V60

Diode-Laser

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1 Objective

The aim of this experiment is to study the working principle of a diode laser proposing a spectroscopy of rubidium using an optical grating.

2 Theoretical Foundations

2.1 Basics of Lasers

A laser (light amplification by stimulated emission of radiation) is a source of intensive coherent light through photon emission. Therefore a laser can be used to excite atoms and to pump energy into a medium. In atoms the electrons possess different discrete energy levels. The basic priciples of photon electron interaction are shown in figure 1, that includes absorption, spontaneous and stimulated emission of a photon.

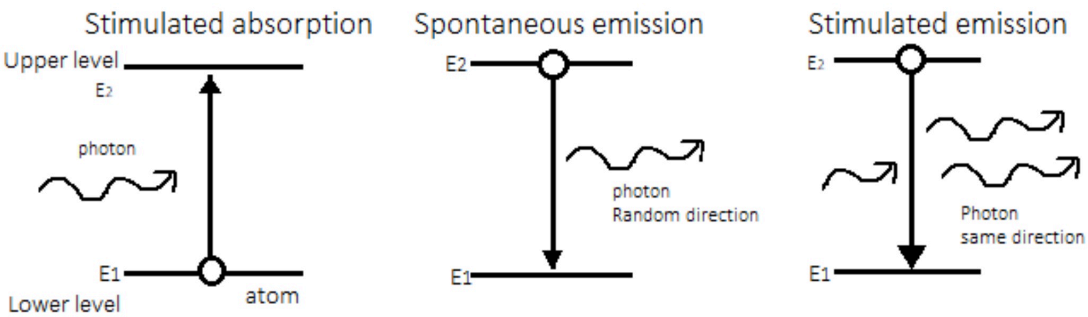


Abbildung 1: Graphic for interaction between photon and electron [1].

If a photon γ has enough energy to excite an electron from a lower to a higher state, it can be absorbed. Spontaneous emission discribes the opposite, where a photon is emitted due to a transition to a lower energy level that happens spontaneously. The most interesting process when it comes to a laser system, is the stimulated emission. Stimulated emission is induced by an incoming photon which energy has to be equal to the gap energy. As a result two coherent photons with the same direction and energy will be emitted, what is fundamental to run a laser. In order to reach a higher probability of stimulated emission a population inversion is needed, where the electron density in the higher state has to be higher than in the lower state. This can only be achieved through pumping in an at least three energy level system as shown in figure 2.

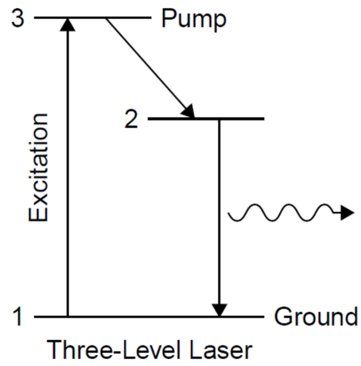


Abbildung 2: Three level scheme [2].

The transition from level 1 to level 3 is induced by absorption of energy through continuously pumping with electric current. Electrons in level 3 are spontaneously relaxing in a lower state 2 with a high decay rate. Considering that level 3 has a higher decay rate than level 2 the pumping creates the required population inversion between level 2 and level 1.

2.2 Diode-Laser

A basic configuration of a diode laser is shown in figure 3.

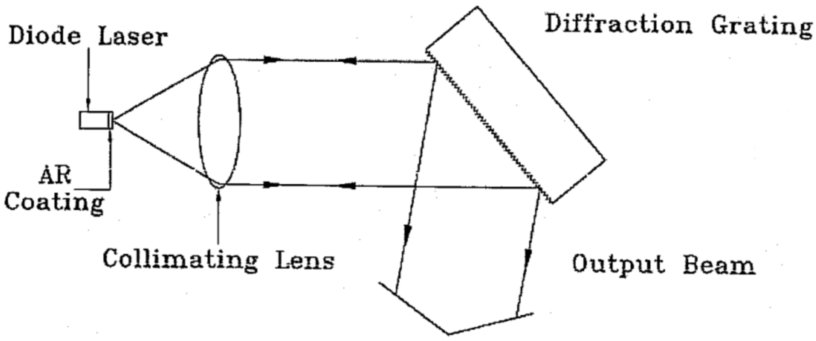


Abbildung 3: Basic configuration of a diode laser [8].

A lasing system is in need of four essential components. In the following the components itself and their net gain shown in figure 4 will be discussed.

1. **Gain medium**

   A gain medium in which a population inversion is created by pumping is necessery. In this experiment the gain medium is a semiconductor with the desired energy gap which determines the wavelength of the emitted photons. A semiconductor is a solid material with a band gap between the positive p-doped region with an excess of holes and the negative n-doped region with an excess of electrons. the band

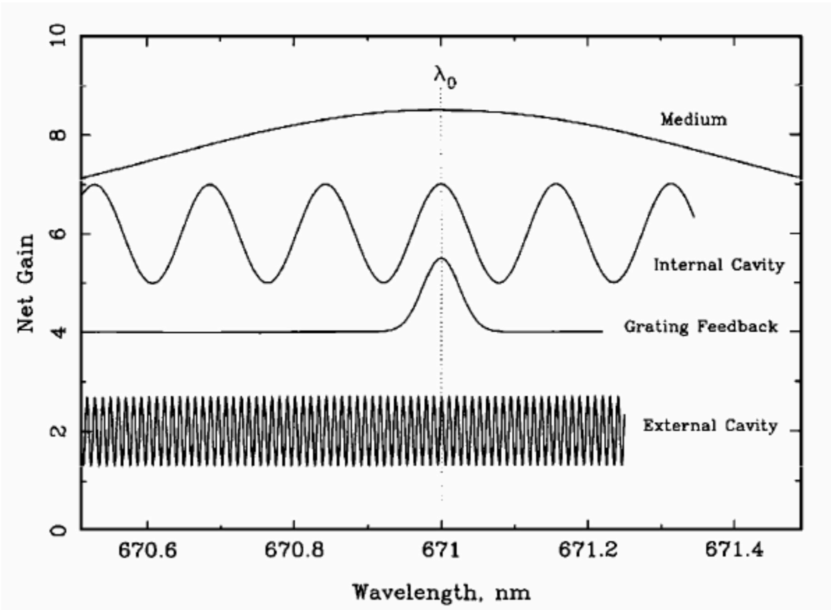


Abbildung 4: Different contributions to the net gain of a laser as a function of wavelength [8].

gap depends on the temperature and current as if the temperature or current is increased, the band gap decreases. The net gain has its maximum at the wavelength of the emitted photons corresponding to the band gap.

2. **Internal cavity**

   The internal cavity is formed by two reflective surfaces of which only one is fully reflective. the other side is only partially reflective and is used as the output coupler. This reflection leads to a standing wave in the cavity.

3. **Grating**

   The grating reflects the light in a way where the first order diffraction is sent back into the diode. The wavelength can then be found from the bragg condition $\lambda = 2\,d\sin\theta$ where d is the line spacing and θ is the grating angle. In figure 4 the peak of the grating feedback appears at this exact wavelength, as no other wavelengths are reflected to the diode.

4. **External cavity**

   The external cavity posseses a by far greater length than the internal cavity and they both share the partially reflecting surface. Since the external cavity is much larger the period length of the gain to the frequency is much smaller. The position of the modes can be varied by changing the position of the grating and the length of the external cavity.

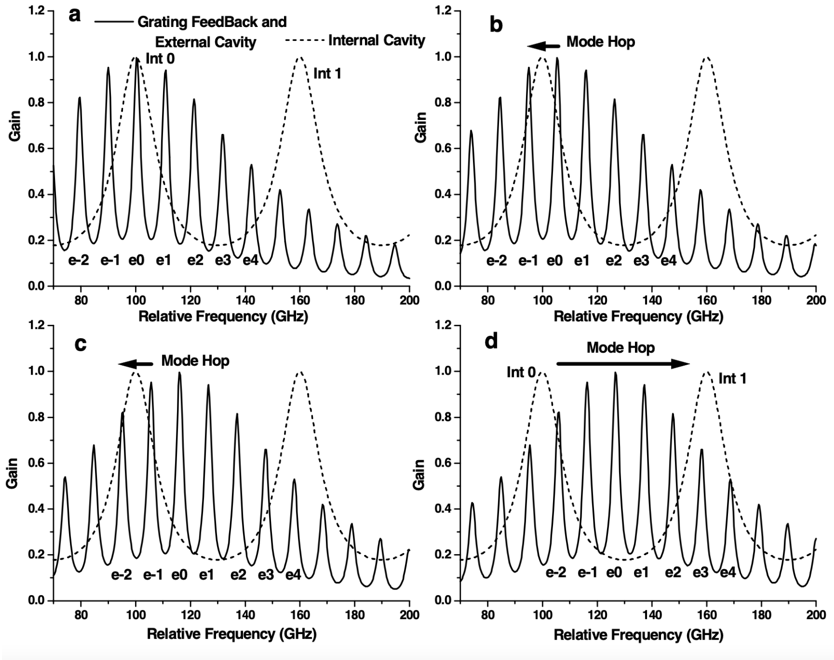


Abbildung 5: Series of graphs showing the procedure of mode hopping [8].

One effect than can occure when changing the grating is a 'mode hop'. This happens when the maximum gain changes because of a switch from one peak of the internal cavity function to another one. Since the external and internal cavity are not influenced the same way by temperature a 'hop' can happen. This effect is illustrated in figure 5.

3 Setup and Procedure

To determine the rubidium absorption spectrum with a diode laser it is important to make different premeasurements. For each measurement it is necessary to use another setup. For all setups it is advisable to darken the room.
In the following each setup aim and the setup itself will be explained.

3.1 Threshold current

First of all it is important to register the threshold current since below it the diode only works as a LED and only above as a laser. The setup for this is really simple. The laser is connected to a powersource where the current can be changed. In front of the laser is a businesscard holder placed with a card which is converting infrared light into visible light. Since the laser is operating in the infrared spectrum this card is necessary to make the light visible. A camera is directed at the card too. The setup is sketched in figure 6.

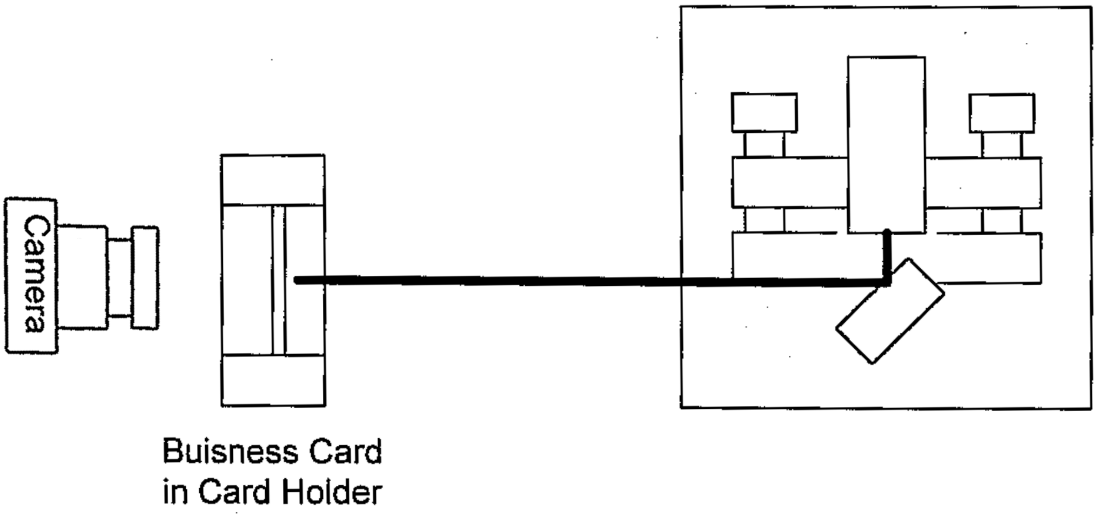


Abbildung 6: Sketch of the setup for finding the threshold. [8]

By changing the current the threshold can be found. The threshold current is at the transition point where the light spot becomes significantly brighter and begins to crimble in the video of the camera.

3.2 Rubidium fluorescence

The next setup is build to see the fluorescence of the Rubidium. The businesscard holder is replaced by a chamber filled with Rubidium. The laserlight is directly directed into the chamber. On the right hand side of the chamber is a cutout where a camera is placed to observe the fluorescence light. The setup is sketched in figure 7. Also the ramp generator and piezo controller are wired as shown in figure 8.

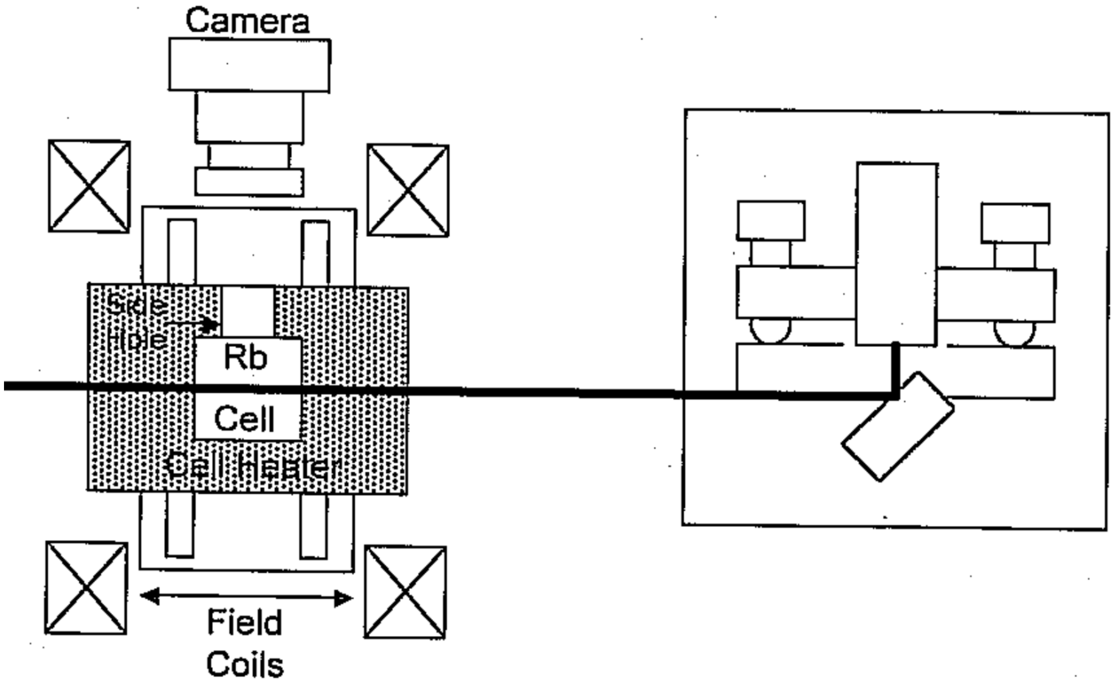


Abbildung 7: Sketch of the setup to observe fluorescence light. [8]

The current gets set to the threshold and then slowly increased until a light beam is visible in the video of the camera.

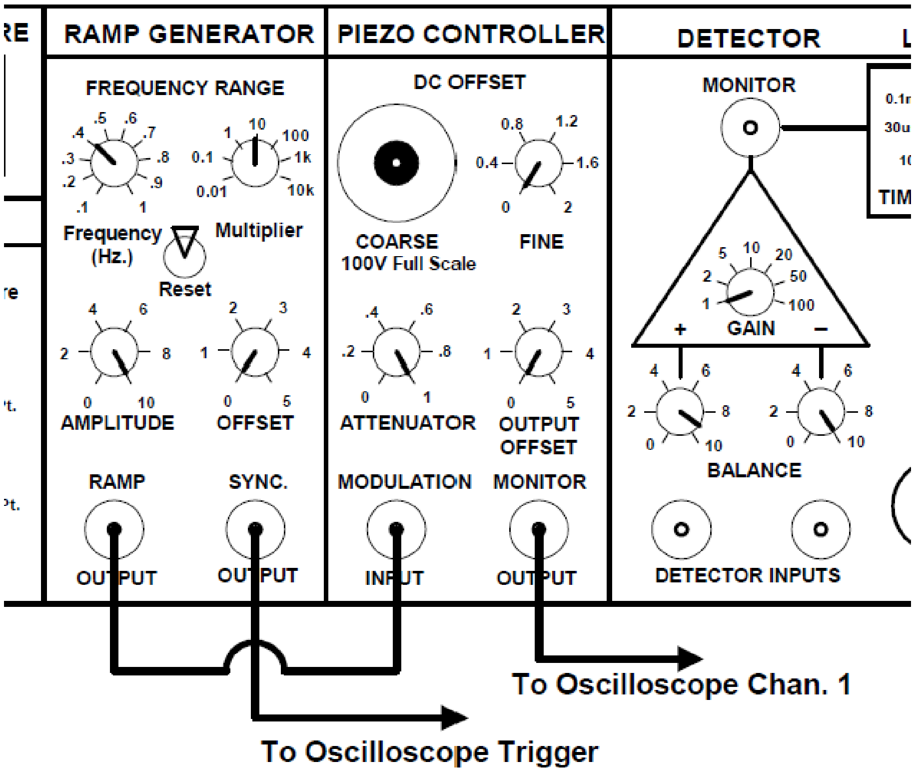


Abbildung 8: Wiring of the ramp generator and the piezo controller. [8]

It is also important to note that the laser has two knobs. With the upper one the verticle angle of the grating can be changed and with the lower one it is possible to change the horizontal angle.

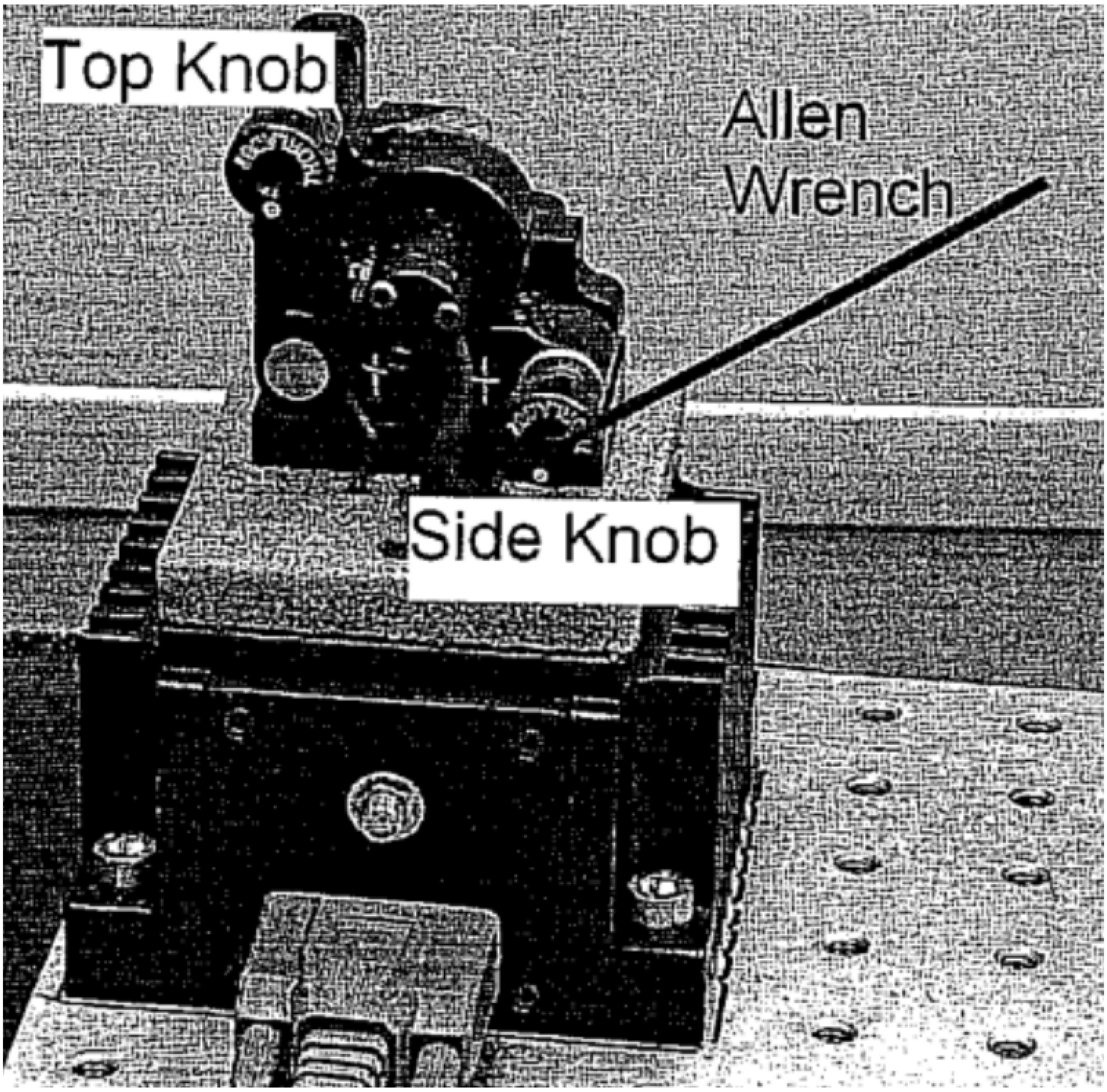


Abbildung 9: Picture of the laser with the knobs. [8]

3.3 Rubidium absorption spectrum

The final setup is to detect the absorption spectrum of Rubidium. For this 2 photodetectors, a half-transparent mirror (reflects half of the light), a glas nd-filter and a gelatin nd-filter is added. The way they are added is shown in figure 10 and the wiring is shown in figure 11.

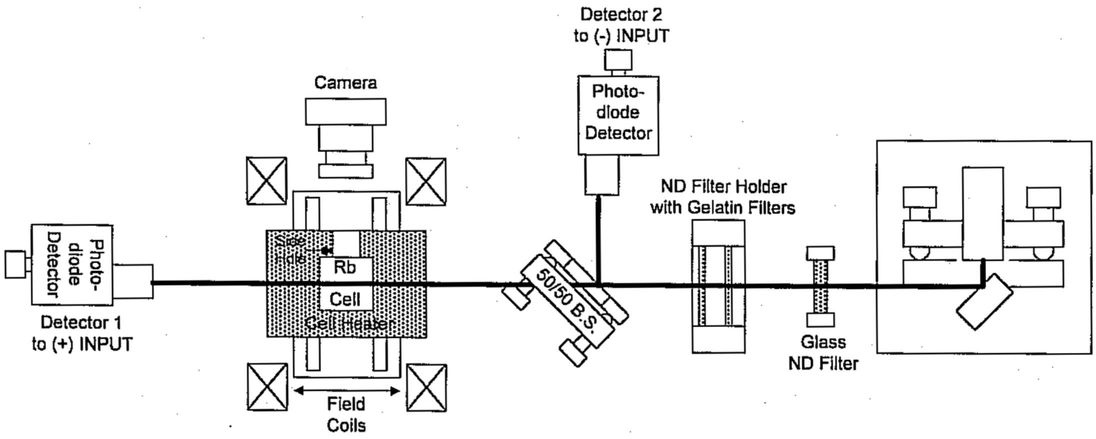


Abbildung 10: Setup to observe the Rubidium fluorescence. [8]

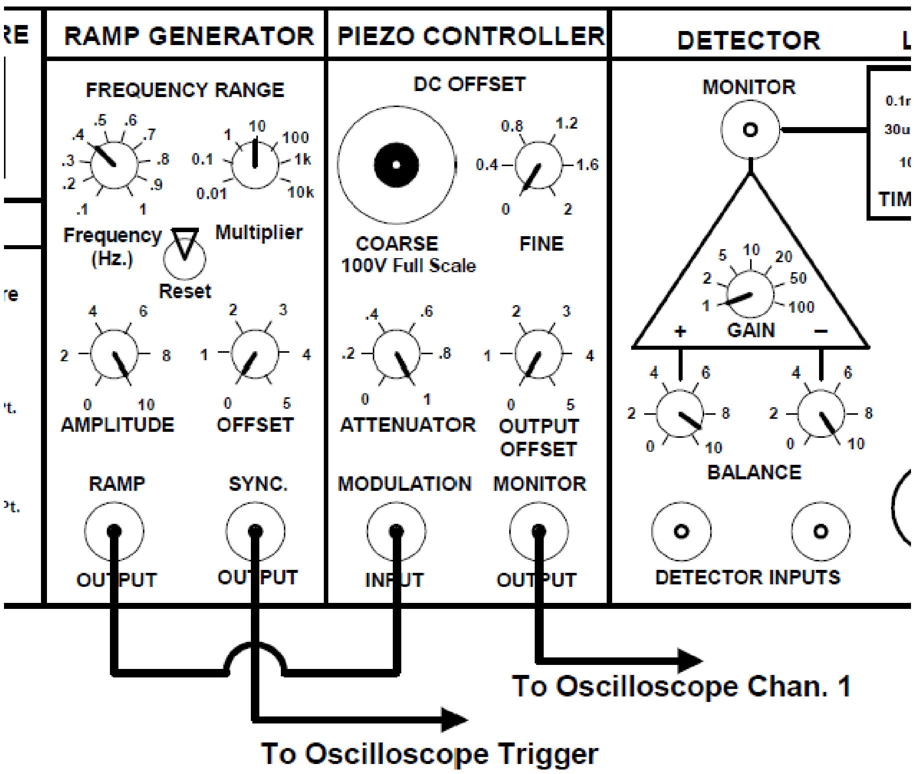


Abbildung 11: Wiring of the control element to observe the Rubidium fluorescence. [8]

The first photodetector is necessary to detect the out going light beam, the second one is needed to flatten the curve of the detected spectrum, since it is proportional to the

current created by the ramp generator and piezo controller.
The filter are needed because the photodetectors get easily overloaded by the high energy of the laser beam. The spectrum of interest can be seen in the oscilloscope.

4 Results

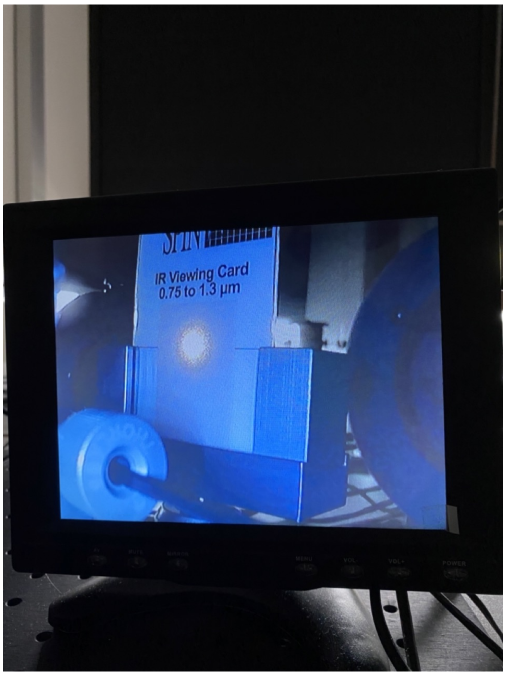
4.1 Threshold current

The threshold current gets detected at

$$I_{\text{threshold}} = 34.1\text{mA}\,.$$

The following pictures are taken from the videoscreen of the camera and show the laserbeam slightly below (a) und slightly above (b) the threshold. The difference in the intensity of the light is really good to see.

(a) Diodelaser works as a LED.



(b) Diodelaser working as a laser.

4.2 Rubidium fluorescence

The fluorescence light of the Rubidium is emitted along the laser beam. This can be observed in the picture 13. The yellow horizontal line is the light of interest, the lower one is just a reflection which occured by the angle.

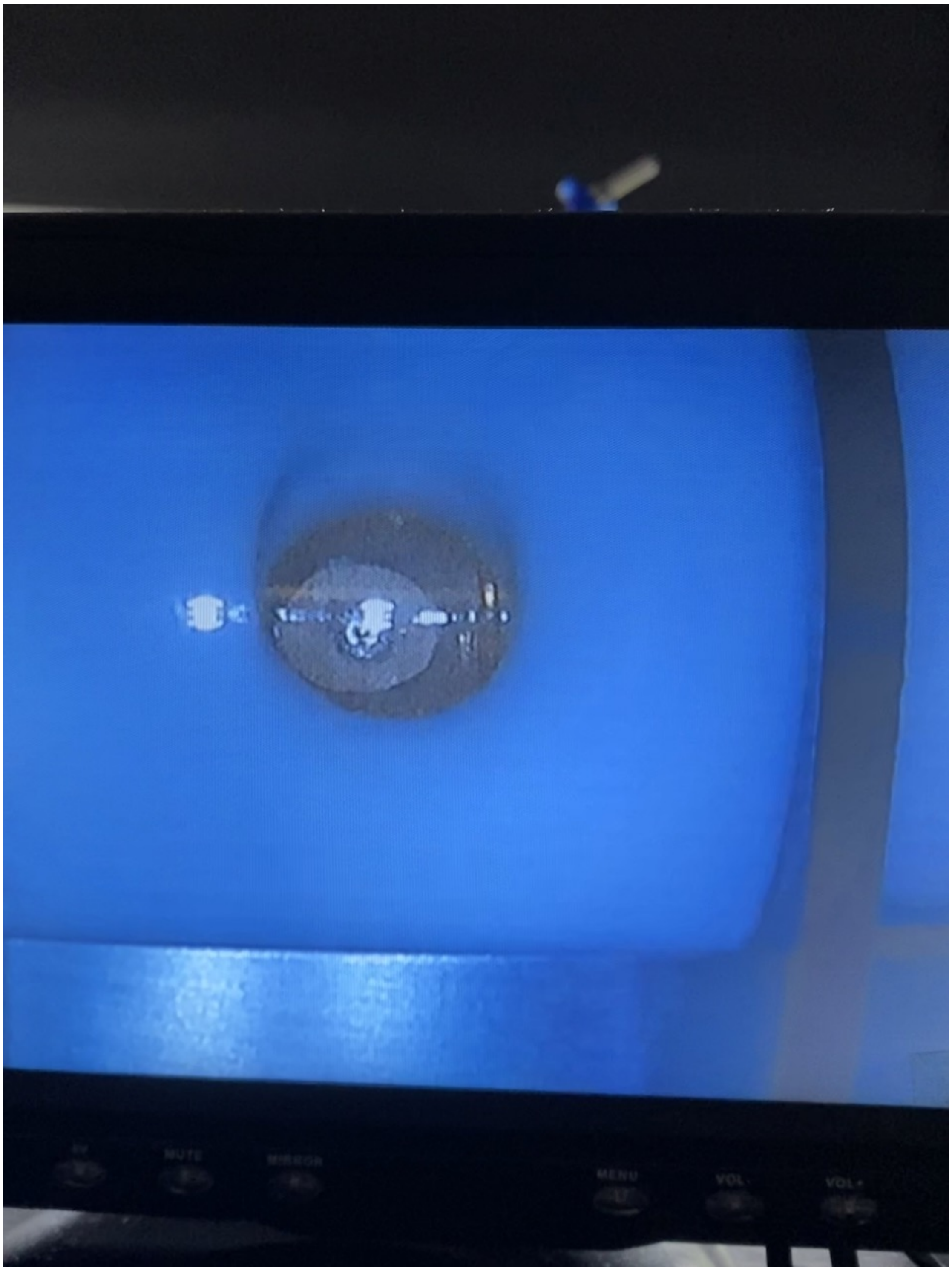


Abbildung 13: Foto of the rubidium fluorescence.

4.3 Rubidium absorption spectrum

In figure 14 the measured absorption spectrum is shown in yellow. The blue trace is the piezo monitor, which shows the voltage on the piezoelectric stack as a function of time.

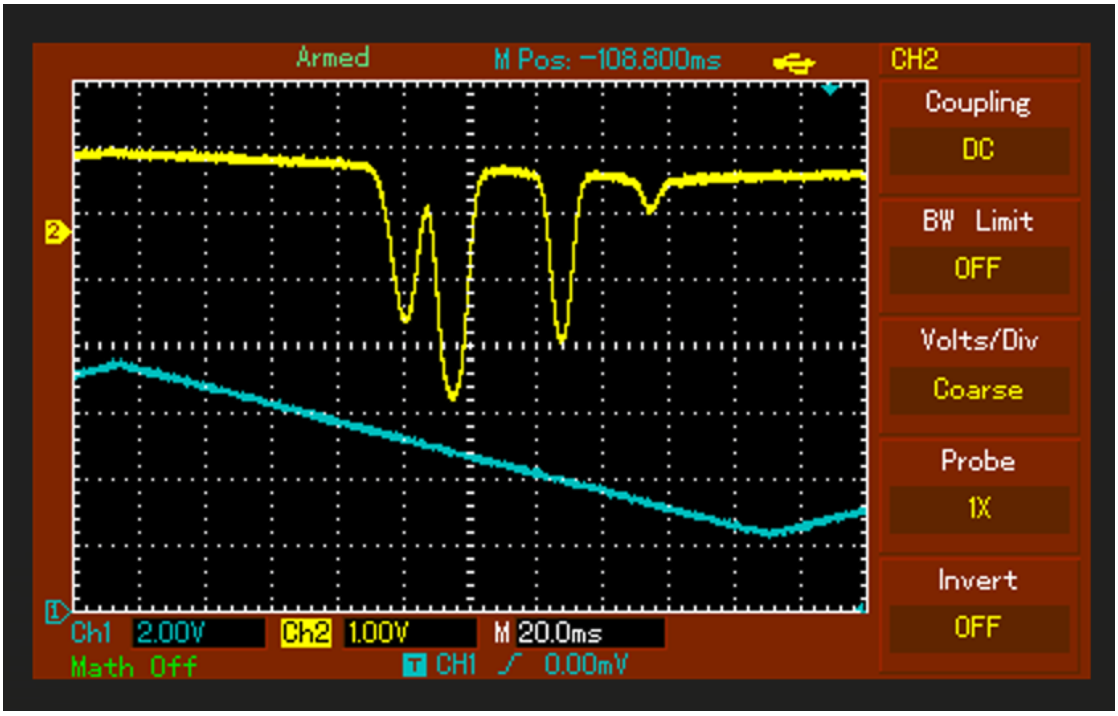


Abbildung 14: Signal from the photodiode and the ramp generator.

The adjustment of the laser seems to be perfect since there are 4 dips as expected (so no mode hops). The expected graph and the reason for it is shown in figure 15.

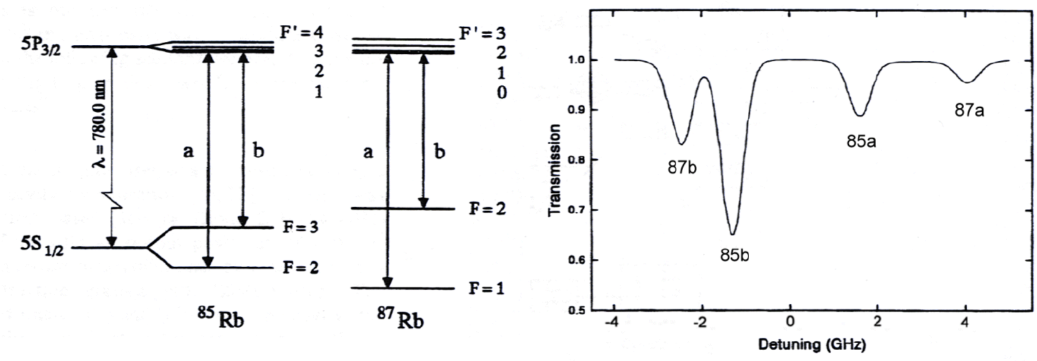


Abbildung 15: Energy level Diagrams and the Doppler broadened spectrum [8]

5 Diskussion

The generel preciseness of the measurement of the threshold really depends on the adjustment skills of the experimentator.
Another difficulty of the experiment was that the knobs of the laser are really sensetive to small mechanical disturbances. A little hit on the table changed already the adjustment made. Also it was hard to find the right knob adjustment as well as the right currents to pick as well as the right frequency.
Also the oscilloscope behaved strangly while measuring. Sometimes no signal got detected and other times the oscilloscope had to be restarted (no changes to the settings where made) to get the expected picture back.

Literatur

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