Laser Power Noise Measurements on a Cataphoretic He-Cd+ Laser

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Laser power noise has been measured on a cataphoretic $He\text{-}Cd^+$ laser. Care was taken especially to stabilize the temperature of the external cadmium source and to thermally insulate the discharge capillary. It was found that high and low noise operating regions exist with noise values below 1% rms at power levels up to 80% of the maximum obtainable ones.

Power output fluctuations at frequencies in the kHz to MHz range are commonly observed in gas lasers. In case of the cataphoretic He-Cd laser violent fluctuations of the order 50% peak to peak can occur [1]. This noise appears to be different in nature from e.g. He-Ne laser noise [2]. Its origin was attributed to neutral cadmium vapor density fluctuations [3] and to the coupling of Penning electrons to helium metastables [4]. In [5, 6, 7, 8] the role of moving striations in the positive column was investigated as being responsible for the output power fluctuations. Especially in [8] direct connections between noise and plasma oscillations were proven.

Several different attempts have been made to reduce He-Cd laser noise to slightly below the 1% rms level by special tube constructions [3, 4]. Unfortunately these constructions are more complex than the simple cataphoretic $He\text{-}Cd^+$ lasers with a single externally heated Cd-source and no diffusion return pass, but which normally exhibit rather high noise levels of the order 3–10% rms [5, 10]. To reduce this noise to the 1% rms level or slightly below, negative feedback [9] or modulation of the discharge current [10] has been employed. On the other hand, no attempt has been made to our knowledge to investigate the possibility of noise reduction by careful temperature stabilisation in case of these laser tubes.

Our He-Cd laser tubes are similar to the ones described in [5]. The positive column of the discharge is operated in a 2 mm internal diameter Pyrex capillary of 50 cm length with the Cd-reservoir being located in a side pocket near the anode end. The capillary is mounted coaxially within a 60 mm diameter glass tube, which provides thermal insulation of the laser capillary and also serves as a helium gas reservoir. The cadmium condensation zone at the cathode end of the tube is separated from the discharge region by employing a current path return. A tungsten wire and an externally dc-heated emitter cathode serve as electrodes. The cadmium vapor pressure is carefully controlled by externally heating the Cd-reservoir in a thermally insulated oven, the temperature of which can be stabilized to ± 0.3 °C by an electronic regulator. This corresponds to cadmium vapor pressure changes of the order 2%. The electrical power supply used is voltage regulated and a 20 kΩ resistor in series stabilizes the discharge.

The laser output power at $\lambda = 441$ nm is measured with a PIN photodiode, which covers the noise frequency range of interest here (0–1 MHz). A digital voltmeter records both the dc power and the rms noise (bandwidth 10 Hz–1 MHz). Peak to peak fluctuations are recorded with an oscilloscope. The frequency spectrum of the laser power is measured with a spectrum analyzer, which covers the frequency range 0–400 kHz.

Figure 1 shows the results of laser power fluctuation measurements as a function of Cd-oven temperature for $I = 100$ mA and $p = 5.4$ mbar. The solid curve represents the average laser power and the hatched area indicates its peak to peak fluctuations. The broken line gives the ratio of rms noise power to average laser intensity. Figure 1 shows

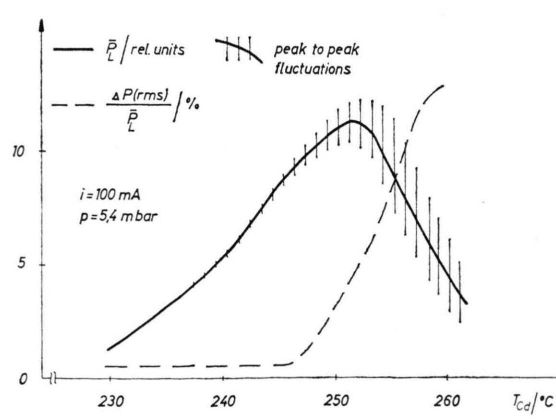

Fig. 1. Laser output power noise as a function of Cd-oven temperature.

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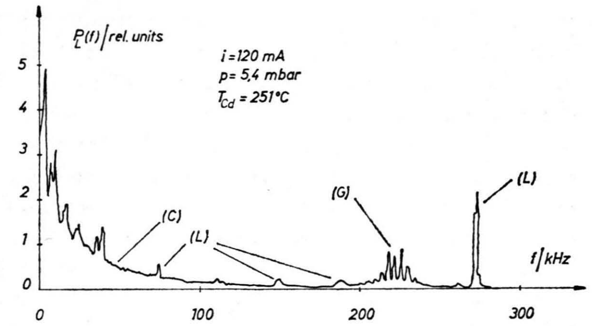
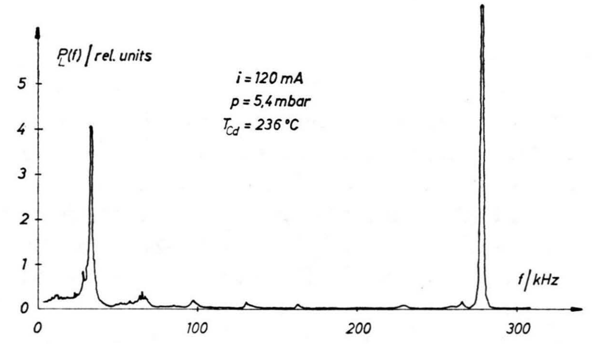


a)



b)

Fig. 2. Frequency spectra of laser output power a) high noise, b) low noise.

clearly that for temperatures below approximately 246 °C laser output fluctuations are lower than 1% rms, but exhibit a sudden, step-like increase towards higher temperatures. This behavior is in qualitative agreement with the results reported in [5], but in the low fluctuation range our noise values are lower by a factor of 2–3.

Figures 2a, b show two frequency spectra of the laser power as measured with the spectrum analyser for $i = 120$ mA, $p = 5.4$ mbar for high (Fig. 2a, $T_{Cd} = 251$ °C) and low noise (Fig. 2b, $T_{Cd} = 236$ °C) operating conditions. The power spectrum of Fig. 2a consists mainly of a low frequency continuous component (C), which roughly is inversely proportional to frequency, of "isolated lines" (L) and "grouped lines" (G). The features (L) and (G) can be traced back to positive column microinstabilities, known as moving striations [8]. On the other hand, the origin of (C) is unclear. It is interesting to note in this context that side light spectra of the laser discharge only show (L) and (G) but not (C), an observation which was first made by Knauer and Penning [8]. For low noise conditions the shape of the power spectrum changes. In Fig. 2b both the low frequency component and the "grouped lines" disappeared, while the intensity of the "isolated lines" increased. Our data show that an increase of cadmium oven temperature gradually shifts the frequencies of (G) and (L). The rather sudden transition to low laser noise (see Fig. 2) occurs when the frequency difference between (L) at f 280 kHz and (G) is small enough for (G) to be locked by (L) to a single frequency. At the same time the low frequency continuum (C) disappears. Similar observations were made in [8, 10]. This phenomen suggests that the $1/f$-noise component, which contains most of the total noise power, is closely related to the "grouped lines", possibly via some nonlinear interaction.

We have measured laser power noise of cataphoretic He-Cd^+ lasers with external Cd-source, carefully stabilized cadmium oven temperature and thermally insulated discharge capillary. High and low noise operating regions were found. Noise values below 1% rms could be obtained for power levels up to 80% of maximum power.

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