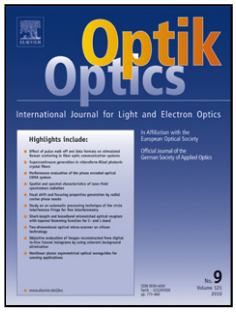

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PII: S0030-4026(17)30451-5
DOI: http://dx.doi.org/doi:10.1016/j.ijleo.2017.04.048
Reference: IJLEO 59090

To appear in:

Received date: 16-1-2017
Revised date: 13-4-2017
Accepted date: 13-4-2017

Please cite this article as: Yu Han, Zhigang Zang, Feng Qiu, Swift-heavy ion implanted Nd:YVO4 waveguides with birefringence preservation and Raman gain enhancement, Optik - International Journal for Light and Electron Opticshttp://dx.doi.org/10.1016/j.ijleo.2017.04.048

Swift-heavy ion implanted Nd:YVO_4 waveguides with birefringence preservation and Raman gain enhancement

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Abstract: A planar waveguide has been fabricated in a Nd:YVO_4 crystal by 20MeV N^{3+} ion implantation. The waveguide can confine three and two modes for ordinary and extraordinary light, respectively. It is for the first time to realize birefringence preservation in ion implanted Nd:YVO_4 waveguides. Based on the Raman characterization, it is also found that the Raman gain at 892cm^{-1} can be enhanced due to ion implantation, which will contribute to develop Raman waveguide lasers.

1. Introduction

Neodymium doped yttrium orthovanadate (Nd:YVO_4) has been paid much attention because it can be applied to a common diode pumped solid state laser and a Raman laser [1]. With respect to bulk lasers, waveguide lasers offer reduced active volumes and consequently much higher optical intracavity intensities, leading to low pumping thresholds and enhanced efficiencies [2, 3]. Up to now, ion implantation and femtosecond laser writing have been only two effective techniques to realize waveguides in Nd:YVO_4 [3, 4]. In femtosecond laser writing, the pulse duration, wavelength, repetition rate and writing energy must be chosen carefully. In addition, it is difficult to precisely control the focus point of the writing laser, because the self-focusing and diffraction effects may happen in some cases [5]. Thus, the waveguide position in the substrate can be hardly estimated before writing. On the other hand, the ion implantation allows precise control of the refractive index in selected regions by adjusting the implantation parameters, i.e. energy and dose. As a result, many works have been reported about ion implanted Nd:YVO_4 waveguides [2, 3, 6, 7], but only one work on femtosecond laser writing [4].

Nd:YVO_4 is a naturally birefringent and uniaxial crystal. Therefore, the propagating light with linear polarizations parallel and perpendicular to the optical axis (c-axis of the crystal) has different properties. In conventional Nd:YVO_4 laser cases, the emission at 1064nm is achieved for light polarization along the c-axis, because the stimulated emission cross section parallel to the c-axis is four times higher than that of the orthogonal case [8]. Furthermore, the birefringence of Nd:YVO_4 can suppress thermally induced depolarization loss when the laser is operated in high power conditions [9]. Unfortunately, all reported ion implanted Nd:YVO_4 waveguides can confine only ordinary light (polarization orthogonal to the c-axis) propagating, which limits the application of the waveguides.

The YVO_4 host has the Raman shift of ~890cm^{-1} and a moderately high Raman gain coefficient. Thus, Nd:YVO_4 crystal has been regarded as an efficient self-Raman laser material [1]. For femtosecond laser written waveguides, there is a slight drop in the Raman gain in the mode of around 888cm^{-1} [4]. For ion implanted waveguides, the Raman properties have not been studied yet.

In this work, we show that a Nd:YVO_4 planar waveguide preserving birefringence is fabricated by swift ion implantation. Based on the Raman spectra, it is found that the Raman gain is enhanced at 892cm^{-1} mode. Both of these results are for the first time and expected for pave the way to developments of waveguide lasers.

2. Experimental

The Nd:YVO_4 crystal (10 × 10 × 0.5 mm^3) is α-cut, b-propagation and doped with 3 at. % Nd^{3+} ions. The ordinary and extraordinary refractive index (n_o and n_e) of the crystal at the wavelength of 632.8 nm is 1.9930 and 2.2110, respectively. It was irradiated with 20MeV N^{3+} with the fluence of 1.5 × 10^{14}