the helium-neon gas was the first continuous-wave laser in the world. On account of its visible emission line at 632.8 nm, it is still among the most common lasers.

Essentially, a laser consists of three components:

- An active medium, in which a population inversion is produced in one or several energy levels by means of an energy supply.
- An energy pump (e.g. flashbulb, gas discharge) that produces this population inversion.
- An optical resonator that stores the radiation emitted by the active medium and drives it back into the active medium. There, radiation is amplified by stimulated emission until amplification in the active medium and losses in the resonator are of the same magnitude.

The helium-neon laser is a four-level laser. A mixture of He and Ne gasses (in a 7:1 ratio approx.) at a total pressure of a few millibar serves as an active medium. The energy supply is provided by a gas discharge that is ignited in a thin glass capillary. He and Ne atoms are excited by an electron collision. There are two metastable states in helium, the 2^1s and the 2^3s state (see Fig. 1). Therefore, a high population density of He atoms in these states is built up in the discharge.

These energy levels almost match energy levels 5s and 4s in the Ne atoms. Hence, through these collisions a very efficient energy can be transferred from the excited He atoms to the Ne atoms (type 2 collisions). In this way, a population inversion is produced in the Ne atoms. It is possible to have different optical transitions into deeper levels such as 4p and 3p from energy levels 5s and 4s. All four levels are repeatedly decomposed, so that a vast number of possible laser transitions result. The transition between one of the 5s states and one of the 3p states at 632.8 nm (1.96 eV) is the most well known. Levels 4p and 3p are depopulated into the 3s state by means of spontaneous transitions. From there, atoms jump into the ground state through wall collisions.

In the experiment, the optical resonator is made up of two mirrors whose dielectric coating is optimised for λ = 632.8 nm: a highly reflecting plane mirror (HR) with a reflectivity R > 0.995 and an output mirror (OC) with a reflectivity R = 0.99.

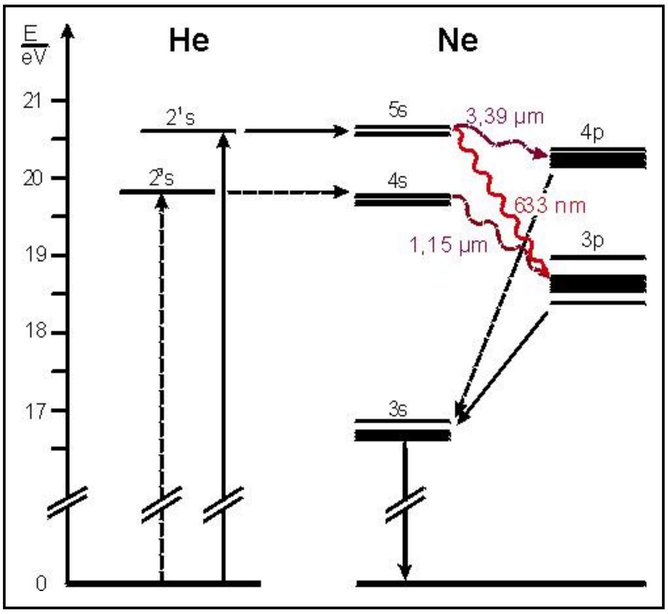

Fig. 1: Schematic representation of energy levels in helium and neon involved in the laser process

On one hand, the maximum power output depends on the amplification in the active medium. On the other hand, the output power also depends on losses in the resonator. So, output power is a function of the form, position, and orientation of the mirror and the tube (see also P5.8.1.3 ff.). Maximum power output can’t always be achieved by simply optimising the mirror orientation. However, this problem can be managed using the “Beam walk” method, in which the position of the final mirror is modified step by step. This also gives access to new resonator modes. In this way, a global power maximum can be found.

CS-0707

Apparatus

1 Basic Set "He-Ne Laser" 471 810
1 Optical bench, 2 m, standard cross section 460 33
1 Iris diaphragm in holder..................................... 460 26
1 Lens in holder, f = 50 mm................................. 460 02
1 STE Photoelement BPY 47 .... 578 62
1 Holder for plug-in elements 460 21
2 Connection lead, Ø 1 mm², 100 cm, black 500 444
1 Multimeter LDanalog 20 .... 531 120
1 Screen... 441 531

Additionally recommended:
Adjustment goggles for He-Ne laser 471 828

Safety Notes

Important: Make sure you also follow the instructions provided with the equipment!

The installed He-Ne laser complies with the Class 3B regulations according to DIN 60825-1 "Safety of Laser Products". Lasers belonging to Class 3B are potentially dangerous if a direct or mirror-reflected beam reaches the unprotected eye (directly looking at the beam).

- Do not look at the direct or reflected laser beam!
- Avoid unintentional mirror-reflections (e.g. through watches, jewellery, tools with metallic surfaces)!
- Block all laser beams by placing an absorbing or diffuse scattering material at the end of the purpose-related beam path.
- Wear laser adjustment goggles (471 828) if necessary.

The laser tube requires voltages >12 kV to ignite the gas discharge and contact-hazardous voltages of up to 2.5 kV for operation.

- The connection to the supply device should only be established through the high voltage plugs.
- Wiring and changes in the experiment setup should only be carried out when the supply device is switched off.
- The supply device should only be switched on when the circuit is completed.

The laser diode complies with the Class 2 regulations according to DIN 60825-1 "Safety of Laser Products". If you follow the corresponding hints in the instruction sheets, experimenting with the laser diode is harmless.

- Do not look at the direct or reflected laser beam.
- Avoid crossing the threshold line of glare (i.e. none of the observers should feel dazzled).

Preliminary remarks

The experiment only succeeds when the setup is thoroughly adjusted and all optical surfaces are free of impurities. Cleaning a precision optics system always represents a risk for the surface. In order to reduce the need to clean the optics as much as possible, they should be preserved in their original packing or they should be covered with a protective cover in their support when they are not in use.

During the experiment, take measures to avoid damaging any mirror surfaces (including the rear side of the output mirror) and the Brewster window of the laser tube.

- *Do not touch them with your bare hands.*
- *Immediately remove any fingerprints, or oil or water stains, because the skin acids attack the coating on the glass and permanent stains can be left behind.*

If cleaning is necessary, it is advisable to use one of the methods recommended in the instruction sheets.

Setup and Method

In the pictures below, the left edge position of the optics rider is given, in cm, for each element respectively.

a) Adjusting the alignment laser

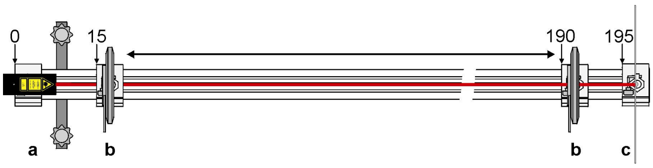

Fig. 2: Setup for adjusting the laser alignment

a Laser diode
b Iris diaphragm
c Screen

- Attach the laser diode (**a**) to an optics rider at the beginning of the optical bench
- Attach the screen (**c**) to an optics rider at the end of the optical bench
- Attach the iris diaphragm (**b**) to an optics rider directly behind the laser diode (**a**). Adjust the height of the iris diaphragm (**b**) to the desired beam height. From now on, **don't** modify the height of the iris diaphragm (**b**) any more!
- Switch on the laser diode (**a**).
- Adjust the height and alignment of the laser diode (**a**) in the optics rider, so that the laser beam passes centred through the iris diaphragm (**b**).
- Slide the iris diaphragm (**b**) in front of the screen (**c**) and secure it.
- Using the adjusting screw at the top of the laser diode (**a**) calibrate the vertical deflection of the laser diode (**a**) so that the beam is also passing through the centre of the iris diaphragm (**b**). If necessary, adjust the lateral deflection by carefully turning the laser diode (**a**).
- Once more, slide the iris diaphragm (**b**) in front of the screen (**c**) and secure it, without changing its height.
- If necessary, repeat the last four steps several times until the laser diode's (**a**) beam passes through the exact centre of the iris diaphragm (**b**) at both ends.
- From now on, **don't** modify the position and alignment of the laser diode (**a**) any more!

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b) Adjusting the laser tube

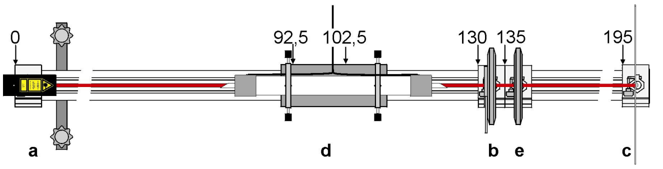

Fig. 3: Setup for adjusting the laser tube

a Laser diode
b Iris diaphragm
c Screen
d Laser tube in laser support
e Lens in holder, f = 50 mm

- Attach the laser support with two optics riders at the centre of the optical bench.
- Attach the laser tube (**d**) in the centre of the laser support, so that the Brewster window faces away from the observer. The strong reflections from the Brewster window are then reflected away from the observer.
- Adjust the height of the laser support so that the Brewster window facing the laser diode (**a**) is at the height of the alignment laser beam.
- Set the alignment iris diaphragm (**b**) about 10 cm behind the Brewster window that faces the screen. Mount the lens in holder f = 50 mm (**e**) behind the alignment iris diaphragm.
- Completely loosen the upper locking screws of the laser support; any further adjustment is done with the lower locking screws.
- With the screws pointing to laser diode (**a**) adjust the laser tube (**d**) so as to impact the Brewster window approx. at its centre.
- With the screws pointing toward the screen, adjust the laser tube (**d**) so that the light from the laser diode (**a**) passes through the capillary of the laser tube (**d**). Readjust the screws pointing to the laser diode (**a**) if necessary.
- As long as the laser beam is not going through the centre of the capillary, a noticeable deformation and deflection of the laser beam is produced due to diffraction at the capillary (Figure 4, left).
- By gradually readjusting the laser support's screws, align the laser tube (**d**) so that the laser beam goes centred through the alignment iris diaphragm. Next, carefully optimise the adjustment so that the laser beam profile is symmetrical on the screen (Figure 4, right) and the laser beam also passes centred through the alignment iris diaphragm (**b**).
- From now on, **don't** modify the position and alignment of laser tube (**d**) any more!

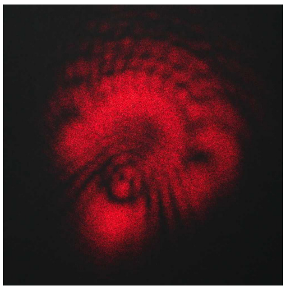
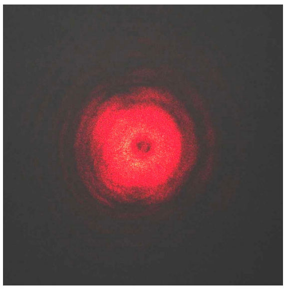

Fig. 4: Picture of the laser beam behind the capillary in cases of a misaligned laser tube (left) and a well-aligned laser tube (right).

c) Adjusting the right resonator mirror

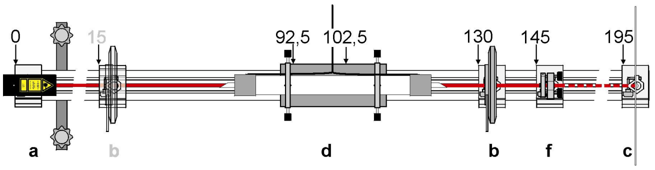

Fig. 5: Setup for adjusting the right resonator mirror

a Laser diode
b Iris diaphragm
c Screen
d Laser tube in laser support
f Output mirror OC, R = -1000 mm

- Remove the lens (f = 50 mm) in holder (**e**)
- Mount output mirror OC with R = -1000 mm (**f**) in the mirror holder and attach it behind the Brewster window of the laser tube (**d**) that faces the screen. The reflecting side points to the laser tube (**d**). Adjust the height of the mirror holder so as to impact the output mirror (**f**) at its centre.
- Using the fine adjustment screws of the mirror holder, align the output mirror (**f**) so that the reflected laser beam again passes centred through the alignment iris diaphragm (**b**), i.e. it should be reflected back at itself as much as possible.
- Set the alignment iris diaphragm (**b**) directly in front of the laser diode (**a**).
- Optimise the alignment of the mirror holder so that the reflected laser beam passes centred through the iris diaphragm (**b**).
- Remove the alignment iris diaphragm (**b**).

d) Adjusting the left resonator mirror

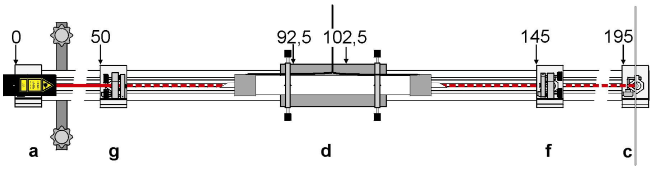

Fig. 6: Setup for adjusting the left resonator mirror

a Laser diode
c Screen
d Laser tube in laser support
f Output mirror OC, R = -1000 mm
g Highly reflecting plane mirror HR

- Mount the highly reflecting plane mirror (**g**) in the mirror holder and attach it in front of the Brewster window of the laser tube (**d**) that faces the laser diode (**a**). The reflecting side points to the laser tube (**d**). Adjust the height of the mirror holder so as to impact the plane mirror (**g**) on the centre.
- With the fine adjustment screws of the mirror holder, align the plane mirror (**g**) so that the laser beam coming from the laser diode **(a)** is reflected back at the rear side of the mirror towards laser diode (**a**).
- Switch off the laser diode (**a**).

d) Ignition of the gas discharge

Warning:

From now on, contact-hazardous voltages are present in the laser tube!

The laser radiation emitted by the built-in laser can be potentially dangerous after igniting the gas discharge!

- Connect the laser tube's (**d**) high voltage plugs firmly to the power supply. Do not move the laser tube in the process.
- Switch on the power supply by turning the key-operated switch. The gas discharge ignites after 5 seconds. Laser activity should start with more or less intensity. This should be recognised, for example, from the red points on the mirror surfaces.
- If laser activity is visible: Go on to point e) Performance optimization.
- If no laser activity is detected:
  - Carefully turn the upper fine adjustment screw of the mirror holder (**g**) in both directions. If laser activity is visible: Go on to point e) Performance optimization.
  - If laser activity is still not detected: Turn back the fine adjustment screw to the starting point. Carefully, turn the lower fine adjustment screw of the mirror holder (**g**) in both directions. If laser activity is visible: Go on to point e) Performance optimization.
  - If no laser activity is detected: Turn back the fine adjustment screw to the starting point. Repeat the previous steps with the mirror holder (**f**).
- If laser activity is still not detected: Repeat the adjustments from the beginning. Position the highly reflecting plane mirror closer to the laser tube if necessary. On account of the higher output power now available, this can make the adjustment easier.

e) Easy performance optimization

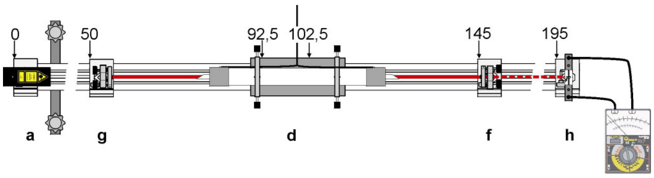

Fig. 7: Performance optimization

a Laser diode
d Laser tube in laser support
f Output mirror OC, R = -1000 mm
g Highly reflecting plane mirror
h Photoelement on holder for plug-in elements

- Attach the photoelement (**h**) to the holder for plug-in elements.
- Remove the screen and mount the holder for plug-in elements on the optics rider, so that the laser beam impacts the photosensitive side approx. at the centre.
- Using the current measurement cables, connect the photoelement to the multimeter. Switch on the multimeter.
- Using the mirror holder's fine adjustment screws, align the highly reflecting plane mirror (**g**) so as to obtain a maximum current.

  Warning: a change in ambient light can also produce a change in the current.
- Next, optimise the alignment of the output mirror (**f**) so as to obtain a maximum current.
- Repeat the last two steps until no further current rise is possible. Write down the maximum current.

Hint:

In some cases, the maximum value can only be obtained by turning in a certain rotation direction. If the maximum value is overstepped, only lower values are obtained by turning back. You have to approach the maximum in the rotation direction for which the maximum value is obtained.

f) Performance optimization by "Beam walk"

Optimising the horizontal alignment of the mirror

- Turn the lower fine adjustment screw on the highly reflecting plane mirror's mirror holder (**g**) **clockwise** until the current is reduced by 50% approx.
- Using the other fine adjustment screws – beginning with the output mirror's (**f**) mirror holder lower fine adjustment screw – optimise the output power and write down the maximum current.

If the maximum current has gone up:

- Turn the plane mirror's (**g**) mirror holder lower fine adjustment screw **clockwise once more** until the current is reduced by 50% approx.
- Using the other fine adjustment screws, optimise the output power and write down the maximum current.
- Repeat the last two steps until the current for two consecutive positions is no longer increasing.
- Set the plane mirror's (**g**) mirror holder lower fine adjustment screw in the position with the maximum current. Optimise the output power by adjusting the other fine adjustment screws.
- Last, optimise the output power by adjusting **all** fine adjustment screws.

If the maximum current has decreased:

- Turn the highly reflecting plane mirror's **(g)** mirror holder lower fine adjustment screw **counter clockwise** until the current is reduced by 50% approx.
- Using the other fine adjustment screws – beginning with the output mirror's (**f**) mirror holder lower fine adjustment screw – optimise the output power and write down the maximum current.
- Repeat the last two steps, until the current for two consecutive positions is no longer increasing.
- Set the plane mirror's (**g**) mirror holder lower fine adjustment screw in the position with the maximum current. Optimise the output power by adjusting the other fine adjustment screws.
- Last, optimise the output power by adjusting **all** fine adjustment screws.

Optimising the vertical alignment of the mirror

- Carry out the vertical optimisation just as you carried out the horizontal alignment of the mirror holder. In this process, turn the highly reflecting plane mirror's (**g**) mirror holder upper fine adjustment screw until the current is reduced by approx. 50%.

Measuring example

In the above measuring example, we see the following results at the photoelement (h):

- after the easy performance optimization: $I_E = 49$ µA
- after optimising the horizontal alignment: $I_H = 64$ µA
- after optimising the vertical alignment: $I_V = 72$ µA