FURTHER MEASUREMENTS ON THE NOISE OF A D.C. EXCITED He-Ne LASER OSCILLATOR

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In our search for high-intensity radiation sources showing degeneracy effects in the photon noise as predicted by Bose-Einstein statistics, we tentatively tried to interprete in our earlier work the high excess noise of a He-Ne laserbeam in these terms [1]. Other authors finding considerably less excess noise in different types of He-Ne lasers [2-5], have suggested that the excess noise is a modulation effect of discharge fluctuations on the laser beam [3,5]. Our further measurements to be described here confirm this suggestion.

The laser used by us is a d.c. excited short He-Ne laser with plane parallel mirrors operating at 1.153 μ wavelength of the type described in ref. 6. The central bore of the tube had a diameter of 1.5 mm instead of 3 mm, which resulted in a single axial mode operation [7]. In fig. 1 we plotted the frequency spectrum of the discharge current noise, the discharge light noise and the laser noise. The discharge current noise and the light noise as well as the laser noise change in a similar way with varying discharge current. In contrast with the current noise the laser noise power as a function of frequency was checked to be constant down to at least 20 c/s. Below 3.8 mA discharge current the laser exhibits noise levels several orders of magnitude less than those shown in fig. 1.

The noise spectra shown in fig. 1 suggest the existence of a phase correlation between the laser noise and the discharge current noise as well as the discharge light noise. The absolute value of the coefficient of cross correlation between discharge current noise and laser noise turned out to be 35% at frequencies below the peak-frequency in the discharge noise spectrum and was found to increase up to 100% in the range from 30 kc/s to 100kc/s. The phase angle of the correlation coefficient increases from 8° at 2 kc/s to about 90° at 20-30 kc/s and decreases again to less than 5° at higher frequencies

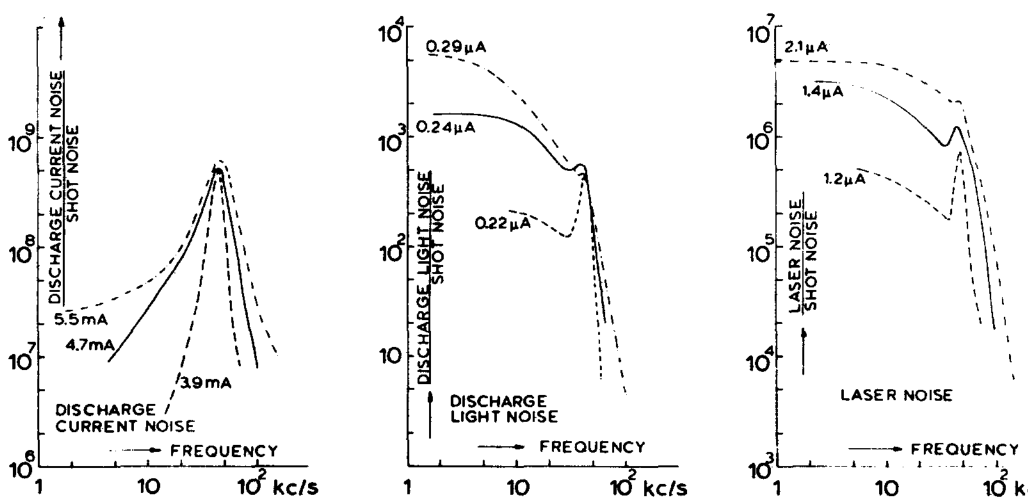

Fig. 1. Discharge current noise, discharge light noise and laser noise compared to shot noise, plotted as a function of frequency for discharge currents of 3.9, 4.7 and 5.5 mA.

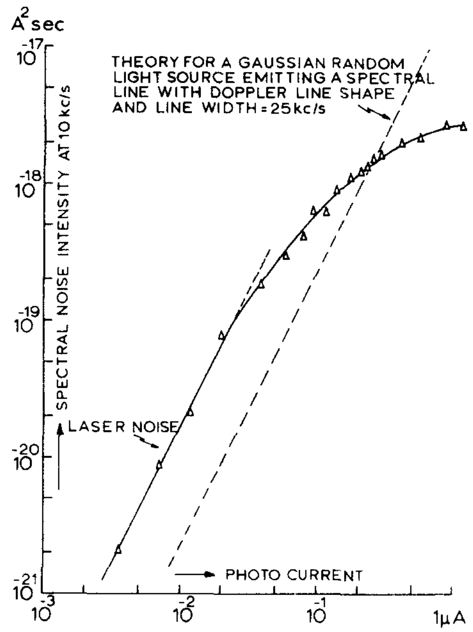

Fig. 2. The spectral noise power at 10 kc/s plotted as a function of photo current. The photo current is proportional to the d.c. output of the laser.

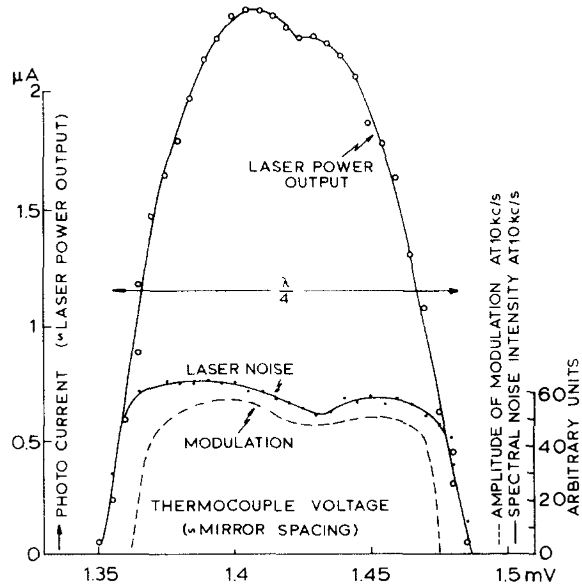

Fig. 3. Photo current, spectral noise power and modulation amplitude plotted versus thermocouple voltage, which is a measure for the temperature of the wall of the lasertube.

(cf. ref. 5). The correlation between discharge light noise and laser noise was found to depend on the part of the discharge column viewed by the detector, probably due to differences in phase angle.

The spectral noise power of the laser, measured at 10 kc/s, as a function of photo current, is plotted in fig. 2, and compared to the theoretically predicted B. E. noise of a Gaussian random source [9]. The d.c. photo current which is proportional to the laser power output, was varied by thermal tuning of the interferometer [8]. The systematic deviation between experimental and theoretical noise values are evident. In our previous measurements [1] the oscillation frequency was near line centre and noise levels were found, which were always lower than the theoretical value (in fig. 1 of ref. 1 the scale of the theoretical curve should be multiplied by a factor 10).

The well-known single mode tuning dip in the power output at line centre is less pronounced with naturally occurring neon, as used in our case [10-12]. Fig. 3 shows that the curve describing the noise power also reveals a dip. In addition, a dip was found in the a.c. output of the laser when the laser output was purposely modulated by injecting an a.c. current into the discharge circuit. These dips show clearly the saturation of the atomic resonance curve. Further analysis has been shown that it is not possible to predict the laser noise from the discharge current noise on the basis of the relation found between laser modulation and current modulation.

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1. P.T.Bolwijn, C.Th.J.Alkemade and G.A.Boschloo, Physics Letters 4 (1963) 59.
2. H.Z.Cummins, Physics Letters 5 (1963) 39.
3. J.A.Bellisio, C.Freed and H.A.Haus, Appl. Phys. Letters 4 (1964) 5.
4. R.L.Bailey and J.H.Sanders, Physics Letters 10 (1964) 295.
5. L.J.Prescott and A.Van der Ziel, Appl. Phys. Letters 5 (1964) 48.
6. H.G.Van Bueren, J.Haisma and H.De Lang, Physics Letters 2 (1962) 340.
7. J.Haisma, H.De Lang and M.Koedam, private communication.
8. J.Haisma and H.De Lang, Physics Letters 3 (1963) 240.
9. C.Th.J.Alkemade, Physica 25 (1959) 1145.
10. W.E.Lamb Jr., Phys. Rev. 134 (1964) A 1429.
11. R.A.McFarlane, W.R.Bennett Jr. and W.E. Lamb Jr., Appl. Phys.Letters 2 (1963) 189.
12. A.Szöke and A.Javan, Phys. Rev. Letters 10 (1963) 521.