Dependence of the Output Power on the Position of the Laser Tube inside the Resonator

Experiment Objective

- Determining the output power for different positions of the laser tube inside the resonator

Principles

The helium-neon laser is among the most common lasers. In experiment P5.8.1.1, a helium-neon laser is assembled using individual components.

In experiment P5.8.1.4, the effect of the position of the laser tube inside the resonator on the amount of output power is studied. The more closely the beam path matches the dimensions of the amplifying medium inside the resonator, the higher the output power. The dimensions of the amplifying medium of a helium-neon laser are determined by the dimensions of the capillary where the gas discharge is ignited. The capillary diameter of the laser tube used in this experiment is approx. 1.5 mm; the length is approx. 25 cm.

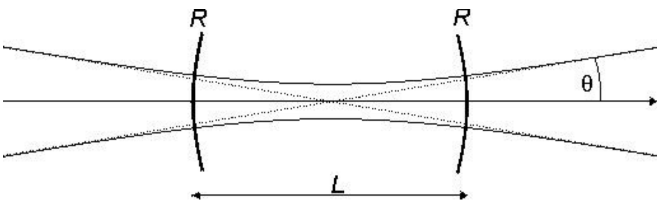

Fig. 1: Beam path for a resonator with $R_1 = R_2 = R$

Figure 1 shows the beam path for a resonator that has two concave mirrors with the same curvature radius ($R_1 = R_2 = R$). The beam path is symmetrical. The beam diameter is uniform in the resonator (see also P5.8.1.3). As a result, the position of the laser tube does not greatly affect the output power. The dependence is approximately symmetrical.

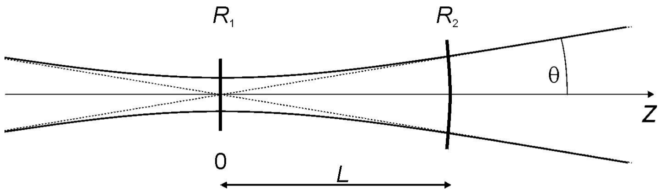

Fig. 2: Beam path for a resonator with $R_1 \rightarrow \infty$

In comparison, Figure 2 shows the beam path for a resonator with a plane mirror ($R_1 \rightarrow \infty$) and a concave mirror. Near the plane mirror, the beam diameter is at its minimum and does not change. Near the concave mirror, the beam diameter rises continuously (see also P5.8.1.3). Therefore, the amplifying medium can be better utilized near the plane mirror.

In this experiment, the position of the laser tube relative to the resonator mirrors is gradually changed. As a loss of adjustment in the laser tube is difficult to correct, both end-point mirrors are shifted by the same distance respectively. Power is optimised for each position by adjusting the orientation of the resonator mirror. The measured values are recorded and represented graphically.

Apparatus

1 Basic Set "He-Ne Laser" 471 810
1 Optical bench, 2 m, standard cross section 460 33
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:

1 Laser mirror, HR, R = -1000 m 470 103
Adjustment goggles for He-Ne laser................... 471 828

CS-0707

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.

Laser tubes require 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.

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 and placed in their support when they are not in use.

During the experiment, make sure 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 fingerprints, 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

Setup and calibration of the He-Ne laser are described in the experiment P5.8.1.1. L = 90 cm is used as mirror separation at first. The laser tube is placed in the middle of the resonator. Figure 3 shows the setup for the present experiment. The left edge position of the optics riders is given in cm for each element respectively.

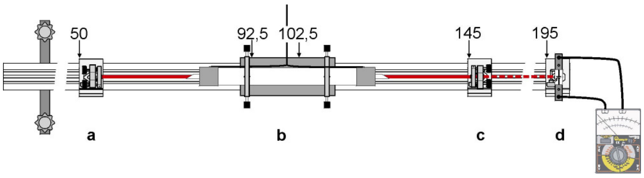

Fig. 3: Experiment setup

- **a** Highly reflecting plane mirror ($R_1 \rightarrow \infty$)
- **b** Laser tube in laser support
- **c** Output mirror OC, R_2 = 1000 mm
- **d** Photoelement on holder for plug-in elements

Method

Important: The laser process should not stop while moving the laser mirror. If necessary, shift the mirror in small increments and optimise the output power in each case, beginning with the shifted mirror. If the laser process stops, move the laser mirror back. If the laser process is not able to start again on its own, carefully turn the fine adjustment screw on the shifted mirror. If the laser process is still not starting, a complete recalibration is required (see Experiment P5.8.1.1).

- Record position A of the highly reflecting mirror (**a**), position B of the output mirror (**c**) and the maximum current (see Table 1).
- Move the highly reflecting mirror (**a**) 5 cm to the right. Re-optimise the output power, beginning with the shifted mirror (**a**).
- Also move the output mirror (**c**) 5 cm to the right and re-optimise the output power, beginning with the shifted mirror (**c**).
- Record position A of the highly reflecting mirror (**a**), position B of the output mirror (**c**) and the maximum current (see Table 1).
- Gradually move the mirror further away and record the maximum current for each distance until the highly reflecting mirror (**a**) is directly in front of the laser tube.
- Repeat the measurement, but now move the highly reflecting mirror (**a**) and the output mirror (**c**) to the left, beginning with the output mirror (**c**).

If necessary, repeat the measurements for other, noticeably different, mirror separations or combinations of mirror radiuses. Due to the stability criterion for resonators, the maximum possible mirror separation L is defined as

$$0 \le g_1 g_2 \le 1 \text{ with } g_1 = 1 - \frac{L}{R_1},\ g_2 = 1 - \frac{L}{R_2}$$

(see also Experiment P5.8.1.5). For $R_1 \rightarrow \infty$ and R_2 = 1000 mm results: $0\ \text{cm} \le L \le 1000\ \text{cm}$.

Measuring example and analysis

Table 1 shows a measuring example. The distance between position A of the highly reflecting mirror (**a**) and the centre of laser tube is C = 100 cm. The resulting distance D between laser tube and highly reflecting mirror is given by the equation: D = 100 cm – (A + 5 cm). By adding 5 cm, we make sure that the location of the highly reflecting mirror is distinguished from the position reading.

For a plano-concave resonator ($R_1 \rightarrow \infty$, R_2 = 1000 mm, L = 90 cm) the values I_{pk} result. For a biconcave resonator ($R_1 = R_2$ = 1000 mm, L = 90 cm) the values I_{kk} were measured.

A / cm	B / cm	D / cm	I_{pk} / µA	I_{kk} / mA
25.0	120.0	70.0	0	530
30.0	125.0	65.0	0	590
35.0	130.0	60.0	0	580
40.0	135.0	55.0	0	560
45.0	140.0	50.0	4	540
50.0	145.0	45.0	68	550
55.0	150.0	40.0	190	550
60.0	155.0	35.0	300	580
65.0	160.0	30.0	460	570
70.0	165.0	25.0	540	530
74.0	169.0	21.0	560	480

Tab. 1: Measuring example

In Figure 4, the measured values I_{pk} for $R_1 \rightarrow \infty$, R_2 = 1000 mm and L = 90 cm are represented graphically as a function of distance D. If the distance from the laser tube to the highly reflecting plane mirror is small, then the output power is high. As the distance increases, the output power decreases. For D > 50 cm laser activity is no longer possible.

Figure 5 shows the measured values I_{kk} *for* $R_1 = R_2$ = 1000 mm and L = 90 cm. Compared to Figure 4, the current, i.e. the output power, changes minimally. The curve is almost symmetrical with two maximums at approximately 34 cm and 62 cm.

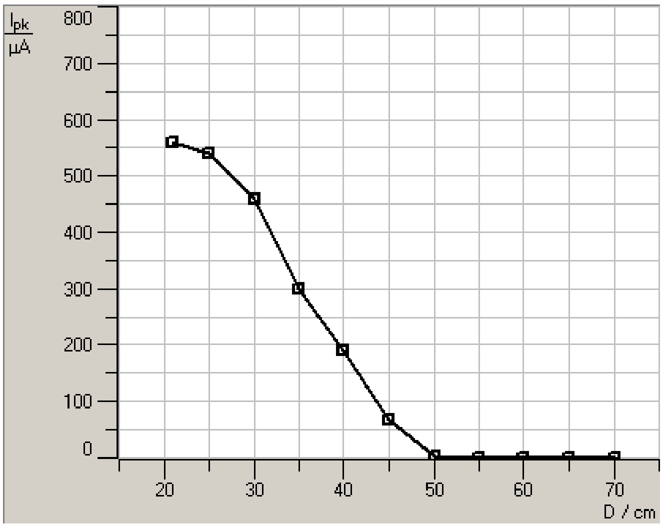

Fig. 4: Dependence of the output power on the laser tube position for $R_1 \rightarrow \infty$, R_2 = 1000 mm and L = 90 cm

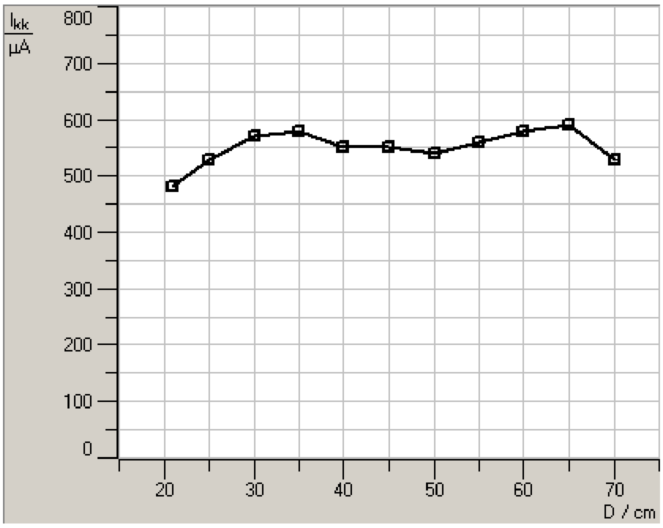

Fig. 5: Dependence of the output power on the laser tube position for $R_1 = R_2$ = 1000 mm and L = 90 cm