Ultrafast Moving Bubbles Initiated During The Propagation of Focused laser Pulses in water

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Abstract. The propagation in water of nanosecond focused laser pulses having power densities up to terra watts / cm2 and wavelength of 532±2nm, has been investigated extensively by our group. Fast imaging as well as time resolved photography of the nonlinear optical processes, revealed the formation of running spherical foci as well as luminous cavitation bubbles along the direction of the propagating beam. Associated mechanical effect of shock pressure was measured at the exit window as soon as the bubbles collapsed, using piezoelectric silicon gauge. The lifetime of the luminous cavitation bubbles and running spherical foci were found to vary between 160 to 50 ps. Their propagation velocities were estimated to be of the order of 10^6 m/s. The results are discussed and could be explained partially according to the Moving Focus Model, the self-phase Modulation Model and other associated processes.

1. INTRODUCTION

Laser induced nonlinear optical and mechanical effects in aqueous fluids are of importance for medical applications of lasers in surgery, ophthalmology, dermatology and dentistry. Water being one of the main constituents of biological tissue has been chosen by several researches as well as in this study as the fluid medium. The numerical studies of nonlinear propagation of picosecond laser pulses in water [1], predicted that self focusing preceded laser induced breakdown. The physical processes encountered when pulsed low energy nanosecond and picosecond laser pulses pass through various aqueous fluids [2-5] served as a tool of optimization for various possible applications. Calculations of thresholds for laser induced plasma formation in water were reported for l00 ns and l00 fs time duration of laser pulses on the bases of a rate equation [6]. The evolution of two or three photon fluorescence was visualized as filamentation when femtosecond laser pulses passed through dilute coumarine solution in methanol [7]. Schroeder and Chin [8] explained the formation of filaments in dilute dye solution due to the interaction of femtosecond IR laser pulses, in the frame of group velocity dispersion and ending at self-steepening. Several experiments have been reported for propagation of femtosecond laser pulses invapour and in air [9-12] as well as their expected importance for atmospheric information [13].

In this work we present temporal and spatial optical and mechanical effects when nanosecond high energy laser pulses of the second harmonic wavelength λ=532±2 nm of the NdYAG laser was focused to power densities up to terra watts/cm2 in bi-distilled deionized water. The results obtained are analyzed according to the Moving Focus Model (MFM) providing intensity clamping leading to tunnel ionization of the water molecules. Possible evolution of plasma would lead to shock wave propagation. The experimental results measured and estimated helped to reach better understanding of the encountered processes.

2. EXPERIMENT

A block diagram of the experimental set up is shown in figure 1. It consists mainly of the interaction pyrex cylindrical cell of diameter 2.5 cm, length 20 cm fixed on a translational table with its axis parallel to the horizontal plane. It has an input quartz window through which the laser beam could be focused by an external lens L1 into the cell at a distance of 1 cm from the input window to a diameter of ~20-50 μm and could propagate along the cell axis.

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