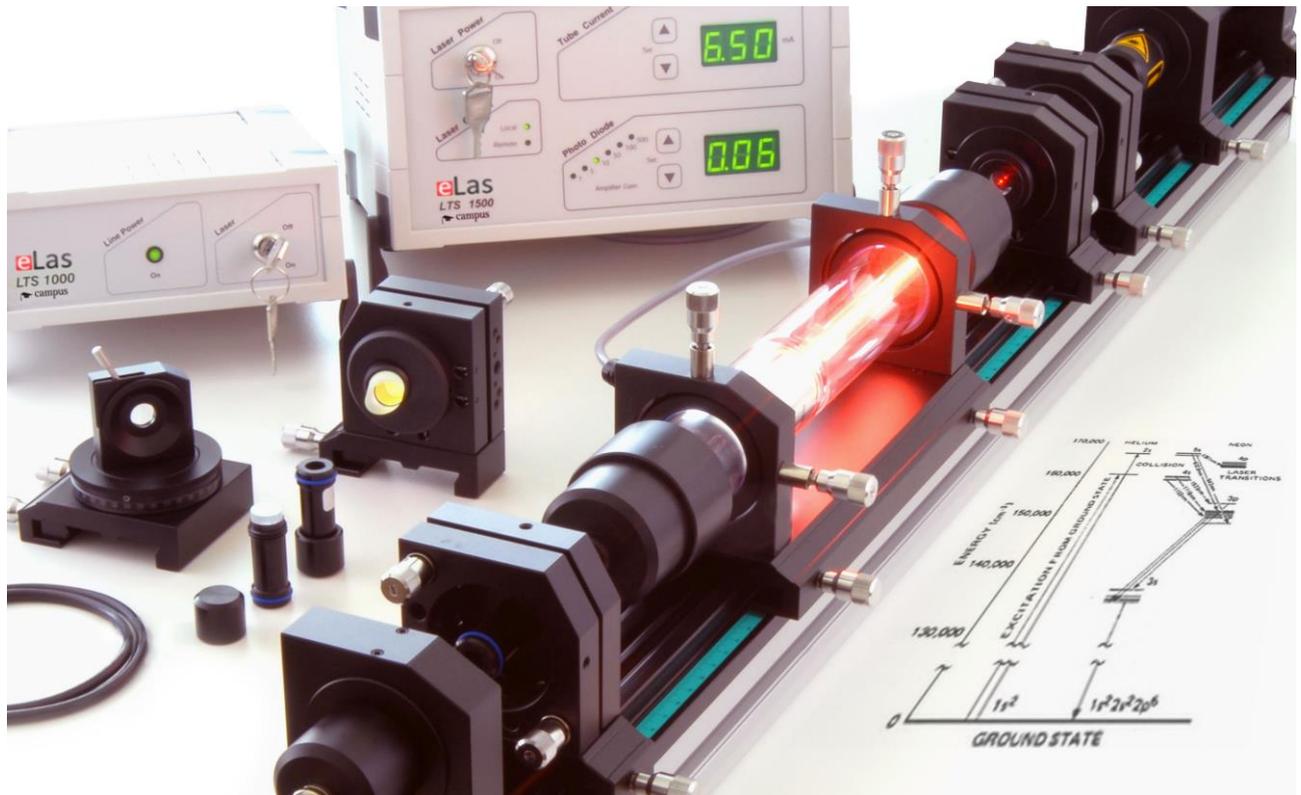


## **Helium Neon Laser (CA-1200)**



The Helium Neon Laser is a versatile gas laser source designed for training and education, but can also be used in research applications. With all of its elements, this system offers a wide range of experimental possibilities, and is the most flexible HeNe system on the market.

This educational kit has been designed to supply the students in understanding the interaction of the different components of a gas laser, laser resonators, mode properties, up to the influence of different wavelength selective optical components used for gas lasers.

### ***Educational Objectives of Investigation***

- Properties of Gas Lasers
- Pumping by Electrical Discharge
- Emission Lines and Energy Levels of Helium and Neon
- Output Power Optimization by Resonator Alignment
- Laser Emission as a Function of Laser Tube Current
- Laser Beam Width and Shape in and outside of the Resonator
- Stability Criterion of Laser Operation and Cavity Optimization
- Transversal Resonator Mode Properties (TEM<sub>00</sub> and higher)
- Longitudinal Mode Selection by Single Mode Etalon
- Laser Line Selection by Birefringent Filter
- Laser Line Selection by Littrow Prism
- Output Power with varying the Output Coupling

## ***Modes of Operation***

The basics of gas lasers like resonator types and stability, coherence and mode behavior are shown in practice with this open-frame gas laser and are discussed in the comprehensive manual. By variation of the resonator mirrors (the set comprises 5 mirrors) the resonator properties and its influences on the laser power and stability are evaluated. Changing the resonator length and laser tube position continuously, the stability criterion of several resonators is evaluated.

The possibilities of wavelength selection with optical components like Littrow Prism and birefringent filter is investigated and described. The influence to the laser resonator modes of an etalon inside the laser cavity is imparted to the students.

Some of the possible modes of operation are

- several confocal, hemispherical and concentric resonators (symmetric and asymmetric) at 632.8nm with low (<1mW) output power
- the same resonators as above, but with high (>5mW) output power
- HeNe Laser with birefringent filter for wavelength tuning at 611.8nm, 629.8nm, 632.8nm, 635.2nm and 640.1nm
- HeNe Laser with Littrow prism for wavelength tuning at 611.8nm and 632.8nm
- HeNe Laser with single mode etalon for single mode operation

All optical and fine-mechanical parts for setting up the kit are included. Mounted on an optical rail all components can be installed and exchanged in short time. The provided electronics controller for the HeNe laser tube allows a variation of the tube current and comprises an internal photo diode amplifier with indication. A quick start-up alignment of the laser resonator is ensured by delivery of an adjustment DPSS laser in a holder with own power supply to define the optical axis on the flat rail.

Besides the Full Version (CA-1200) a Basic Version of the HeNe system is available (CA-1201) comprising all components necessary for set up and operate the HeNe laser in various resonator configurations. Further, all experiments of the Full Version plus measurements of polarization and crystal optics are performed with the Extended Version of the HeNe Laser (CA-1202). Wavelength and mode selection are possible with the HeNe Full Version and Extended Version only.

Finally, an IR option mirror set consisting of two IR coated concave mirrors for operating the HeNe laser on its IR emission lines is offered (CA-1205).

## ***Ordering Information***

This ordering information gives an overview of ordering numbers of the several versions of the HeNe laser kit. All modules of the kits can be ordered separately, if required.

For ordering the Helium Neon Laser Full Version (CA-1200)

use ordering number: 490091200

For ordering the Helium Neon Laser Basic Version (CA-1201)

use ordering number: 490091201

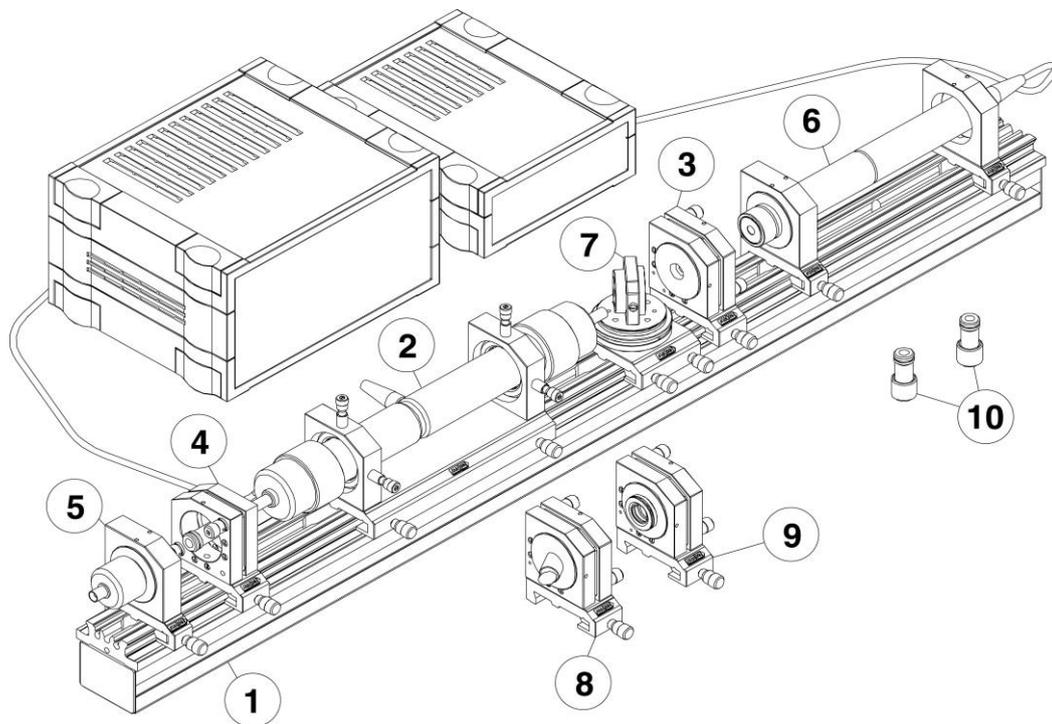
For ordering the Helium Neon Laser Extended Version (CA-1202)

use ordering number: 490091202

For ordering the Helium Neon Laser IR extension mirror set (CA-1205)

use ordering number: 490091205

## Setup and Components

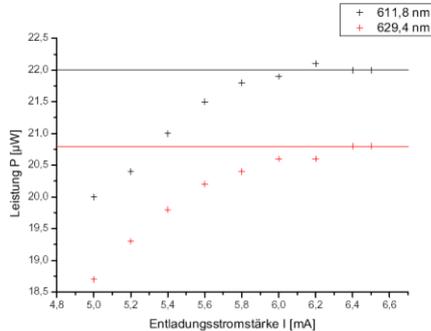


- 1 Flat rail 1500 mm reinforced by profile with scale
- 2 Controller LTS 1500 for HeNe tube and photo diode amplifier
- 3 Right kinematic mirror adjustment holder on carrier
- 4 Left kinematic mirror adjustment holder on carrier
- 5 Photo detector in holder on carrier with BNC cable
- 6 Adjustment laser (green DPSS module) in holder on carrier with power supply
- 7 Birefringent filter in rotating holder on carrier platform with rotating insert (Full and Extended Version)
- 8 Littrow prism in adjustable holder on carrier (Full and Extended Version)
- 9 Single mode etalon in adjustable holder on carrier (Full and Extended Version)
- 10 Set of 5 laser mirrors (3 mirrors in the Basic Version)
- 11 Optical transmission grating on carrier (Full and Extended Version, not shown)
- 12 Non-reflecting caliper (not shown)
- 13 Pair of polarization filters in rotational holders on carriers (Extended Version)
- 14 Half-wave plate in rotational holder on carrier (Extended Version)
- 15 Pair quarter-wave plates in rotational holders on carriers (Extended Version)
- 16 Set for optics cleaning (not shown)
- 17 User manual (not shown)

## Measurements and Handling

Some of the possible measurements are presented in the following list:

- **Output power versus laser tube current**

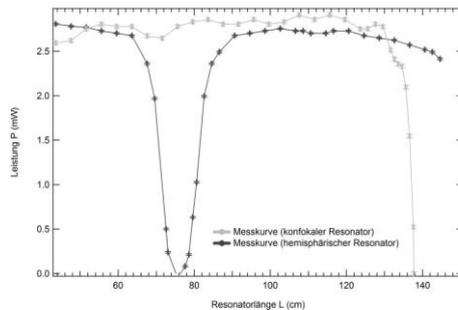


Within this experiment the current of the laser tube is stepwise increased from the minimum to the maximum value. The relative output power values of the HeNe laser as a function of the tube current is plotted in a graph as shown in the picture. The laser power behavior can be tested for several mirrors (curved, planar) and resonator types (hemispherical, confocal).

Black points: power values as a function of laser tube current for the 611.8 nm laser line

Red points: power values as a function of laser tube current for the 629.4 nm laser line

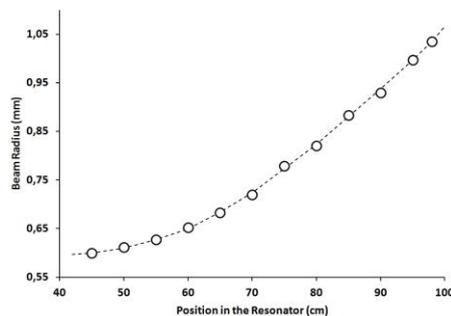
- **Optical stability area of the resonator**



The output power of the He-Ne laser is measured as a function of the resonator length  $L$ . Using a spherical resonator with mirrors HR ( $r = 850$  mm) and OC ( $r = 700$  mm) a breakdown of laser operation is observed in the instable range  $700 \text{ mm} < L < 850$  mm. Beyond this range stable laser operation is found up to resonator length of  $L = 1500$  mm.

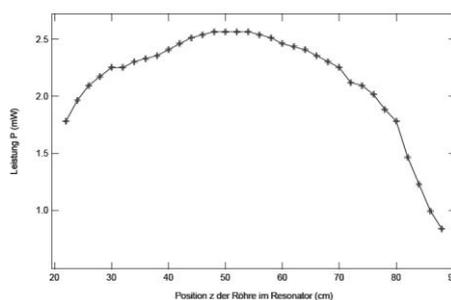
Stable laser operation is obtained extending a confocal resonator with mirrors HR ( $r = 700$  mm) and OC ( $r = 700$  mm) up to spherical case with  $L = 1400$  mm.

- **Laser beam width in the resonator**



Using a caliper gauge the beam diameter as a function of the position inside the resonator is evaluated. The width of the caliper is stepwise reduced and kept in the resonator until the laser stops to emit. The width of the caliper as a function of the caliper position in the resonator is displayed (see graph). Hemispherical and confocal resonator types can be tested and results can be compared with theoretical calculations.

- **Relative power versus laser tube position in the resonator**



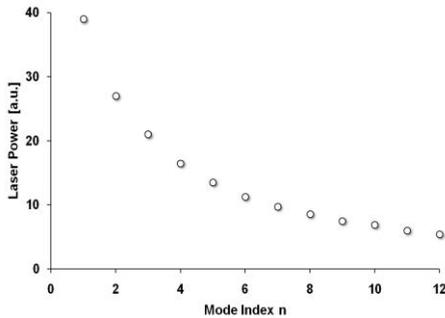
Within this measurement the position of the laser discharge tube is varied and its influence on the relative out-put power is determined. Using a spherical resonator with mirrors HR ( $r = 700$  mm), OC ( $r = 700$  mm) and resonator length  $L = 1100$  mm the output power versus tube position is studied (see graph). The maximum output power is achieved if the tube stands in the middle position. Here, the active medium is used most efficiently due to the smallest beam waist in the tube. This measurement can be performed for hemispherical and confocal resonators.

- **Mode structures**

By slightly misaligning the cavity mirrors of a long resonator, mode structures of higher orders than TEM<sub>00</sub> can be achieved. This test can be performed with different types of resonators.

Transversal modes can be observed also by using a thin wire or hair placed in the laser beam (see below *“Measurements with additional equipment”*).

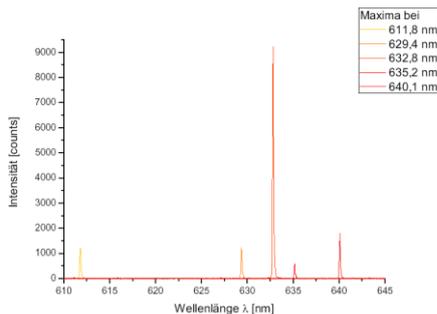
- **Single mode operation with etalon (full version)**



This single mode etalon in its adjustment holder has a thickness of 10 mm. Modes of higher index can be adjusted by tilting of one of the fine-adjustment screws of the etalon holder. When increasing the tilting angle the laser turns first off, before it emits again in the next higher longitudinal mode. This test can be done up to more than 10 mode orders.

In addition, longitudinal modes and their frequency distance can be determined by the Fabry-Perot resonator kit from eLas or by a spectrum analyzer (see below *“Measurements with additional equipment”*).

- **Wavelength selection with birefringent (Lyot) filter (full version)**



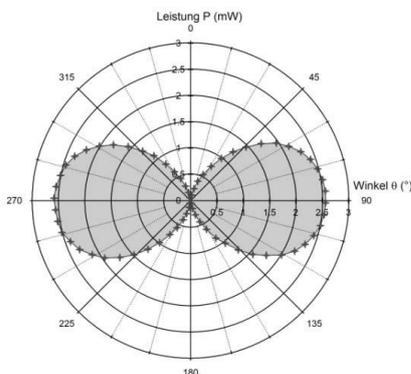
A disc of birefringent quartz is mounted in a rotator unit which allows the tuning of different wavelengths in the laser system.

If the birefringent filter is rotated around its axis one can get up to five wavelengths with different gains. A provided optical grating allows distinguishing the different wavelengths via their different diffraction angles. By Bragg's law the wavelengths can be calculated.

- **Wavelength selection with Littrow prism (full version)**

A high quality ‘Littrow’ prism is provided for laser wavelength selection. A selection of the main laser line at 632.8 nm and of the orange line at 611.8 nm is possible. For selection of lines close to 632.8 nm the resolution of the Littrow prism is too small.

- **Polarization measurements (extended version)**



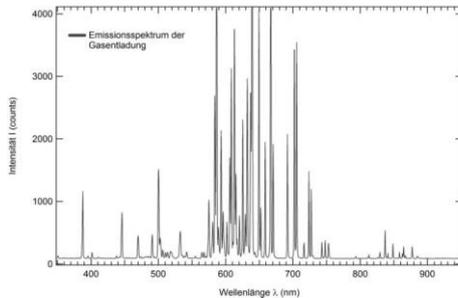
Using a rotatable analyzer and the photodiode detector the intensity distribution of the linear polarized laser light and its cos<sup>2</sup>-dependence can be proved. For this reason an adjustment of the Brewster windows can be achieved to get an exact p-polarized beam essential for later wavelength selection experiments with Littrow prism or Lyot filter.

Further basic polarization experiments can be carried out: (1) to generate and investigate elliptical and circular polarized light using in addition quarter-wave plate and (2) to turn linear polarization using half-wave plate.

## Measurements with additional equipment

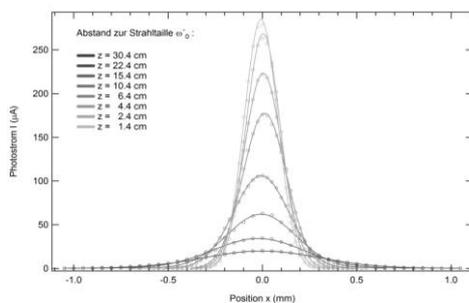
In the following further experiments requiring additional equipment are listed. The required additional equipment is mentioned in brackets and can be provided from eLas.

- **Transmission and emission spectra (micro-spectrometer, optical fiber, white LED)**



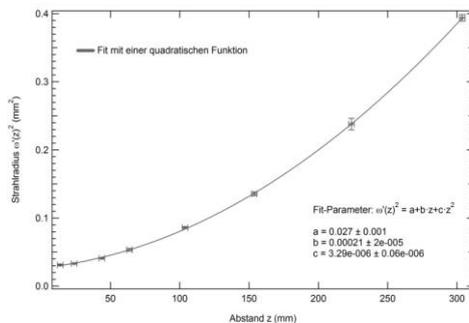
Transmission spectra of dielectric laser mirrors are measured using micro-spectrometer with optical fiber and halogen lamp or white light LED. The transmission spectrum shows clearly the spectral range of high reflectivity as well as structures due to multilayer interferences. Furthermore the emission spectra of the pure gas discharge and of the laser line are studied, too. In the latter case in addition lines of gas discharge are still found outside the spectral range of high mirror reflectivity.

- **Beam waist measurements (aperture, lens module, aperture on xy stage or waist meter)**

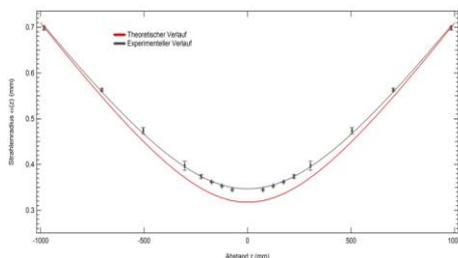


Beam waists, divergences, diffraction indices of  $M^2$ , beam qualities are studied at two different types of resonators.

At first a confocal resonator (HR and OC both with  $r = 700$  mm) is prepared with an intracavity aperture to generate  $TEM_{00}$ . If the beam waist is located within the active medium, a transformation of the Gauss-beam is needed through a lens to generate a new waist  $w'$  outside of the resonator. The measurements of lateral intensity profiles are performed at different distances  $z$  behind the expected new waist  $w'$ . To do this, a waist meter or an aperture (diameter about 0.2 mm) with a large area photodiode can be used. The aperture has to be adjustable in both lateral  $x$ - and  $y$ -directions. From Gauss-fittings of the measured lateral profiles the widths at  $1/e^2$  are obtained. The transformed waist  $w'$  results from the graph  $1/e^2$ -width versus  $z$ . Now, the original waist  $w$  is calculated from the knowledge of  $w'$ , the distance between OC-mirror and transforming lens and of its focal length.

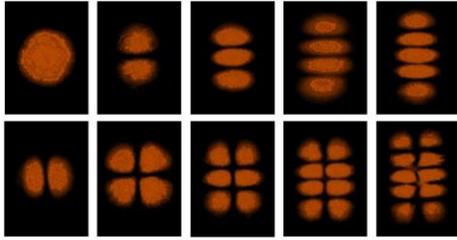


Secondly, the waist of the hemi-spherical resonator with mirrors HR ( $r = 700$  mm), OC (planar) and length of  $L = 700$  mm can be measured without transformation because the waist is located on the planar mirror. To do this, the lateral intensity beam profiles are measured at different distances  $z$  behind the OC-mirror. As above the graph  $1/e^2$ -width versus distance  $z$  are plotted. Using a quadratic fit now the beam waist on the mirror at  $z = 0$  is obtained.



Additionally, from these measurements divergences, diffraction indices of  $M^2$ , beam quality parameters  $K$  are obtained for both resonator types.

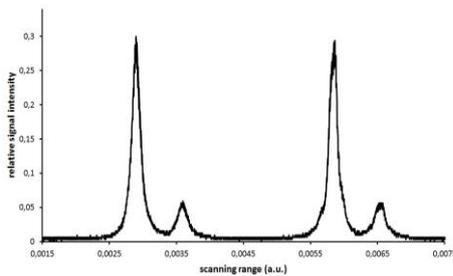
- **Transversal modes (adjustable thin wire in the resonator, camera)**



By slightly misaligning the cavity mirrors of a long resonator, mode

structures of higher orders than TEM<sub>00</sub> can be achieved. Also different TEM-modes are observed if a thin wire is located within a confocal resonator (HR, OC both  $r = 700$  mm and  $L = 700$  mm) not far from the OC-mirror. The wire has to be adjustable in both x- and y-directions and may be rotated. If the wire position is carefully changed high gain modes can be suppressed in favor of further modes, like TEM<sub>0,n</sub>, TEM<sub>1,n</sub>, TEM<sub>2,n</sub> up to  $n = 4$ . Using a lens, enhanced TEM-modes pictures are imaged on a translucent glass screen and recorded with a camera. Open programs can be used for e.g. three dimensional pseudo-color plots.

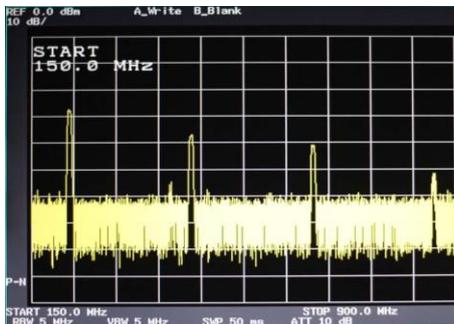
- **Longitudinal modes with Fabry-Perot resonator (scanning Fabry-Perot, for example eLas experiment "Fabry-Perot resonator" CA-1145)**



Using a scanning Fabry-Perot resonator the longitudinal modes of the laser can be displayed on an oscilloscope screen. The free spectral range as well as the finesse of the Fabry-Perot is evaluated, and the mode distance of the laser modes can be calculated.

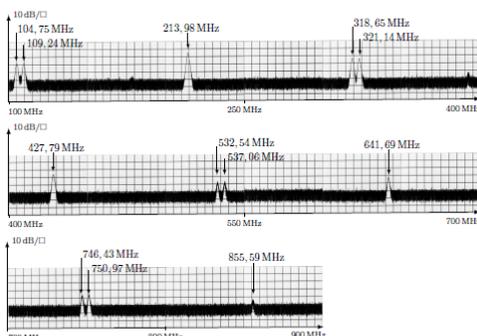
Especially the difference between single- and multi mode operation of the HeNe laser can be shown impressively with the intra-cavity single mode etalon (included in the HeNe full version).

- **Longitudinal modes (fast photodiode with spectrum-analyzer)**



The beat frequencies between different longitudinal modes (TEM<sub>0,0,q</sub>) are measured with a fast photodiode and a spectrum analyzer. Here, a nearly confocal resonator (HR, OC both  $r = 700$  mm and length  $L$  of about 700 mm) with an intracavity aperture is used to generate TEM<sub>0,0,q</sub> only. From the number  $p$  of measured beat frequencies the number  $p+1$  of longitudinal modes are obtained occurring within the gain profile. Now, the exact resonator length is calculated from the relation  $L = c/2\Delta f$ , where  $\Delta f$  is the smallest beat frequency, which is 213,92 MHz in the example in the picture.

- **Beat frequencies between longitudinal and transversal modes, resonator length and curvature of mirrors (fast photodiode and spectrum analyzer)**



The beat frequencies between longitudinal (TEM<sub>0,0,q</sub>) and transversal modes (TEM<sub>m,n,q'</sub>) are measured with a fast photodiode and a spectrum analyzer. Here, a nearly confocal resonator (HR, OC both  $r = 700$  mm) with a length  $L$  of about 701 mm) is used. The beat frequencies  $\Delta f$  are given by

$$\Delta f_{m,n,\Delta q} = \frac{c}{2L} \left( \Delta q + \frac{1}{\pi} (\Delta m + \Delta n) \arccos \sqrt{g_1 g_2} \right)$$

With  $g_i = 1 - \frac{L}{R_i}$  as mirror parameters.

From the measured beat frequencies it can be obtained: (1) the number of longitudinal modes occurring in the gain profile, (2) all participating TEM-modes, (3) the exact resonator length, and (4) the exact curvature of the mirrors.