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Letters to the Editor

Compact N_2 laser pumped dye 4 laser for tumor diagnostics

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Two laser systems of compact construction and easy operation have been designed. The Ne_2 laser system appeared very useful for cancer diagnosis. The nitrogen-dye laser generated a longer pulse (than TEA N_2 laser) of different wavelengths to match different photosensitizers.

1. Introduction

Photodynamic therapy (PDT) has become an effective modality in the treatment of cancer, especially in the early stages. This method has also coupled successfully with surgical methods. There have been several attampts to apply different laser systems to cancer diagnosis and therapy.

An excimer-dye laser has been commonly used [1], [2] as a light source to excite photosensitizers, *e.g.*, hematoporphyrin derivative (HpD). In this system, the laser emitted 405 nm and 630 nm wavelength of pulse irradiation for diagnosis and treatment, respectively.

Since the diagnosis can be done with lower radiation power level than that required for treatment, while both can be separated in time, we developed a system based on nitrogen-dye laser, especially destined for cancer diagnostics. In this system, the laser emitting 405 nm wavelength of pulse irradiation is used as a light source to excite a HpD photosensitizer. This system is much simpler than that employing the excimer-dye laser.

Recently, the main purpose of studies was the search for new photosensitizers effective both for photodetection and phototherapy of tumor. In order to excite these photosensitizers, a nitrogen laser was successfully used [3]. The Al-phthalocyanine was used in this case. Under UV-excitation the tissue fluorescence signal consists of auto- and drug-related fluorescent signal. The comparative analysis of these signals, based on developed mathematical procedure, provides the opportunity to detect the useful signal of tumor marker on the autofluorescence background. According to these results [3], we designed a N_2 laser based on Nitro series of TEA N_2 laser adding fiber optics necessary for PDT application.

2. Laser system constructions

We have constructed a sealed-off laser working with nitrogen at low pressure. The laser generates radiation ($\lambda = 337.1$ nm) with the pulse duration of 5 ns and energy up to 0.3 mJ. The pulse repetition frequency ranges from 1 to 10 Hz. In this N_2 laser, the LC-invert circuitry with automatic UV preionization was applied. The capacity of two batteries of capacitors was 22.5 nF and 10 nF, respectively. The electrodes of 30 cm in length were separated by 2 cm. A simple dye laser was connected with N_2 laser in one unit. The N_2 pumped radiation is focused on the dye cuvette by plane-cylindrical lens. This lens plays also the role of a resonator coupled mirror in the nitrogen laser. The dye solution is circulated. The dye laser radiation is led out using fiber guidance. The schematic diagram of the elaborated laser system is shown in Fig. 1.

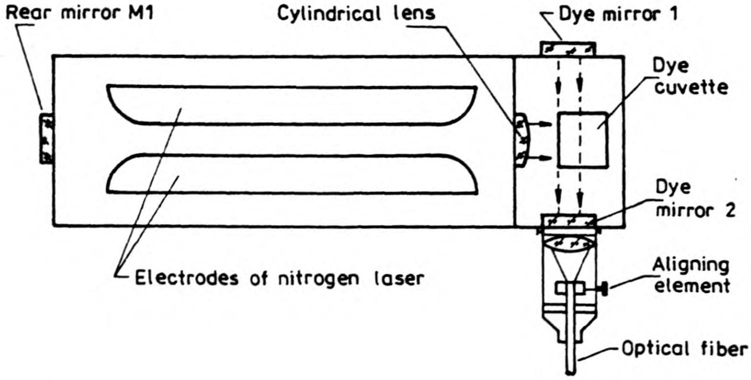

Fig. 1. Schematic diagram of the dye laser pumped by compact nitrogen laser

The results presented below were obtained from preliminary study performed using solution of diphenyl stilbene (PDT) in dioxane and, in consequence, the laser generated radiation of 405 nm wavelength. The output power of the dye laser as a function of pump power N_2 laser is presented in Fig. 2a. The maximum efficiency was 12.5%. The output laser power as a function of the dye concentration is

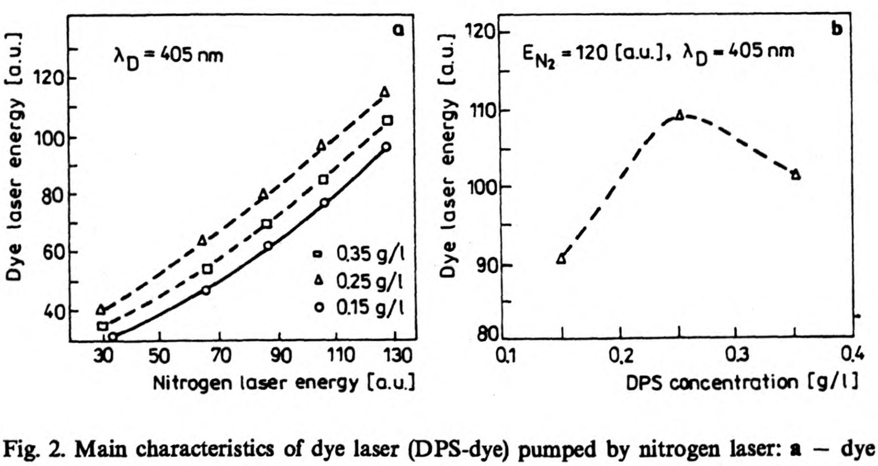

Fig. 2. Main characteristics of dye laser (DPS-dye) pumped by nitrogen laser: a – dye laser energy as a function of nitrogen laser energy, b – dye laser energy as a function of laser dye concentration

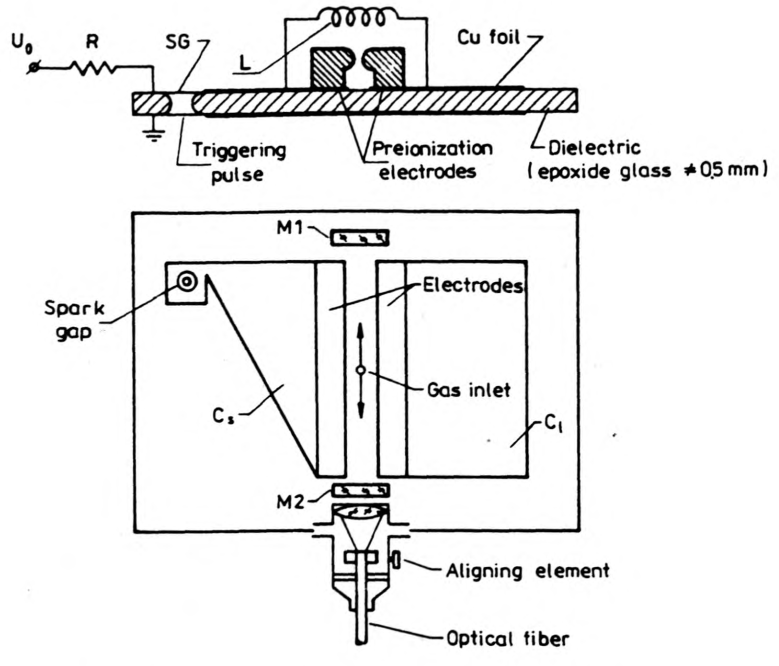

Fig. 3. Schematic diagram of nitrogen laser with fiber optic coupler

presented in Fig. 2**b**. The maximum laser power was obtained for concentration of 0.25 g/l. The radiation of 405 nm wavelength was suitable to excite the HpD photosensitizer.

A second N_2 laser construction was designed to excite another photosensitizer, *i.e.*, Al-phthalocyanine. This construction was based on small TEA N_2 laser concept. The idea of this laser depends on realization of transverse electric discharge in a gas, while the discharge wave propagates along the laser channel and is properly synchronized with the radiation propagation in the active medium. A scheme of this laser system is shown in Fig. 3.

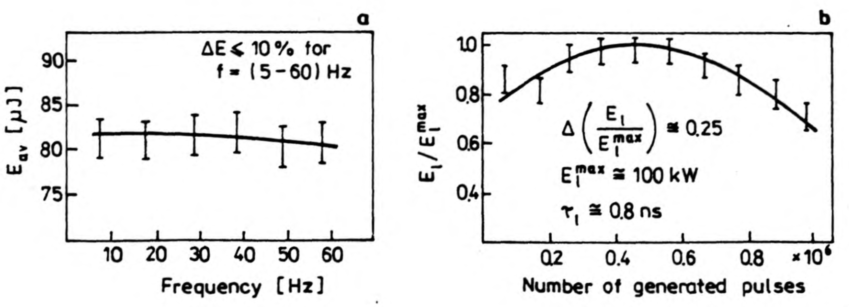

Fig. 4. Some results of investigation of TEA nitrogen laser: **a** — pulse energy *vs.* frequency, **b** — reliability tests

The laser head consists of three fundamental sub-assemblies. The first one is the laser chamber made of the main electrodes with optimum radii of curvature of their fronts and a casing made from plexiglass ended with optical elements. The second sub-assembly of the laser head is a plate made from two-side copper laminated epoxide glass of 0.5 mm in thickness. Suitably formed top side of that plate makes two plane capacitors (C_l, C_s): storing electric energy (C_l) and forming travelling voltage wave (C_s). The third sub-assembly is two-electrode high-pressure spark gap. The fiber optics was used for output laser beam. The fiber guide is a quartz fiber of 0.6 mm in diameter.

This laser was very intensively studied in respect of output stability. Some results of measurements are presented in Fig. 4. In this figure, laser pulse energy *vs.* frequency and results of reliability tests are shown, respectively.

4. Conclusions

Two laser systems destined for cancer diagnosis have been designed. Both systems are characterized by compact construction and easy operation, especially in comparison with excimer-dye laser. The N_2 laser system is very useful for cancer diagnosis because of its simplicity. The nitrogen-dye laser generates a longer pulse than TEA N_2 laser and offers possibility to generate different wavelengths to match different photosensitizers by using different laser dyes. Both systems are very easy to handle and economical in operation (because of using nitrogen as the active gas), and can be commonly applied for cancer diagnosis. Investigation of these systems under clinical conditions is needed.

References

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