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Laser emission from buried depressed-cladding waveguides inscribed in Nd^{3+}:CLNGG laser crystals by picosecond-laser beam writing

Gabriela Croitoru*, Florin Jipa, Madalin Greculeasa, Alin Broasca, Flavius Voicu, Lucian Gheorghe, Nicolaie Pavel

National Institute for Laser, Plasma and Radiation Physics, Laboratory of Solid-State Quantum Electronics,
Atomistilor Street 409, Magurele 077125, Ilfov, Romania
*gabriela.croitoru@inflpr.ro

INTRODUCTION & MOTIVATION

WAVEGUIDE STRUCTURES are the building blocks for various integrated photonic devices:

- Waveguide lasers and amplifiers
- Beam splitters
- Light modulators
- Directional couplers
- Polarizers

with a set of very important advantages:

- Devices with compact geometries
- Light confinement and propagation in volumes with dimensions at µm scale
- High levels of optical intensities
- Robust functionality

OPTICAL WRITING:

- Local, permanently change of the material refractive index with a laser beam;
- Single-step fabrication process (no masking, immersion in liquids or other additional processes);
- The waveguide formation depends on the nature of the processed material, on the parameters of the laser beam used for writing and on the focusing conditions.
- There are few works that are reporting waveguide realization with laser systems that are delivering pulses in the range of few picosecond (ps-) duration.

• **THIS WORK: REALIZATION of BURIED DEPRESSED-CLADDING WAVEGUIDES in Nd^{3+}:CLNGG crystals by DIRECT LASER WRITING (DLW) with a PICOSECOND-LASER BEAM.**

EXPERIMENTAL CONDITIONS

• **The laser crystals were obtained in our laboratory, from boules grown by the Czochralski technique.**

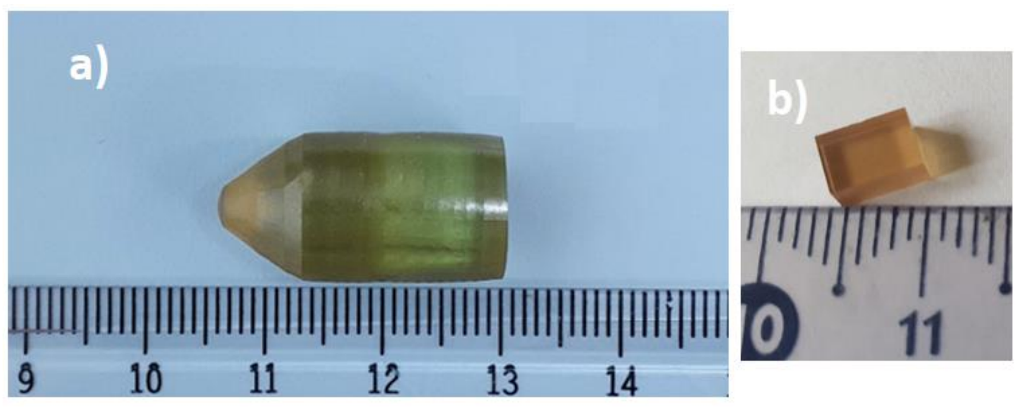

FIG. 1 a) The Nd:CLNGG boule after growing.
b) The 5.9-mm thick, 0.7-at.% Nd:CLNGG laser crystal.

• **Growth parameters**

- pulling rate: 1 mm/h
- rotation rate: 20 rpm
- growth direction: <111>

• **Writing parameters**

- Focusing: Lens (L), f= 6.24 mm, NA= 0.40;
- Waist diameter: ~2.0 µm (in air);
- Pulse energy: 0.2 µJ; Speed: 1 mm/s.

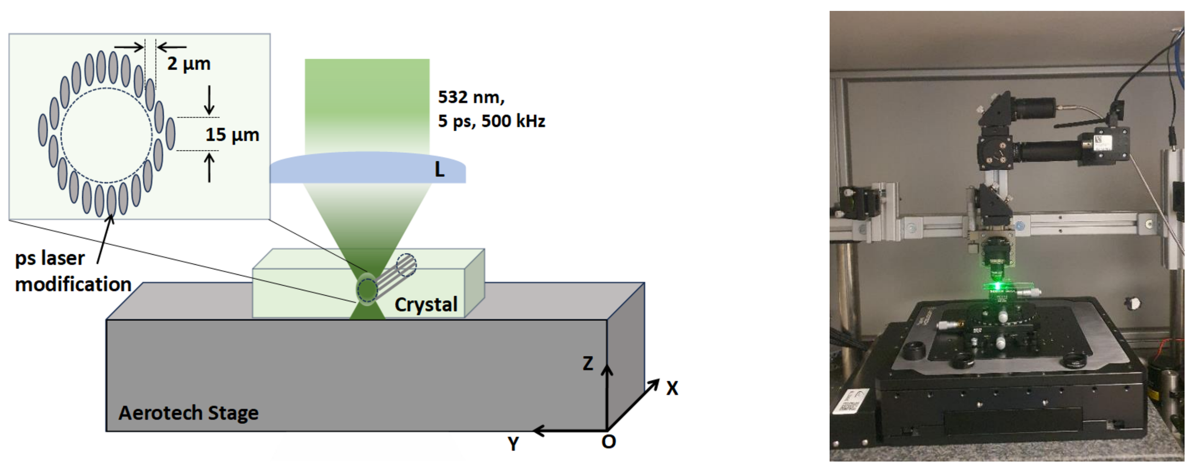

FIG. 2 The experimental set-up used for waveguide writing in the 0.7-at.% Nd:CLNGG crystal is presented. L: lens.

RESULTS & DISCUSSION

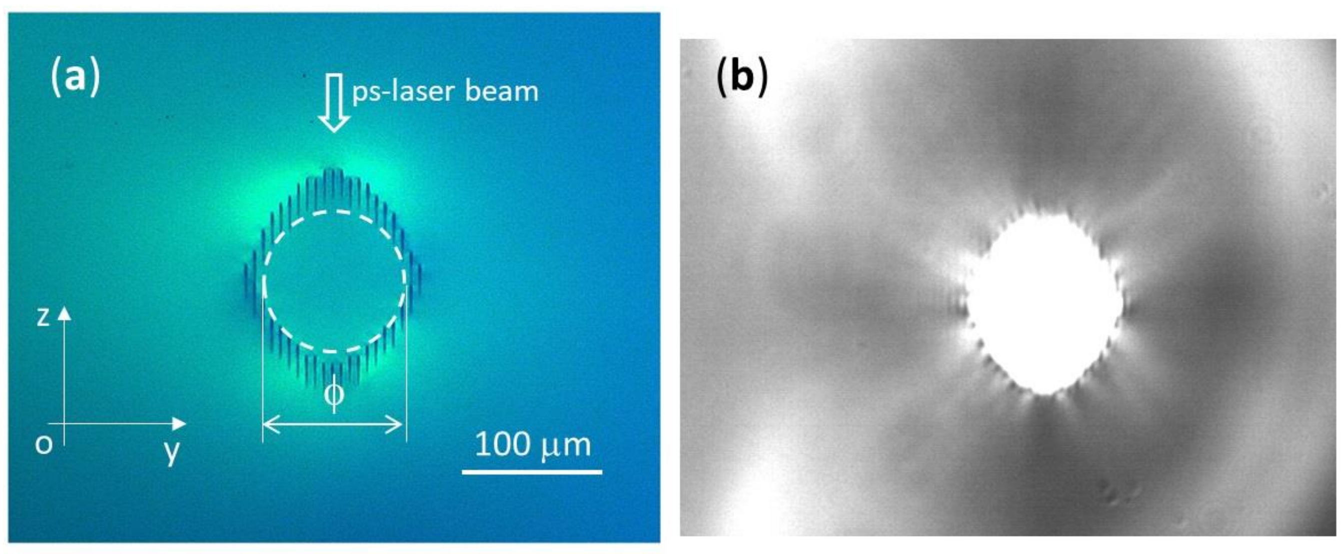

FIG. 3 a) Cross-section microscope view for the circular waveguide NCLNGG-C and **b)** a view of the exit surface under the pump at 807 nm are shown.

Table 1. Propagation losses at 632.8 nm for the waveguides inscribed in Nd:CLNGG crystal.

Waveguide type	Characteristics	Propagation loss, (dB/cm)	
		ps-DLW	fs-DLW*)
Bulk Nd:CLNGG	5.9-mm length	0.4	0.3
circular, NCLNGG-C	diameter, ϕ = 100 µm	0.9	2.65

*)buried depressed-cladding waveguide with circular 100-µm diameter inscribed in Nd:CLNGG crystal with a fs-laser beam; same spacing between the tracks for both inscription methods.

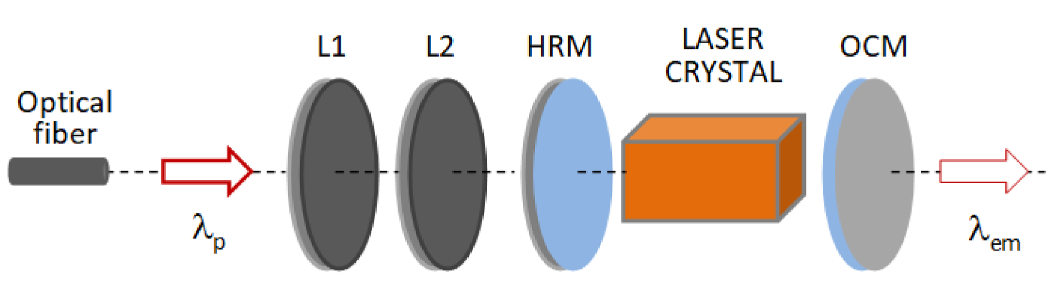

FIG. 4 The experimental set-up used for laser emission at 1.06 µm, under the pump with fiber-coupled laser diode. L1, L2: lenses; HRM: high-reflectivity mirror; OCM: out-coupling mirror.

- **Diode laser: LIMO Co., Germany:**
  λ_p= 807 nm; ϕ= 100 µm; NA= 0.22
- **Coupling optics:**
  L1, f= 50 mm; **L2,** f= 30 mm
- **Resonator: plane-plane**
  HRM: HR at λ_{em} (1.06 µm)
  HT at λ_{pump} (807 nm)
  OCM: transmission T at λ_{em}
- **Pumping:**
  - quasi continuous-wave (5 Hz, 1.0 ms).

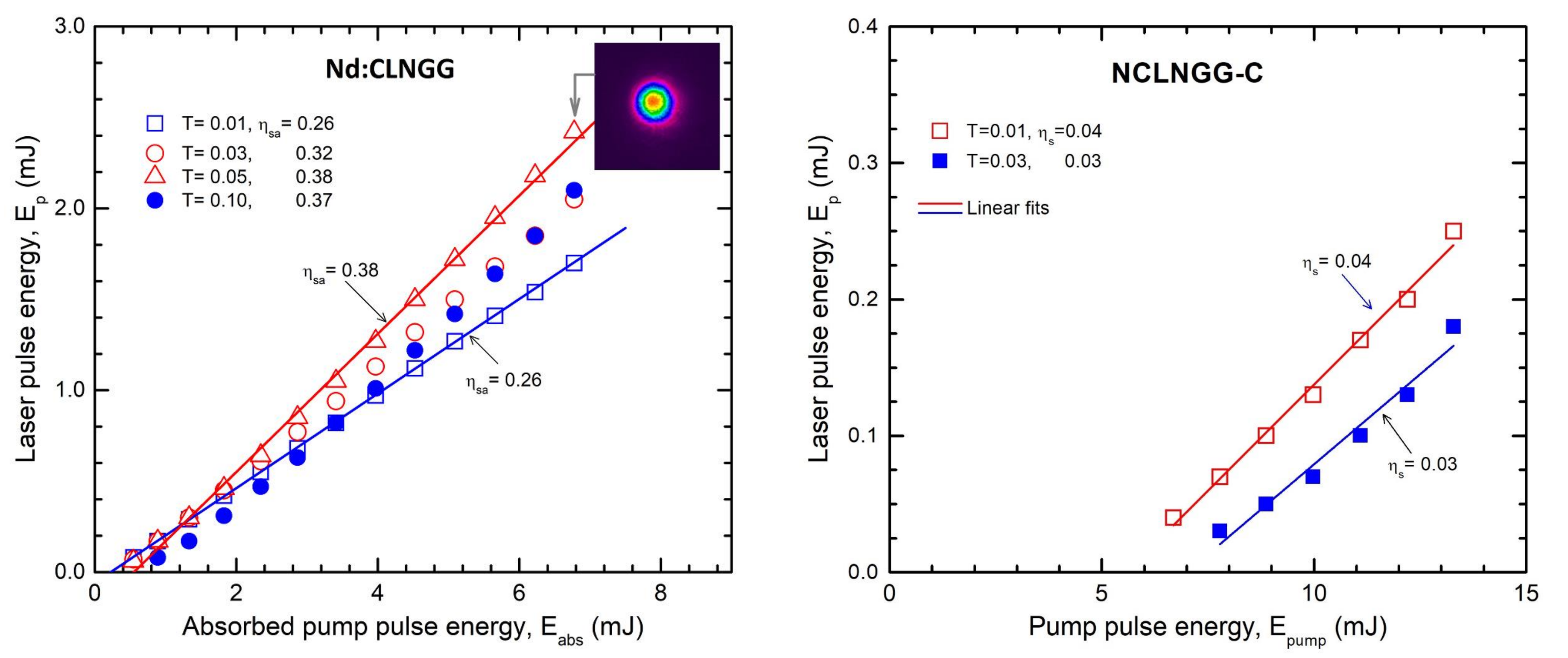

FIG. 5 Laser pulse energy at 1.06 µm vs absorbed pump pulse energy (η_a= 0.81) in **a)** "bulk" Nd:CLNGG and vs pump pulse energy in **b)** the circular waveguide NCLNGG-C. T: OCM transmission. Lines are linear fits of the experimental data.

• **λ_{em}= 1.06 µm** → E_p= 2.4 mJ @ E_{abs}= 6.8 mJ
OCM: T= 0.10; η_{oa}= 0.35; η_{sa}= 0.37

• **λ_{em}= 1.06 µm** → E_p= 0.25 mJ @ E_{pump}= 13.2 mJ
OCM: T= 0.01; η_o= 0.02; η_s= 0.04

CONCLUSION

• **Direct laser writing with a ps-laser beam**

• **The writing speed** is considerably **faster** (1 mm/s) → the **processing time** is **reduced** to approx. 6 minutes for the entire waveguide structure of 5.9-mm;

• **Laser sources** delivering **ps pulses** presents **advantages** (such as the cost and the delivery of high-energy pulses), whereas the **energy transfer** from the **laser beam** to the **lattice material** is **different** from that of **fs-laser beam.**

FUTURE WORK / REFERENCES

References

- K. M. Davis, K. Miura, N. Sugimoto, and K. Hirao, Opt. Lett. **21**(21), 1729-1731 (1996).
- A. G. Okhrimchuk, A. V. Shestakov, I. Khrushchev, J. Mitchell, Opt. Lett. **30**(17), 2248-2250 (2005).
- G. A. Torchia, A. Rodenas, A. Benayas, E. Cantelar, L. Roso, and D. Jaque, Appl. Phys. Lett. **92**(11), 111103 (2008).
- J. Siebenmorgen, T. Calmano, K. Petermann, and G. Huber, Opt. Express **18**(15), 16035-16041 (2010).
- G. Salamu, F. Jipa, M. Zamfirescu, and N. Pavel, Opt. Express **22**(5), 5177-5182 (2014).
- G. Salamu, F. Jipa, M. Zamfirescu, and N. Pavel, Opt. Mater. Express **4**(4), 790-797 (2014).