Gain Measurements in a Nitrogen Laser Amplifier

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An oscillator amplifier nitrogen laser arrangement has been built. A small signal gain up to 340 dB/m was measured. Furthermore, image amplification of 170 times was demonstrated.

Numerical values for the gain in nitrogen lasers are usually obtained from plots of the output power versus the active length of nitrogen laser oscillators [1, 2]. This note describes gain measurements in a nitrogen laser amplifier. In addition we report on an image amplification experiment.

Experimental Results

Figure 1 is a schematic diagram of the system. It consists of two transversely excited N_2 lasers one of which, the amplifier, can be driven with the output of the oscillator attenuated by calibrated neutral density filters NDF. Details of the construction and the performance of this type of N_2 laser are described in [2]. Both tubes are identical in geometric shape to get the same time behavior of the discharge. The tubes have an active length of 90 mm, an electrode spacing of 18 mm and are terminated by quartz Brewster angle windows. The capacitors C_1 and C_2 in Fig. 1 represent the energy storage part of the dual flat plate transmission line which had a characteristic impedance of 0.4 Ω and a capacitance of 10 nF. The oscillator cavity consists of a dielectric coated mirror M_1 of 99% reflectivity at 337 nm at the rear end and of an uncoated quartz plate M_2 as output mirror. The oscillator pulse is monitored by photodiode P_1. With the amplifier unpumped and the attenuating filter removed photodiode P_2 is used to measure the maximum input power, otherwise photodiode P_2 is used to measure the output power. In order to avoid optical feedback from the amplifier to the oscillator, the two lasers are separated by a distance of 1.2 m, corresponding to an optical delay of 4 ns (8 ns round-trip-time), whereas the FWHM of the pulses is 5 ns. The pulse forming parts of both units are connected to a single spark gap through transmission lines. The lengths of those lines have been adjusted so that the difference in pulse propagation time from the spark gap to the laser units equals the optical delay of 4 ns. Thus it is assured that the optical oscillator pulse always reaches the amplifier at the time of its maximum inversion. The gas we used was pure nitrogen at a pressure of 50 Torr in the oscillator and 62 Torr in the amplifier at a typical flow rate of 5 l/min. All measurements were taken at 10 Hz repetition rate. The oscillator pulse proved to be constant within 5%. The input power of the amplifier could be varied from the maximum oscillator power of 5 kW down to .2 W by attenuation with the filter set NDF_1. The power amplification G (in dB) was determined as the log. ratio of amplifier output P to input power P_i:

$$G = 10 \log (P/P_i).$$

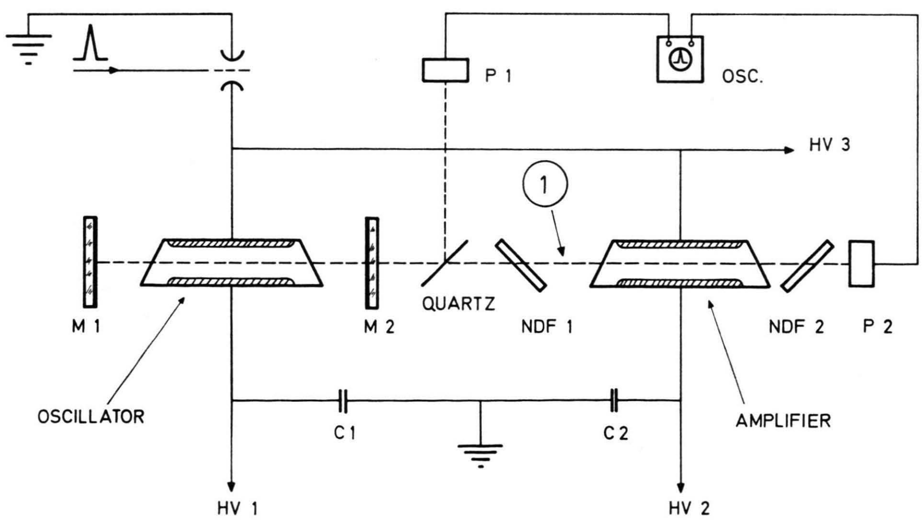

Fig. 1. Oscillator-amplifier arrangement; P_1, P_2: calibrated ITT-photodiodes F4018 UVG; Osc.: Tektronix 519 travelling wave oscilloscope; NDF_1, NDF_2: calibrated neutral density filters on Balzers quartz substrate; C_1, C_2: energy storage part of flat plate transmission lines; HV_1, HV_2, HV_3: regulated high voltage power supplies; M_1: 99% mirror; M_2: uncoated quartz plate.

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The minimum input power that could be used for the measurements was determined by the signal to noise ratio $S/(S+N) > 10$, where the noise power N is mainly spontaneous emission from the discharge in the amplifier tube. At the three discharge voltages 13, 15, and 17 kV the amplifier noise was 14, 20, and 30 W, respectively. The oscillogram of an amplified pulse in comparison with the oscillator pulse is shown in Figure 2. The shapes of pulses are similar but the amplified pulse is slightly shorter and has a slightly faster risetime. The diagram in Fig. 3 shows the gains per meter as a function of incident power P_i. Especially noteworthy are the very high values for the small signal gain that prevail up to 1 W input power. For 17 kV the measured small signal gain is 340 dB/m. Tentative measurements at 19 kV showed that even higher gains could be obtained. At lower operating voltages the number of excited N_2 molecules is decreased and the gain correspondingly lowered. The saturation of the amplification shown at higher input powers is in agreement with an approximate calculation along the lines given by [3].

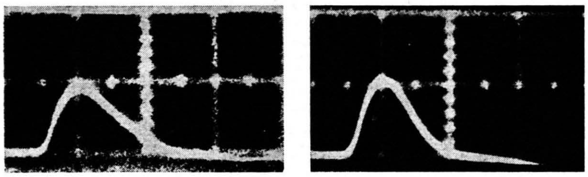

Fig. 2. Several superimposed pulses of a) oscillator (vertical: 2.5 kW/div.; horizontal: 5 ns/div.); b) amplified output (vertical: 45 kW/div.; horizontal: 5 ns/div.).

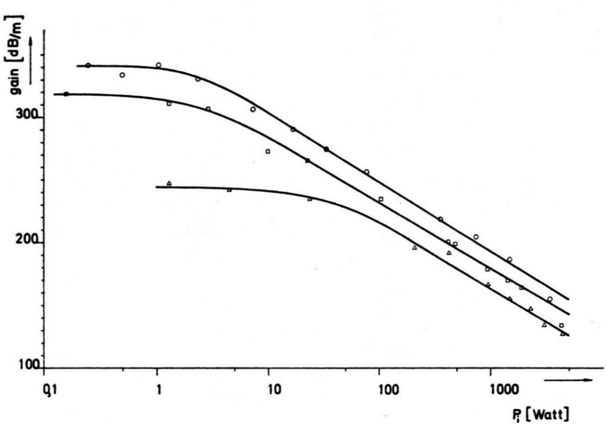

Fig. 3. Gain per meter as a function of incident power P_i. ○: 17 kV; □: 15 kW; △: 13 kV charging voltage.

Application as Image Amplifier

To study the image transfer possibilities of the oscillator amplifier system, a simple setup for image amplification was chosen. For this purpose a slide of 13 mm × 5 mm could be positioned at position 1 in Figure 1. Instead of the photodiode P_2, a camera was mounted. Figure 4 shows a picture of the slide with and without amplification. In the case without amplification, the oscillator signal was attenuated by NDF_1 to the appropriate level to illuminate the slide and give a satisfactory optical density on the film.

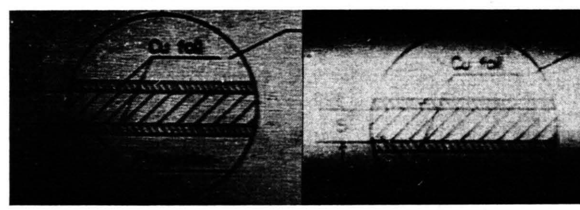

Fig. 4. a) Photograph of image; b) photograph of amplified image attenuated by a factor of 170 referred to a).

When the amplifier was used, an additional set of calibrated filters NDF_2 had to be positioned in front of the camera in order to obtain a nearly similar exposure of the film. In both cases the camera was focused on the slide. From the filter factors, an image amplification of 170 was calculated for a discharge voltage of 14 kV. Figure 4 shows that in spite of the high amplification the image quality is not degraded.

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