**Low-loss optical-lattice-like waveguides in lithium niobate by high-repetition-rate femtosecond laser inscription**

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Tightly focused femtosecond laser pulses of 11-MHz repetition rate and 790-nm wavelength were used to fabricate a set of waveguides in a lithium niobate (LiNbO3) crystal. To establish the inscription conditions for optimal low-loss waveguides, within each sample we varied the laser pulse energy, the speed and direction of translation stage movement, and the focus depth of the laser beam. We deployed two new approaches to enhance the inscription results: 1) increase of the laser pulse energy with increasing focus depth inside the material to compensate for the corresponding decrease of the refractive-index contrast between exposed and unexposed areas, and 2) decrease of the laser energy for the modification tracks closer to the waveguide’s core region to reduce the scattering losses due to high-laser-energy driven waveguide’s non-uniformities. All waveguides had an optical-lattice-like hexagonal packing geometry with a track spacing of 10 μm (optimised for effective suppression of high-order modes). Each structure comprised 84 single-scan Type-II-modification tracks, aligned with the crystalline X-axis of the LiNbO3 wafer. As observed through the optical microscope, the diameters of core and outer cladding of the waveguide were approximately 24 μm and 95 μm, respectively. After thermal annealing at 623K for 3 hours, the minimum attenuation coefficients of (0.4±0.1)dB/cm and (3.5±0.3)dB/cm for the ordinary and extraordinary light polarisation states, respectively, were achieved at the 1550-nm wavelength. These low-attenuation waveguides were obtained with an inscription energy varying between 50.6 nJ and 53.6 nJ and a translation speed of 10 mm/s. The corresponding refractive-index contrast of individual tracks was −(1.55±0.04)×10-3. The waveguides also showed low attenuation in the visible and near-infrared portion of the spectrum (from 532 nm to 1456 nm).

Our results offer promising means for the development of low-loss, preserved-nonlinearity waveguides that are suitable for several applications, including telecommunications, nonlinear integrated optics and quantum optics.

**Keywords:** femtosecond laser micromachining, lithium niobate, optical-lattice-like waveguide, nonlinear waveguide

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