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Output Power Enhancement of the 632.8 nm Monomode He–Ne/I_2-Laser

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Abstract. For the He–Ne/I_2-laser, a stable monomode operation has been realized when the tube pressure exceeds a certain level. An output power of more than 1 mW has been obtained at the 632.8 nm laser transition. Within the monomode tuning range of the laser, the d, e, f, g, and h, i, j iodine hyperfine components of the $R(127)$ line of the 11–5 band of the $B^3\Pi^+_{0u} - X^1\Sigma^+_{0g}$ electronic transition have been observed. The mode selection method used makes it possible to increase the contrast of the iodine hyperfine components.

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The helium-neon iodine-stabilized laser is of particular interest as a wavelength standard in the visible part of the spectrum. Such lasers have been developed by several laboratories [1]. For 632.8 nm single mode operation without mode selector, the use of a short cavity is required, and thus the output power of the He–Ne/I_2-system is about hundred µW. Usually, in order to increase the output power of high stability lasers, the high-power monomode laser frequency is locked to the frequency of a low power, high stability He–Ne/I_2-laser [2].

In this paper we report a simple method to increase the monomode output power of He–Ne/I_2-laser.

1 Single Longitudinal Mode Selection

The laser cavity is made of a thick wall quartz tube. On its two ends mirror holders are cemented which contain piezoelectric transducers used for frequency modulation and tuning. The optical resonator is formed by two spherical mirrors ($R = 2$ m) placed at a distance of $L = 1.13$ m. The transmission of the output mirror is 1.3%. The laser tube and the absorption cell are mounted inside the quartz tube. The laser tube is 0.58 m long and has a 1.85 mm bore diameter. The length of the $^{127}I_2$-absorption cell is 0.20 m and its pressure is adjusted by a thermoelectric cooler. Under these conditions, the laser operation is at the basic transverse mode TEM_{00q}. The experiments were carried out using a natural mixture of Ne and He isotopes.

In order to increase the monomode output power of the He–Ne/I_2-laser, we increased the gas-mixture pressure in the laser tube. This method is proved to be very simple and effective for He–Ne lasers [3–5].

The generation spectrum was observed using a Spectra Physics 450-30 optical spectrum analyzer.

The output power dependence of the He–Ne/I_2-system on the gain tube gas pressure at different temperatures of the I_2 source T_{I_2} is depicted in Fig. 1. Curve (1) shows the output power dependence when the iodine vapour is frozen ($T_{I_2} = -196°$ C). At the maximum laser output power

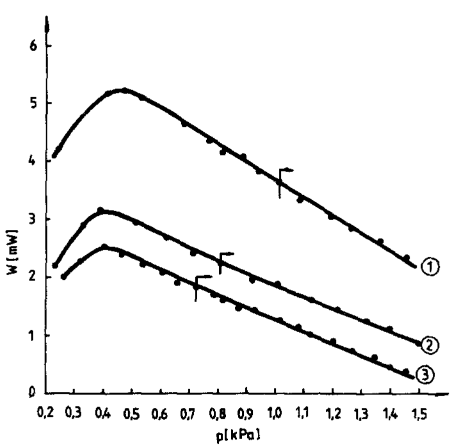

Fig. 1. Dependence of the output power on the gain tube gas pressure at different temperatures T_{I_2} of the I_2 source and He/Ne = 23. At each point, the gas discharge current is optimal (the current at which the output power has an optimum). The optimal discharge current i decreases when the pressure increases, and for the region where only monomode operation exists, i changes from 4 to 2 mA. (1) $T_{I_2} = -196°$ C; (2) $T_{I_2} = 8°$ C, (3) $T_{I_2} = 15°$ C

the laser oscillation occurs at several longitudinal modes. When increasing the pressure, the laser starts monomode generation at the point marked by an arrow. At pressures above this point only monomode operation exists. The multimode power to single-mode power conversion coefficient is $K = 0.69$ ($K = W_1/W_{opt}$, where W_1 is the maximum single-mode output power and W_{opt} the optimum multimode output power).

A larger iodine vapour pressure in the absorption cell causes a slight increase of the efficiency K. This can be seen from curves (2) and (3) in Fig. 1, where the output power dependences at $T_{I_2} = 8°$ C and $T_{I_2} = 15°$ C are shown. (The monomode operation starts at the point marked by an arrow.) In this way, an increase of the gain tube gas pressure results in an efficient single-mode operation for the He–Ne/I_2-system. A monomode output power more than 1 mW is easy to achieve.

2 Saturated Absorption Peaks

To build a frequency stabilized laser, one has to obtain saturated absorption peaks in the power tuning range. The observation and detection technique was modulation of the cavity length with 1.42 kHz and then detection of the resulting 1.42 kHz modulation of the power output with a phase sensitive detector (PSD). This produces a PSD signal proportional to the first derivative of the output power. This derivative was observed as a function of frequency by scanning the length of the cavity and observing the PSD output. A typical first derivative curve is shown in Fig. 2. It may be seen that four peaks fall within the single mode tuning range of the laser which has a mode spacing of 133 MHz. A consideration of the possible hyperfine peaks shows that these peaks correspond to the d, e, f, g iodine hyperfine components of the $R(127)$ line of the 11–5 band of the $B^3\Pi^+_{0u} - X^1\Sigma^+_{0g}$ electronic transition. In this particular case, the other hyperfine components fall outside this range. However, the h, i, j components have been observed by frequency scanning in the opposite direction.

In principle, the mode selection method used makes it possible to increase the contrast of the iodine hyperfine components. Because of the single-mode operation being performed by an increase of the gain tube pressure, the use of a short cavity is not required, and thus the absorption cell length is not limited. According to [6], when the ratio a of the saturation parameters of the absorbing and the amplifying media is $a > 1$, the peak contrast increases monotonically when increasing the absorption. The ratio a is given by $a = I_G/I_A$ [7], where I_G is the saturation intensity of the Ne line and I_A is the saturation intensity of the I_2 hyperfine transition. Under the conditions of our experiment (gain tube gas pressure $p = 0.67$ kPa, I_2 source temperature $T_{I_2} = 16°$ C), we estimate $I_G = 5 \times 10^5$ Wm^{-2} [8] and $I_A = 0.83 \times 10^4$ Wm^{-2} [7].

Our peak contrast measurements have shown a contrast value of (0.3 ± 0.06) %. So, some enhancement of the peak contrast takes place for the concrete He–Ne/I_2-system.

It is well known, that a high gas pressure in the gain tube may lead to plasma oscillations and a decrease of the signal to noise ratio [9]. As a first approach to overcome this problem, a specially built laser tube was examined. It has two anodes located at the two ends of the capillary and one common cathode coaxially to the capillary.

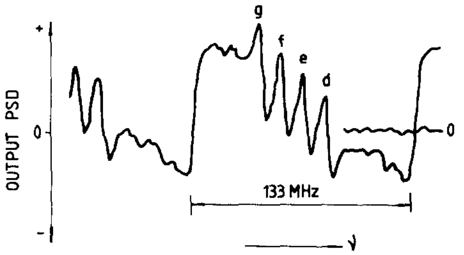

Fig. 2. PSD integrator output as a function of cavity tuning. Output power $W = 0.3$ mW, gain tube gas pressure $p = 0.7$ kPa, He/Ne = 40, and gas discharge current $i = 3.2$ mA. Temperature of the I_2 source $T_{I_2} = 13°$ C

Our experimental investigations have shown that a very effective additional decrease of plasma oscillations can be achieved with this tube by an increase of the He to Ne ratio. At He/Ne = 10 and a gain tube gas pressure of $p = 0.72$ kPa, the ratio N of the average intensity deviation (r.m.s) to the actual intensity reaches $N = 9\%$. At He/Ne = 25, discharge current $i = 2 \div 4$ mA and $p = 0.72$ kPa, the laser intensity stability is $N = 0.1\%$. When He/Ne = $30 \div 40$, $i = 1.5 \div 6$ mA, and $p = 0.72$ kPa, an intensity stability level of $N \leq 0.01\%$ can be achieved. For maximum monomode output power, the optimum He/Ne ratio is 25, and an additional increase of up to 40 does not decrease the laser output power significantly.

3 Conclusions

The monomode output power of a He–Ne laser containing an intracavity I_2 absorption cell is increased by a simple method of increasing the gain tube gas pressure. In the prescence of an increased gain tube gas pressure, seven saturated absorption peaks have been observed within the monomode tuning range of the laser. Peak contrast and signal to noise ratio improvement is obtained. A series of experiments is in progress to investigate the dependence of various parameters on the gain tube, the absorption cell, and the frequency modulation behaviour.

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