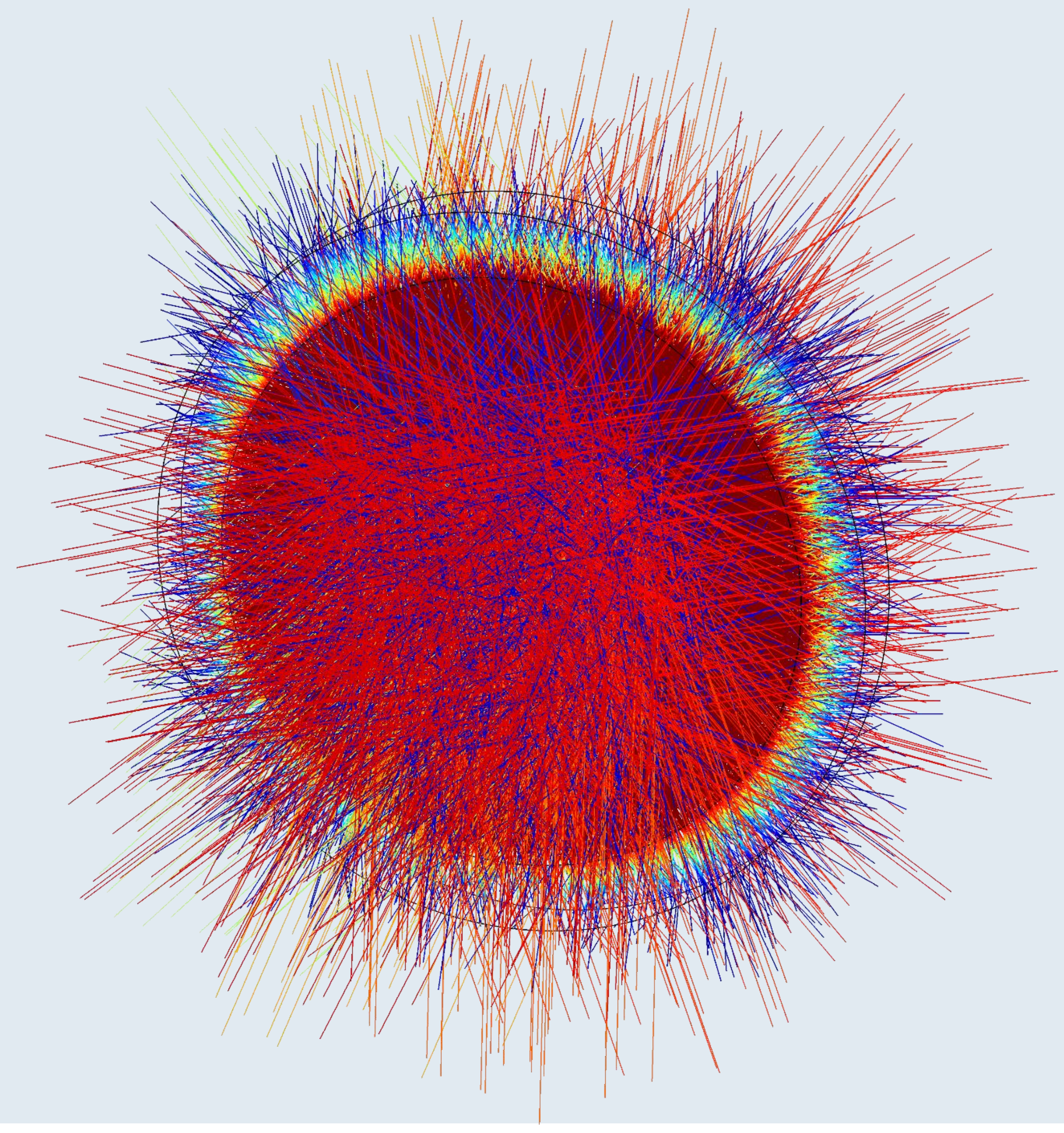

Modelling of Thermal Stress in Yb:YAG to Quantify Depolarisation in a Nanosecond 10 J, 100 Hz Laser

Depolarisation arising due to thermally-induced stress birefringence can be detrimental to some applications of high average power lasers. This work aims to quantify the depolarisation of a propagating seed beam after passing through thermally stressed Yb:YAG gain medium slabs.

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Introduction

The high heat loads intrinsically associated with high-energy, high repetition rate laser systems require sophisticated thermal management analyses to minimise the impact of thermal effects on optical performance [1].

Non-uniform heat deposition in optical elements, such as gain medium, can lead to the onset of thermally-induced stress birefringence which reduces the efficiency of lasers using polarisation-sensitive components [2].

As a result, a model has been developed to simulate thermal effects in Yb:YAG gain medium slabs of a multipass 10 J, 100 Hz laser [3] based on the DiPOLE concept [4] to quantify depolarisation of a seed beam with a defined input polarisation after propagation through the six slabs in the amplifier head.

These findings will inform future optical design work by determining the optimal gain medium properties and cooling parameters to minimise depolarisation.

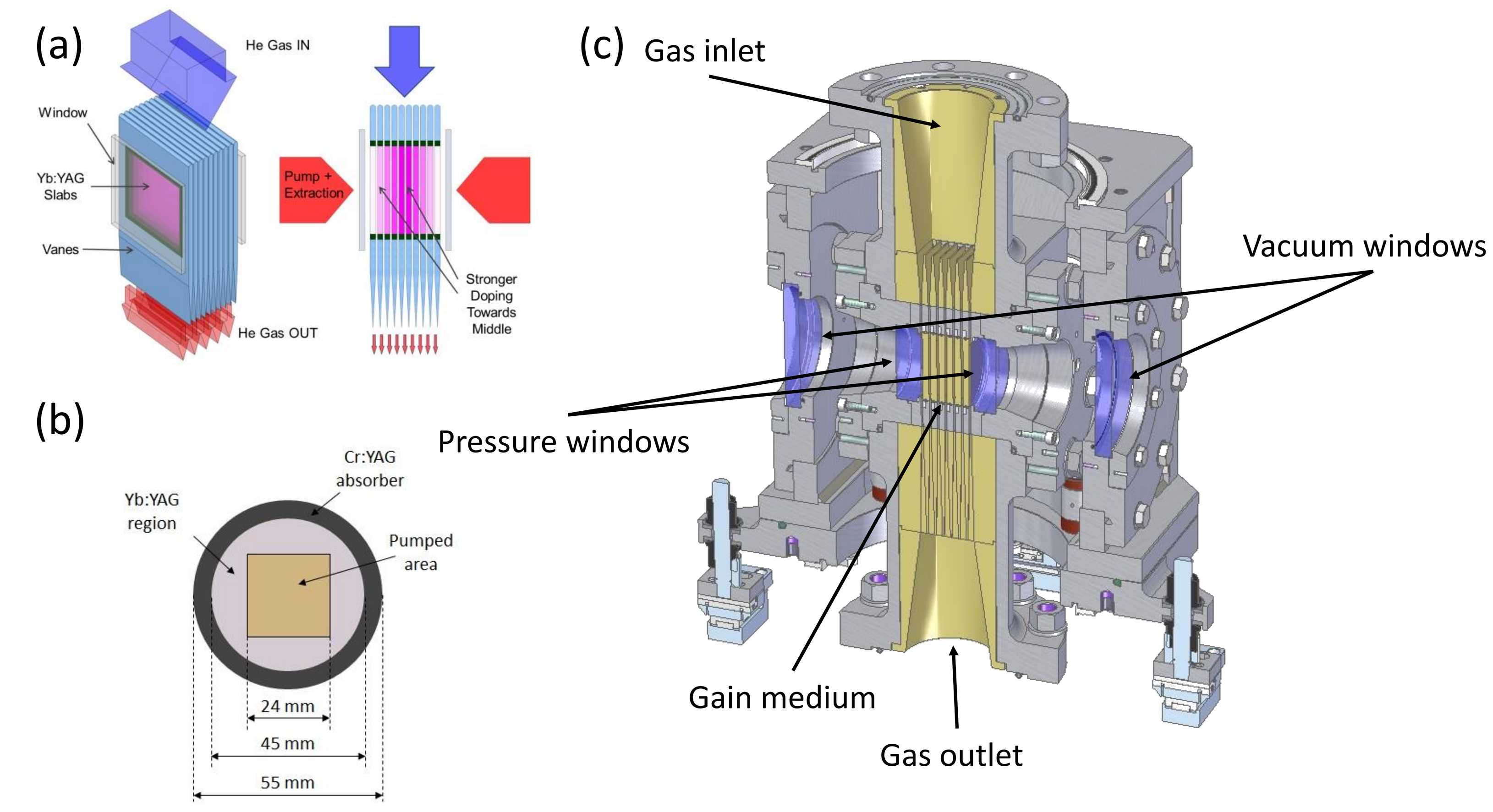

Figure 1. Graphical representation of the DiPOLE concept (a), geometry of the gain medium slab (b), and cross section of the 10 J, 100 Hz DiPOLE laser amplifier head (c).

Methodology

The graded doping concentration results in uniform power absorption over the slab set, meaning only one slab needs to be modelled.

Heating of the slab is a result of the absorption of pump light in the pumped region and the absorption of fluorescence, which is emitted from the pumped region, in the Cr:YAG cladding. The slabs are cooled on each face by cryogenically-cooled helium gas.

Non-uniform temperature distributions results in material stress. These both contribute to birefringence in the normally isotropic slabs. This leads to depolarisation of the propagating seed beam after passing through the amplifier head during amplification.

Results

Figure 2(a) shows the heat deposition map of the slab due to absorption of fluorescence and the quantum defect.

Figures 2(b), 2(c) and 2(d) show various temperature distributions in the slab after cooling with a flow of helium cooled to 140 K at a mass flow rate of 200 g/s.

Figure 2(e) shows a map of the xy component of the stress tensor in the pumped volume, arising due to a non-uniform temperature distribution.

Figure 2(f) shows the resulting depolarisation map of a seed beam with a linear horizontal input polarisation state after one single pass through the six slabs in the amplifier head.

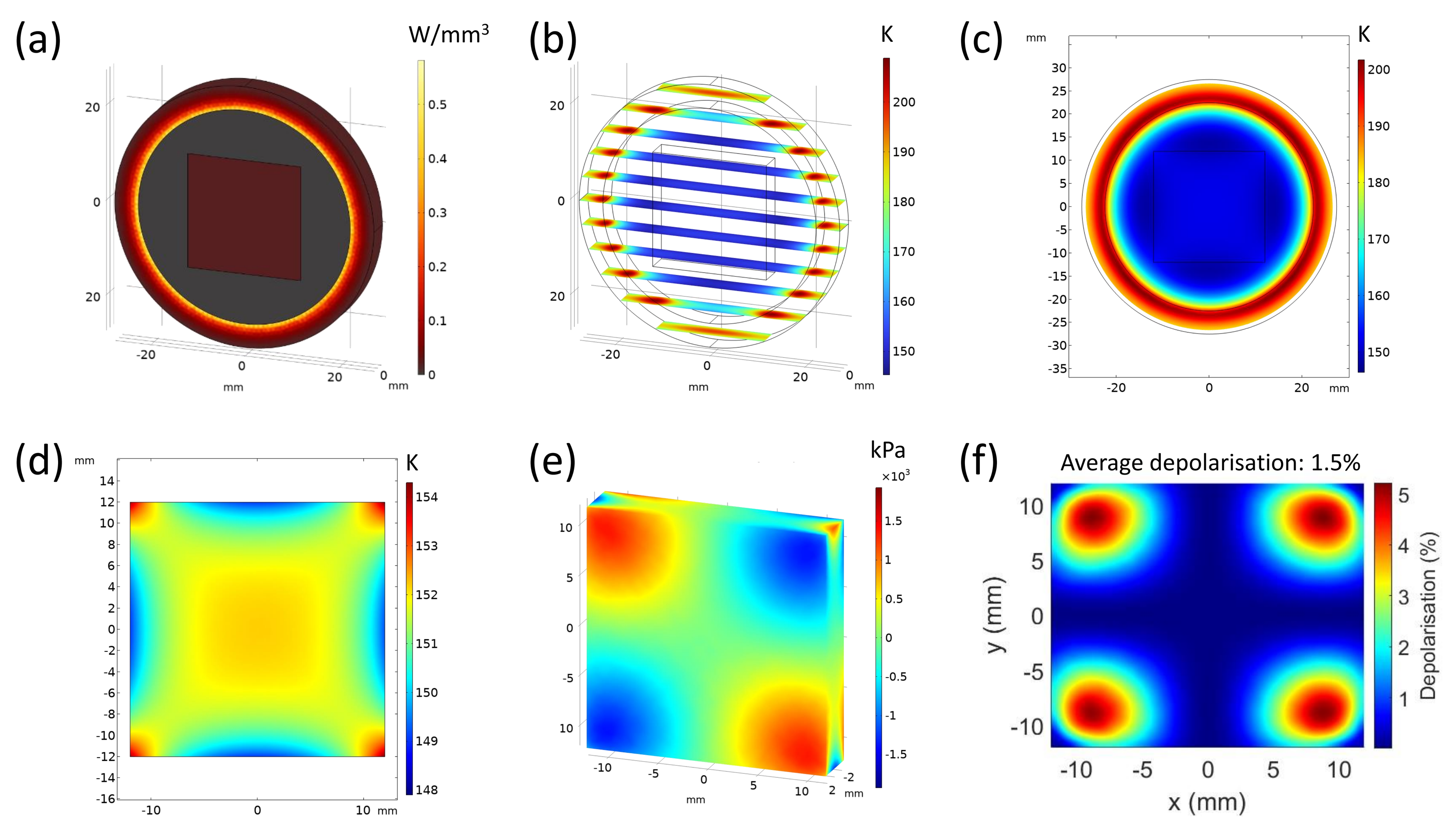

Figure 2. 3D heat load distribution in the slab (a), sliced plot of the temperature distribution in the whole slab (b), temperature distribution in the whole slab averaged across the slab thickness (c), temperature distribution in the pumped volume averaged across the slab thickness (d), distribution of the xy component of the stress tensor in the pumped volume (e), and the resulting depolarisation of the seed beam with a linear horizontal input polarisation state after one pass through the amplifier head.

REFERENCES

[1] - G. Quinn at al., Laser Congress 2021 (ASSL), paper JTu1A.37 (2021).
[2] - M. De Vido et al., Opt. Express, 29(4), pp. 5607-5623 (2121).
[3] - M. De Vido et al., Laser Congress 2019 (ASSL), paper JTu3A.14 (2019).
[4] - K. Ertel et al., Opt. Express, 19(27), pp. 26610-26 (2011).

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