Description

By using femtosecond laser and tight focusing it is possible to create structural changes inside glass [1]. They are called modifications, which are characterized by their axial lengths and refractive index change (in case of type I modifications) [2,3]. This length depends on the laser parameters – pulse energy, focusing depth, scanning speed and even polarization in some cases. To plot these dependencies at first modifications are recorded inside glass substrate (in this case fused silica was used). Then optical microscope is used to measure axial lengths and finally MATLAB is used plot the dependencies and even fit them to create two-dimensional polynomial formulas at different scanning speeds.

Table 1. Laser parameters.

Parameter	Value
Pulse energy (nJ)	100 - 900
Focusing depth (mm)	2,0 - 5,6
Scanning speed (mm/s)	1; 5; 10; 20
Polarization	Linear

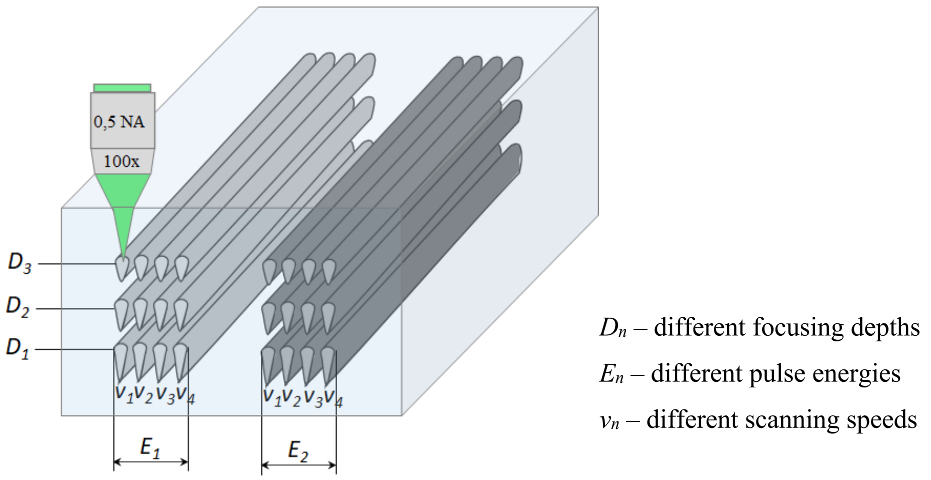

Fig 1. Single modification matrix in glass substrate. Longer modifications occur at the deeper focusing depths because of spherical aberration effect.

To record diffractive optical elements in fused silica volume several modification layers are needed, but it is very important that those layers overlay with the same distance (z direction). This creates more homogeneous element and ensures high diffraction efficiency. As see in Fig. 1 at deeper focusing depths modifications get longer. For this problem modification axial lengths can be fit by two-dimensional polynomial:

$$f(x,y) = c_0 + c_1x + c_2y + c_3xy + c_4x^2 + c_5y^2 + c_6x^2y^2. \tag{2.1}$$

where x is pulse energy, o y – focusing depth. This function calculates modification axial length or modification layer thickness depending on those two parameters. Later this function can be used to describe how layers must be placed to ensure the same overlay value.

Literature

[1] J. W. Chan, T. Huser, S. Risbud, D. M. Krol, Structural changes in fused silica after exposure to focused femtosecond laser pulses, Optics Letters, **26**(21), 1726-1728 (2001).

[2] K. Miura, J. Qiu, H. Inouye, T. Mitsuyu, K. Hirao, Photowritten optical waveguides in various glasses with ultrashort pulse laser, Applied Physics Letters, **71**, 3329–3331 (1997).

[3] S. M. Eaton, M. L. Ng, R. Osellame, and P. R. Herman, High refractive index contrast in fused silica waveguides by tightly focused, high-repetition rate femtosecond laser, Journal of Non-Crystalline Solids, **357**(1113), 2387–2391 (2011).