NUMERICAL INVESTIGATION OF THE PLASMA FORMATION IN SKIN TISSUE BY NANOSECOND Nd: YAG LASER PULSE

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Abstract. A numerical analysis is performed to investigate the comparative contribution of the mechanisms responsible for electron gain and losses in laser-induced breakdown of the skin and underlying tissues. In this regard we adopted a simple theoretical formulation relying on the numerical solution of a rate equation that describes the growth of the electron density due to the joined effect of multiphoton, cascade and chromophore ionization processes. Here, the rate also includes the effect of electron loss due to diffusion and recombination processes. The analysis considered skin tissue irradiated by a Nd:YAG laser radiation in the 200 – 550 nm wavelength range with 6 ns pulse duration full-width half-maximum (FWHM).

1. Theoretical Background

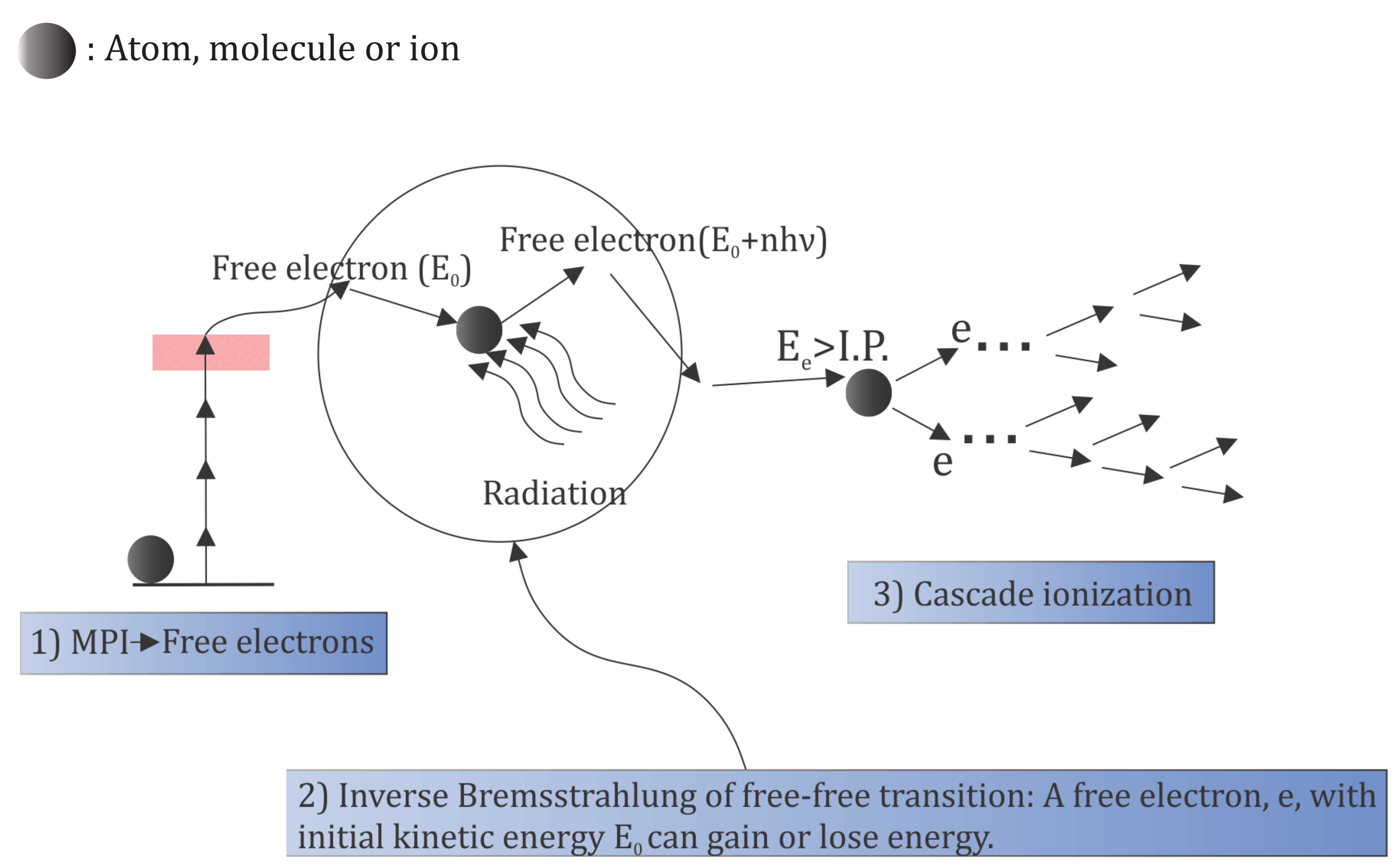


Fig. 1. Visualization of nanosecond laser induced breakdown [Chin, S.L., 2004. From multiphoton to tunnel ionization. In Advances in multi-photon processes and spectroscopy (pp. 249-271)].

Electron gain and loss processes can be described by the following rate equation:

$$\frac{d\rho}{dt} = \left.\frac{d\rho}{dt}\right|_{mpi} + \left.\frac{d\rho}{dt}\right|_{ch} + W_{casc}\,\rho - W_{diff}\,\rho - W_{rec}\,\rho^2. \qquad (1)$$

Electron **gain** processes	Electron **loss** processes
$\left.\frac{d\rho}{dt}\right|_{mpi}$ - multiphoton ionization rate	W_{diff} - diffusion
$\left.\frac{d\rho}{dt}\right|_{ch}$ - chromophore ionization rate	W_{rec} - recombination rate
W_{casc} - cascade ionization rate	

3. Results

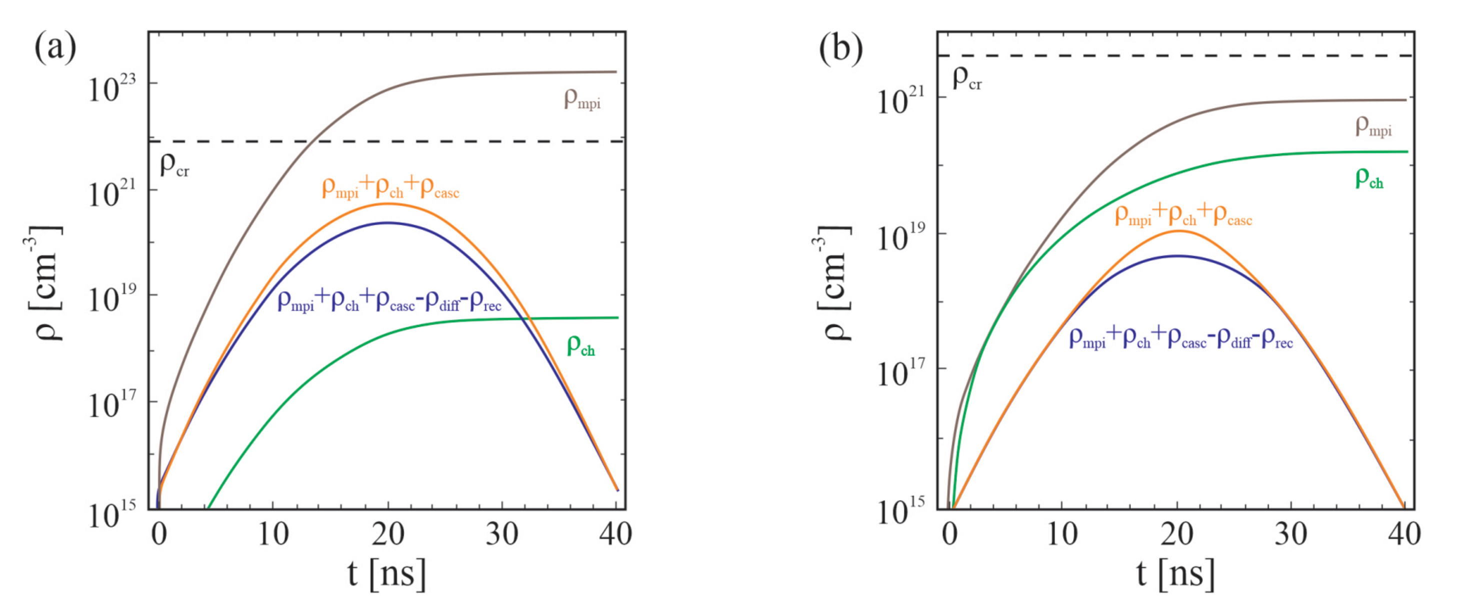


Fig. 2. Evolution of the free-electron density for different gain and loss processes at wavelength: (a) 355 nm and (b) 532 nm. The dashed curve is the critical electron density, ρ_{cr}.

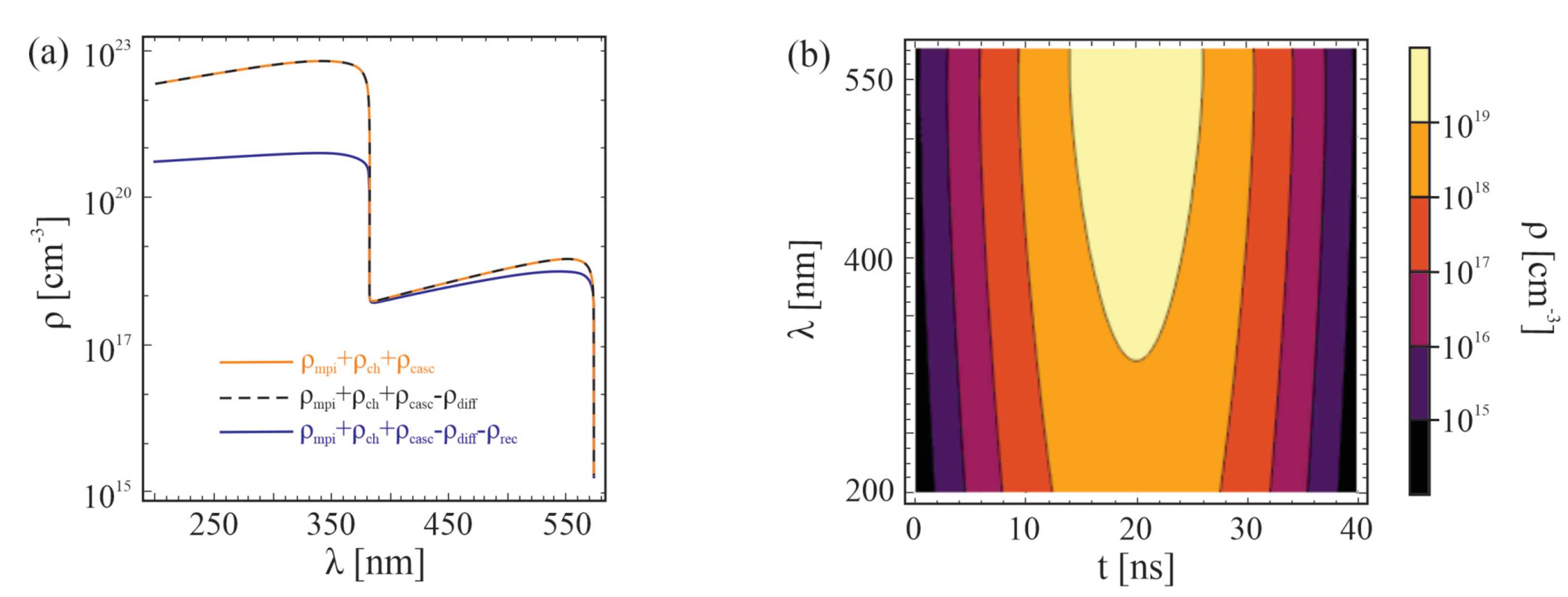
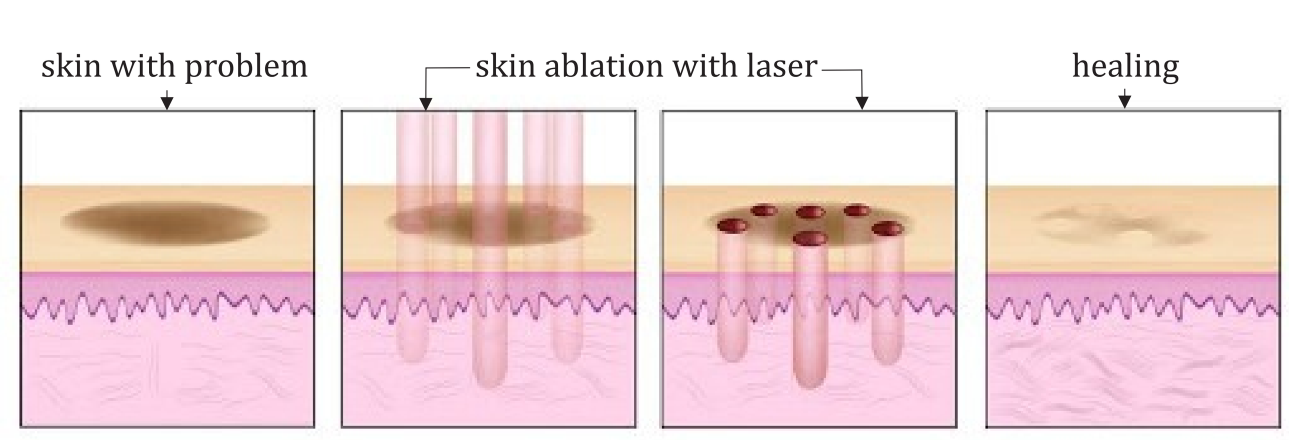
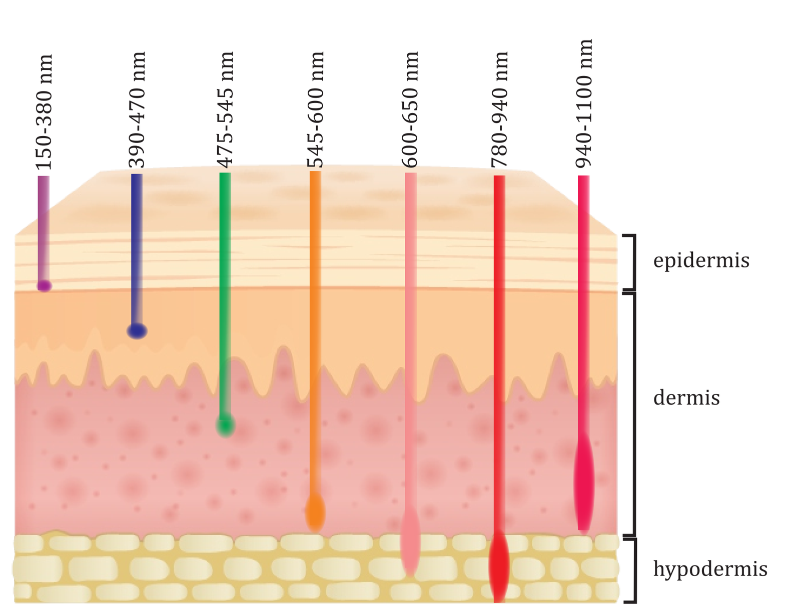
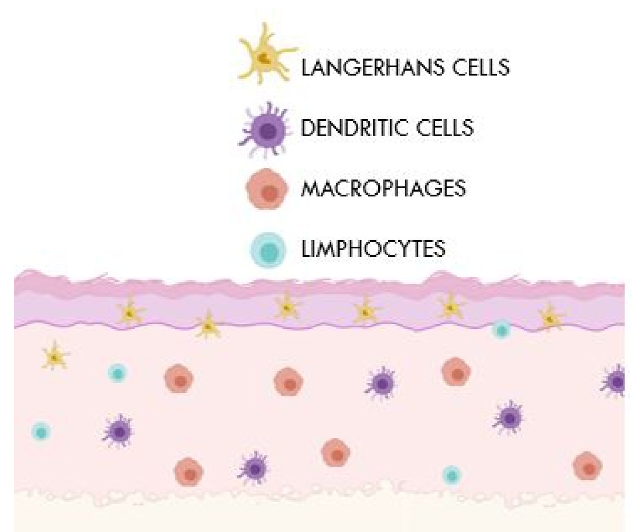


Fig. 3. (a) wavelength dependence of electron density for electron creation and loss processes participating in the electron density equation, (b) contour representation of free electron density as a function of time and laser wavelength.

2. Artificial skin - models and applications







3. Conclusion

In summary, we analyzed the time evolution of the free electron density in the absence and presence of each gain and loss process included in the rate equation describing the time evolution of the free electron density in LIB. Beside standard multiphoton and cascade ionization rates, in this paper we incorporated chromophore ionization pathway to explain the skin tissue ablation by nanosecond laser pulses. The presented results verified that in the nanosecond regime, the losses of the free electrons via recombination and diffusion can be neglected (especially when the wavelength exceeds 532 nm) because of the relatively long lifetime and diffusion time of those electrons. Such statement is also confirmed by other researchers (Vogel A., Noack J., Huttman G. and Paltauf G.: 2005, *Appl. Phys. B*, **8**1, 1020). We also observed the wavelength dependence of the free electron density and analyzed contribution of each gain and loss mechanisms on this dependence. Our results indicated that shorter wavelengths lead to enhanced electron densities and, hence, the optical breakdown becomes possible at lower laser intensities.

Acknowledgements

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