Single-transverse-mode broadband luminescence sources based on PLD grown Ti:sapphire waveguides in rib geometry

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ABSTRACT

Rib waveguides have been fabricated in pulsed-laser-deposited Ti:sapphire layers using photolithographic patterning and subsequent Ar^+-beam milling. Fluorescence output powers up to 300 μW have been observed from the ribs following excitation by a 3W multiline argon laser.

Mode intensity profiles show high optical confinement and the measured beam propagation factors and of 1.12 and 1.16 respectively, indicate single transverse mode fluorescence emission. Loss measurements using the self-pumped phase conjugation technique have yielded comparable values (1.7dB/cm) for the ribs and the unstructured planar waveguide counterparts.

The combination of optimum modal properties and strong optical confinement, together with sufficient levels of fluorescence output, make the single-moded Ti:sapphire rib waveguides a very interesting candidate as a fluorescence source for optical coherence tomography applications.

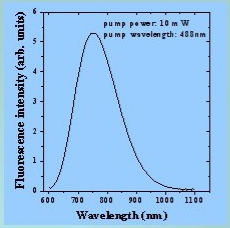
LIGHT SOURCE REQUIREMENTS FOR OCT IN BIOLOGICAL IMAGING

- emission in the near infrared to ensure adequate penetration of the light in the tissue
- a large spectral bandwidth to ensure a short coherence length and therefore improved longitudinal resolution
- high irradiance to achieve a wide dynamic range and detection sensitivity for imaging weakly backscattering structures in the tissue

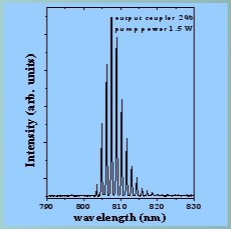
ADVANTAGES OF THE RIB WAVEGUIDE GEOMETRY

- lower threshold for laser structures, due to the lateral confinement of both the pump and laser modes
- improved efficiency provided that the rib fabrication process does not itself introduce any additional loss
- can provide a fully diffraction limited, near circular, single-mode beam and therefore potential for low loss coupling with components such as the fiber optic interferometers used in OCT systems

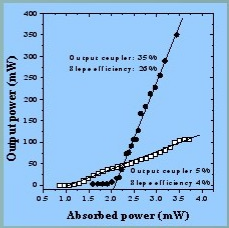
PLD GROWN TI:SAPPHIRE PLANAR WAVEGUIDE LASER



Fluorescence spectrum for a PLD grown Ti:sapphire waveguide



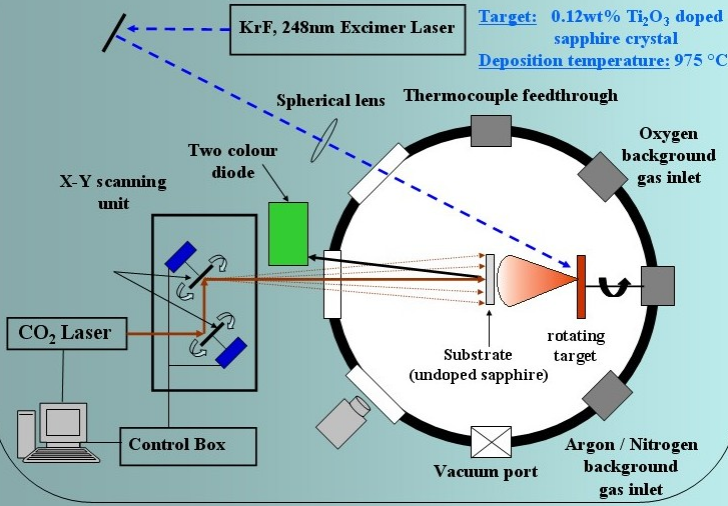
Lasing spectrum for an absorbed power 2x the lasing threshold



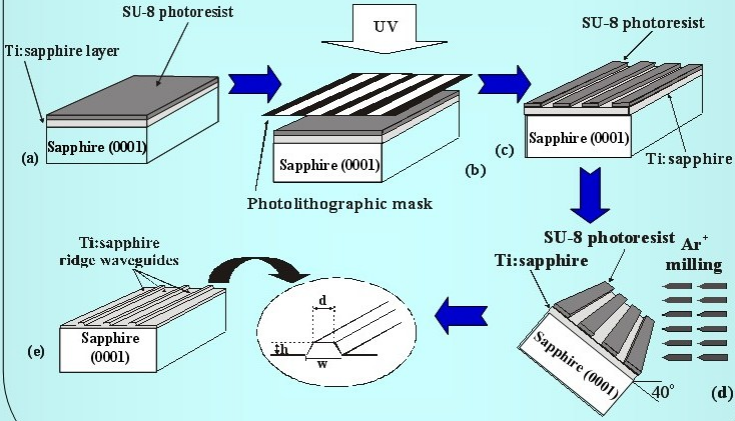
Output power as a function of absorbed power for two output couplers

LASING PUMP THRESHOLD: 0.56 W **PROPAGATION LOSS: 1.6 dB/cm**

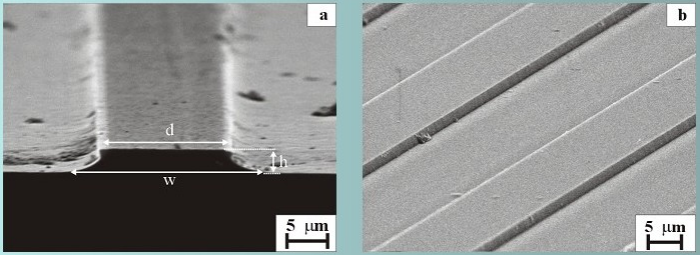
APPARATUS FOR PLD GROWTH OF Ti:SAPPHIRE FILMS



PHOTOLITHOGRAPHIC PROCESS

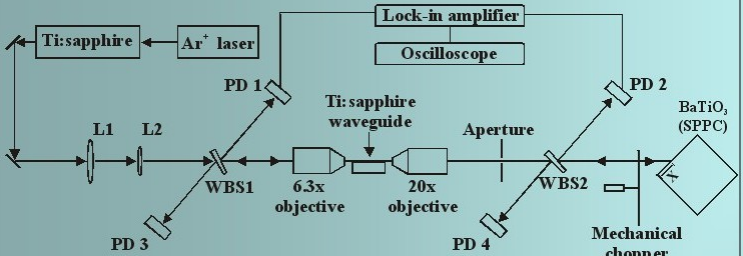


MORPHOLOGICAL PROPERTIES



Scanning Electron Microscope picture of Ar^+ beam structured ribs in a 10 μm thick PLD grown planar waveguide

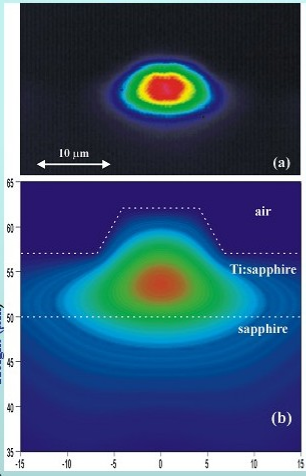
PROPAGATION LOSS MEASUREMENTS

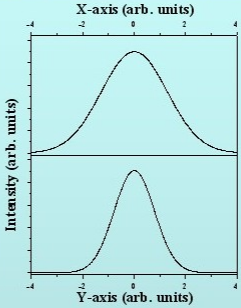


Experimental arrangement for loss measurements via self-pumped phase conjugation

- The propagation loss for the rib waveguide was 1.7±0.1 dB/cm with reproducibility within an error of 5% for a set of 5 measurements.
- The loss level remains essentially unchanged after the rib fabrication process.

TRANSMISSION CHARACTERISTICS





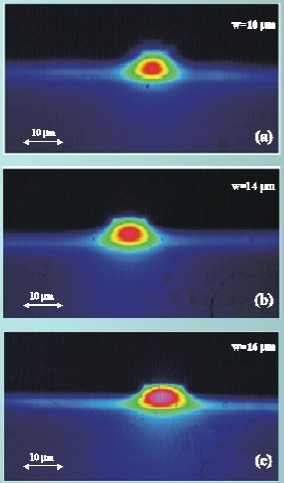
Simulated Gaussian profiles of the outcoupled beam in the X and Y axes

Beam propagation factors:

M_x^2=1.03 and M_y^2=1.09

(a) Experimental and (b) simulated fundamental mode intensity profile of the out-coupled light from a 5 μm deep and 14 μm wide rib structure.

FLUORESCENCE EMISSION PROFILES

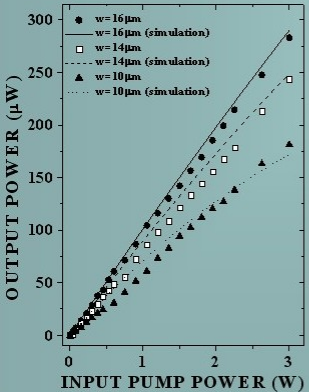


Beam propagation factors:

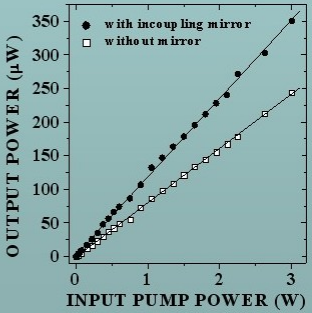
M_x^2=1.12 and M_y^2=1.16

Fluorescence emission profiles measured at the exit face of a Ti:sapphire rib waveguide with a depth of 5 μm and widths *w* of (a) 10 μm, (b) 14 μm, and (c) 16 μm. The thickness of the Ti:sapphire underlying layer was 5 μm.

OUTPUT CHARACTERISTICS



Fluorescence power as a function of pump power from an Ar^+ laser for 5 μm deep ribs with various widths.



Fluorescence output as a function of pump power from an Ar^+ laser with and without incoupling mirror for a 5 μm deep rib with a width of 14 μm

CONCLUSIONS

- Rib waveguides have been fabricated in pulsed-laser-deposited Ti:sapphire layers using photolithographic patterning and subsequent Ar^{+}-beam milling.
- Mode intensity profiles show high optical confinement and the measured beam propagation factors M_x^2 and M_y^2 of 1.12 and 1.16 respectively, indicate single-transverse-mode fluorescence emission.
- Loss measurements have yielded comparable values for the ribs and the unstructured planar waveguide counterparts.
- The optimum modal properties, high fluorescence output, and the device compactness make it a suitable fluorescence source for integration with fibre-optic OCT systems.

FUTURE WORK

- decrease the background losses in the PLD grown Ti:sapphire host film waveguides (1.6 dB/cm) and as a consequence those in the rib structures
- investigation of the use of the amplified spontaneous emission to increase the output power without too large a decrease in bandwidth
- demonstration of laser action in a Ti:sapphire rib waveguides