EPSRC Centre for Innovative Manufacturing in LASER-BASED PRODUCTION PROCESSES

LEONARDO

Time-resolved high-gain short-pulse amplifier model with arbitrary pump and signal fields

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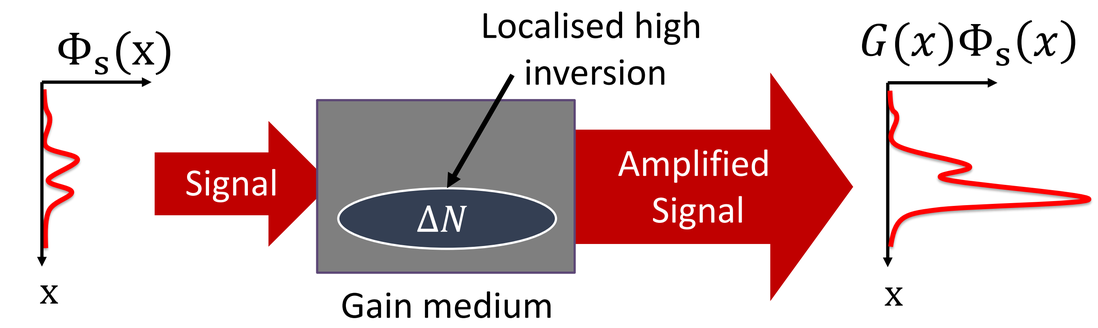
Goals

- Design of a nanosecond multi-pass amplifier based on holmium
- Transient analysis capabilities for dynamic system modelling
- Enable design of highly stable system with active beam shaping and control

Capability

Spatially-dependent gain in waveguide or slab



Assumptions:

- Pulse temporal overlap is ignored (incoherent pulse approximation[1])
- Photon transit time short compared to pulse duration[2]

Benefits:

Quantify the influence of:

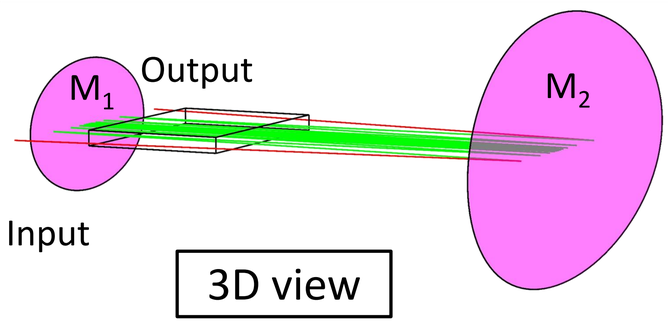
- Pump/gain profile on the amplified beam
- Impact of self-imaging such as in the planar waveguide
- Transient effects & pulse shape distortions
- Thermal profile (and its development over time)

Resonator

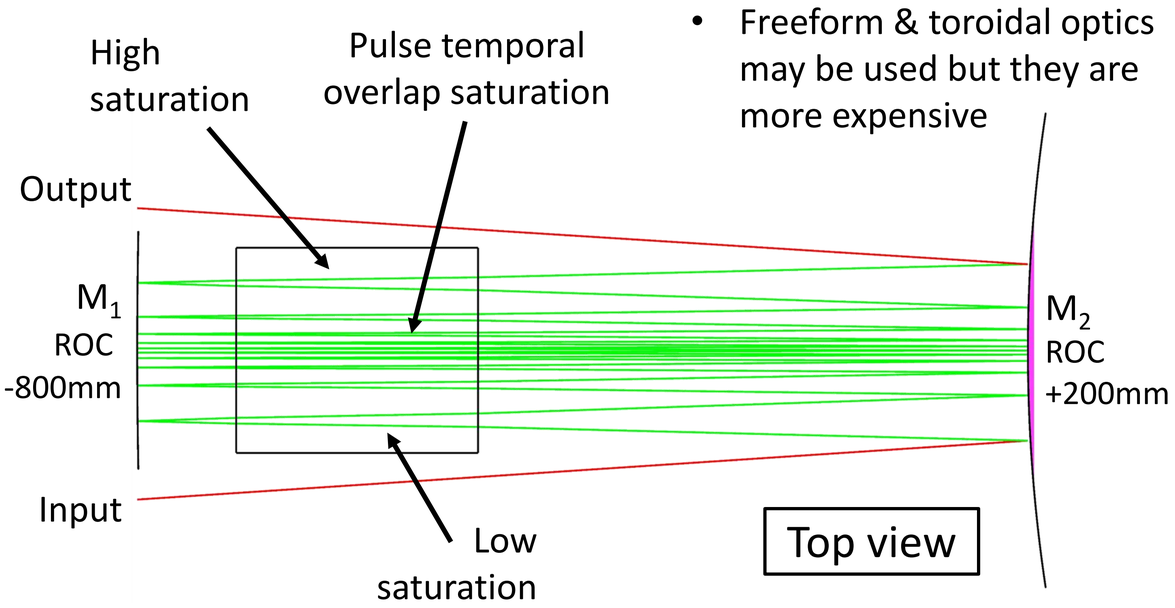
Design methodology

If high gain saturation is achieved throughout medium, thermal load will be heavily influenced by pump beam profile

Example: 20 passes in off-axis unstable resonator using **toroidal** mirrors (ROC –500mm out of page direction)



3D view



Top view

Pros:

- High number of passes possible in one traverse
- Stable cavity in the out-of-slab plane direction helps maintain beam quality

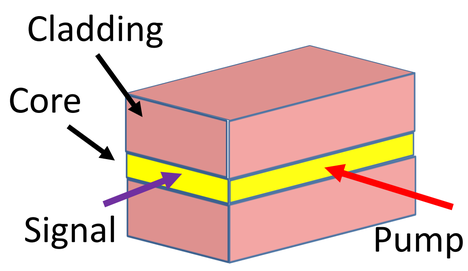
Cons:

- Very sensitive to changes in input alignment with as little as 20-50µrad being the difference between 20 and 100 passes
- Freeform & toroidal optics may be used but they are more expensive

Geometry

A selection of 3 geometries to be investigated:

Side-pumped Planar Waveguide Amplifier



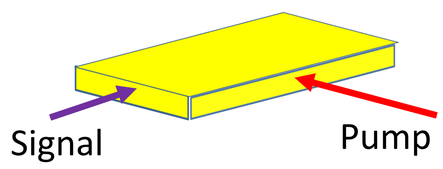
Pros:

- High gain & high confinement
- High efficiency, lower number of passes
- Poor beam quality of pump handled
- Beam quality maintained in signal

Cons:

- Power damage thresholds scale faster
- High cost of manufacture & delicate

Side-pumped Slab Amplifier



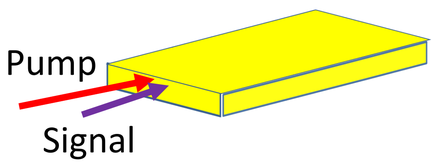
Pros:

- Thermal guiding adjustment possible
- Low cost & wide aperture alignment

Cons:

- High pass paths are very unstable
- In-plane thermal grad. → path walk-off

End-pumped Double-pass Slab Amplifier



Pros:

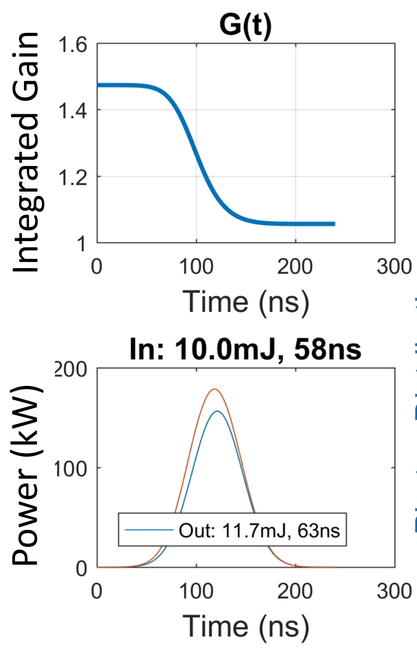
- Thermal guiding adjustment possible
- Low cost & wide aperture/align easier

Cons:

- Pre-amplifier may be required
- Longer slabs require larger heat sinks

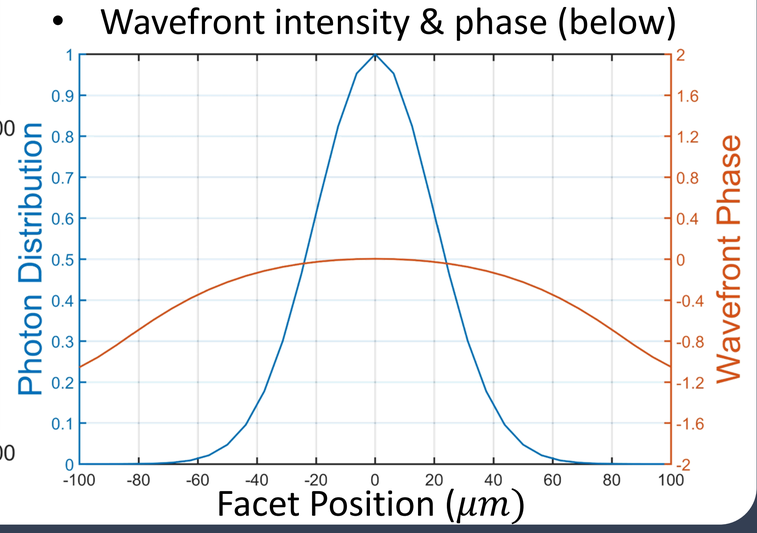
Outputs

Example: single-pass gain in a $\Lambda/4$ self-imaging $200\mu m$ waveguide



Outputs shown:

- Integrated gain, G(t) (top left)
- Pulse shape & energy (bottom left)
- Wavefront intensity & phase (below)



References

[1] M. Li *et al.*, 'Analytical and numerical solutions to the amplifier with incoherent pulse temporal overlap', *Opt. Commun.*, vol. 382, pp. 49–57, 2017.

[2] T. Taira, W. M. Tulloch, and R. L. Byer, 'Modeling of quasi-three-level lasers and operation of cw Yb: YAG lasers', *Appl. Opt.*, vol. 36, no. 9, pp. 1867–1874, 1997.

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