Defect formation in degraded laser diodes.

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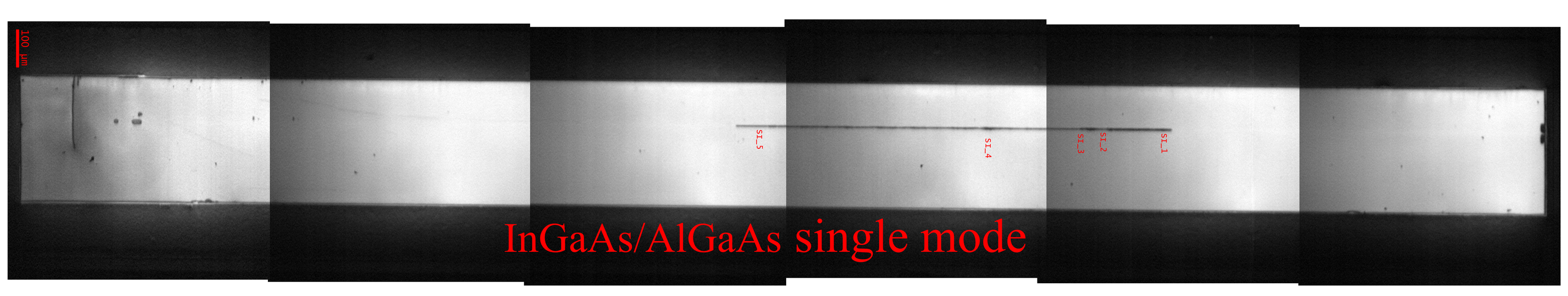
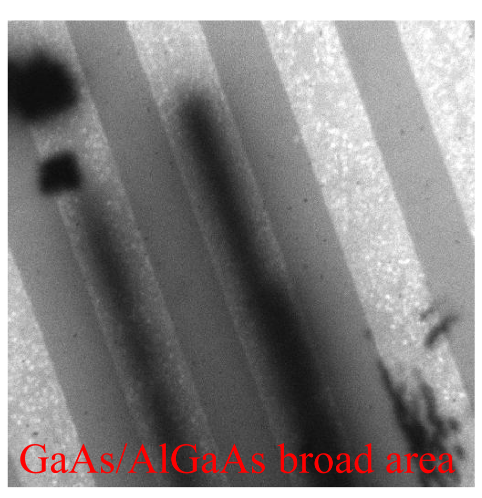
Introduction: Catastrophic optical degradation (COD) of laser diodes is a crucial factor limiting ultra-high power lasers. The degradation is driven by the formation of extended defects with the result of the destruction of the laser cavity. In spite of the extensive study of this phenomenon, there are still unclear aspects about how the COD occurs. The COD is observed as a process in which the active part of the laser diode is destroyed, forming characteristic defects, the so-called dark line defects (DLDs). The DLDs are clusters of dislocations and/or molten and recrystallized regions. The COD has been described as a sudden process, triggered by a thermal flash, as observed by a thermo-camera under high current pulses. The DLDs propagate at a very fast speed, fed by the laser self-absorption.

Experimental



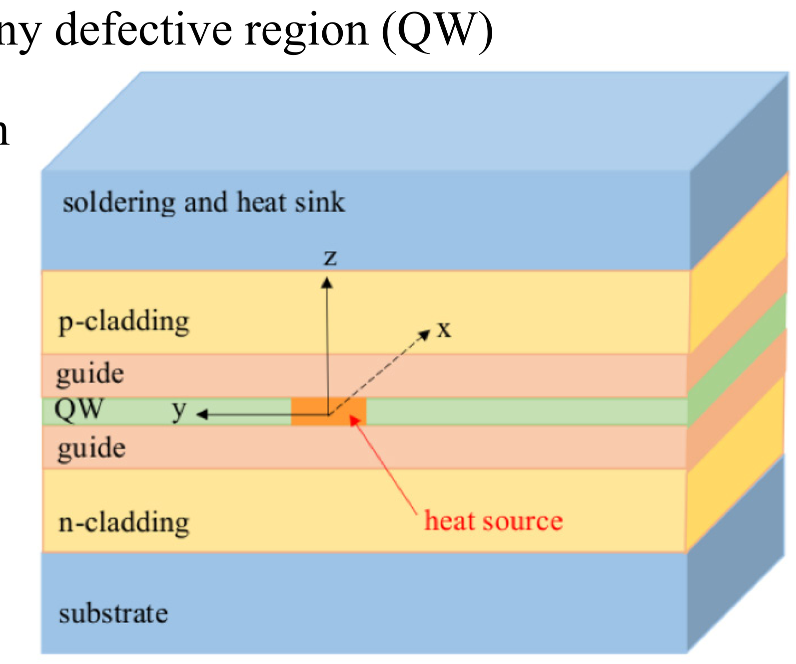


Panchromatic cathodoluminescence (CL) images reveal fully dark regions in the QW that can be associated with clusters of defects.

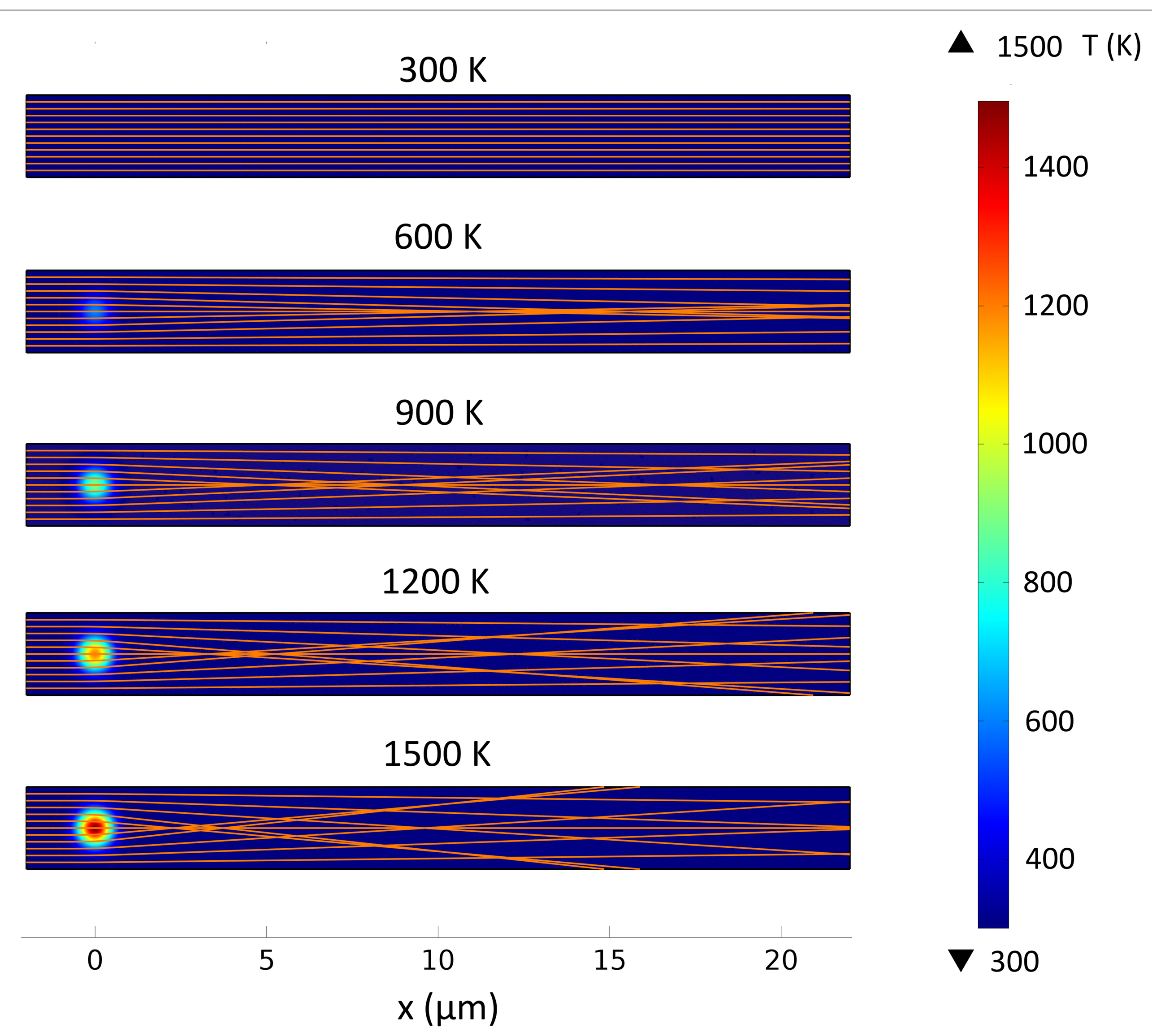
The DLDs are usually aligned along the cavity, as they are guided by the optical field, which feeds energetically an absorbing region of the active zone of the laser.

Structure of the laser and physical model

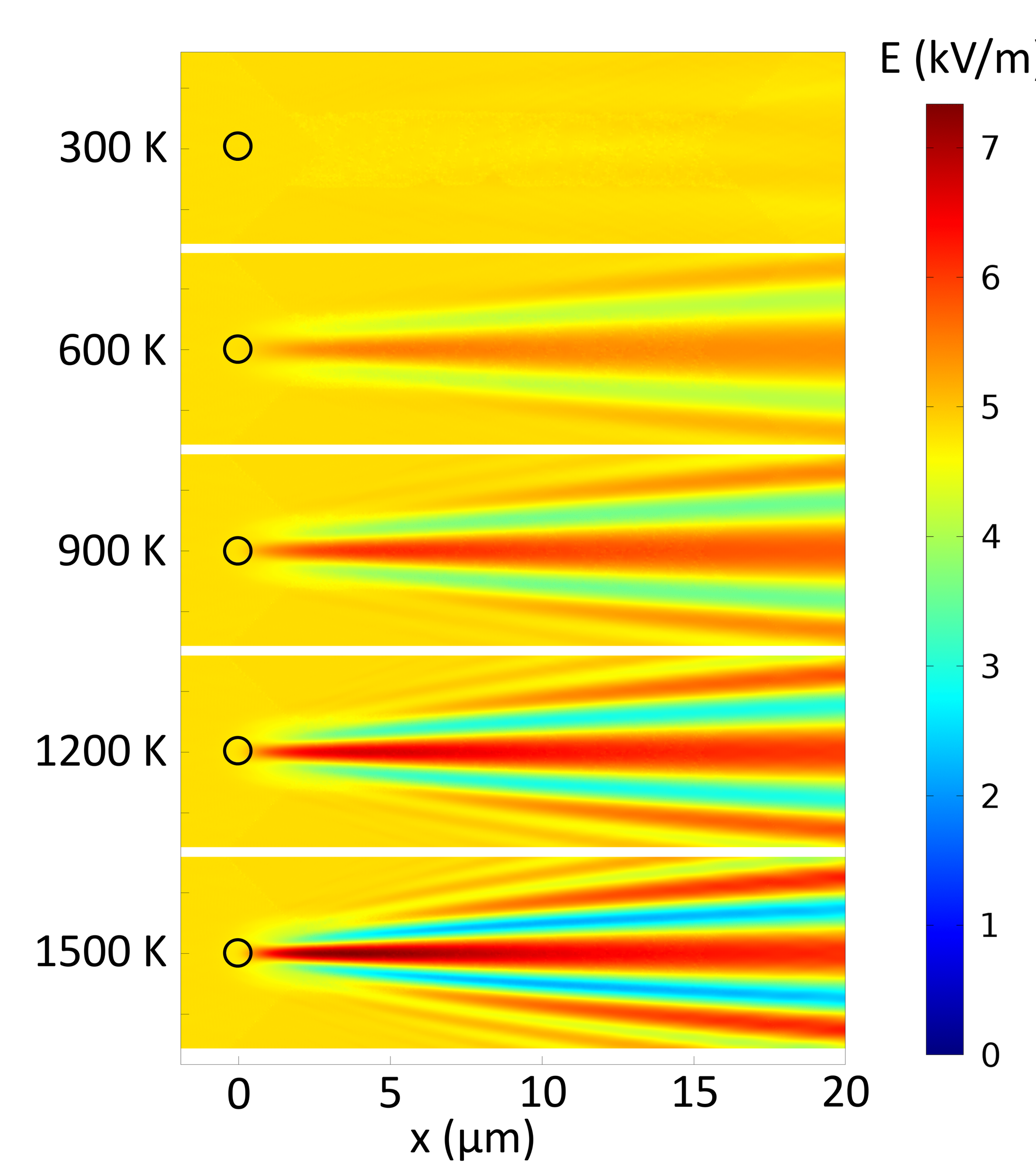
- Graded index separate confinement heterostructure (GRINSCH)
- Initial heat source: laser reabsorption in a tiny defective region (QW)
- Temperature distribution from heat equation (reduced thermal conductivity)
- The increased temperature locally modifies the refractive index
- The trajectory of the laser light is modified (thermal lensing effect)
- Calculations performed via finite element methods (FEM) using Comsol® 4.3a.



Results



Effect of a local heat spot close to the emitting mirror over the laser beam trajectory (Ray Optics module).



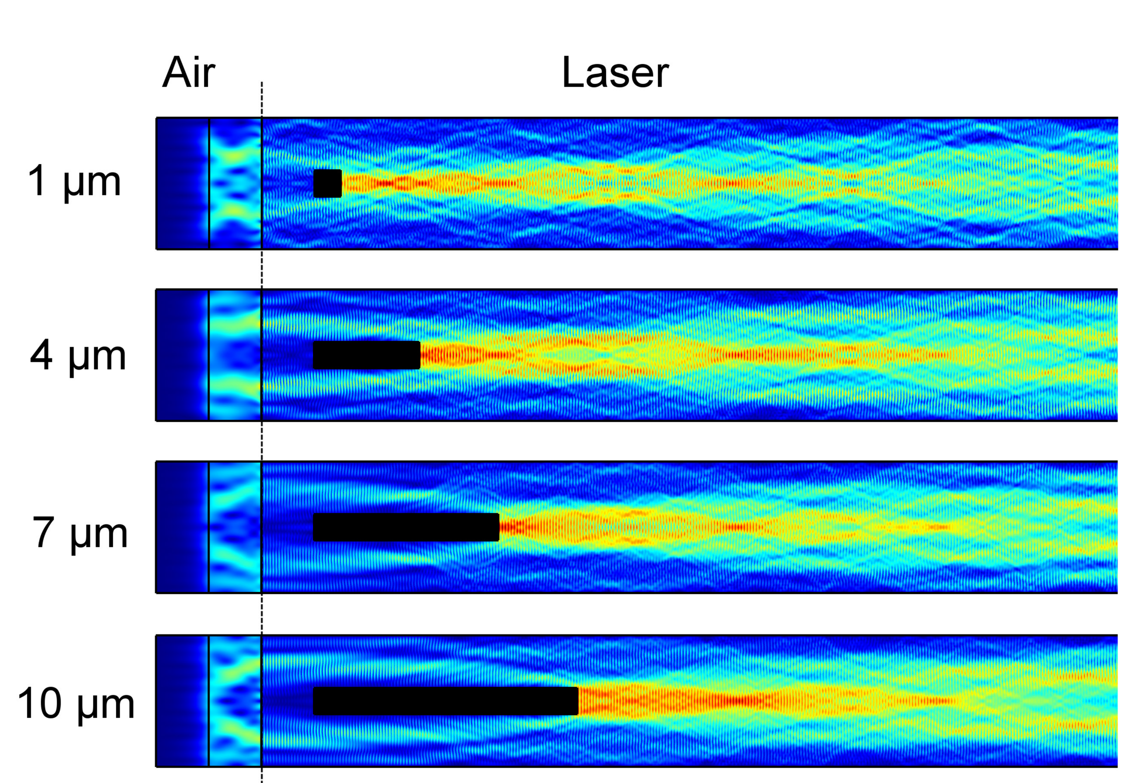
Electromagnetic Waves in Frequency Domain module simulation of the same effect.

The EM field is again enhanced and displaced towards the interior of the QW with respect to the heat source (black circle).

The simulation predicts that the location of the focus does not change noticeably with temperature.

The EM field is progressively concentrated in the focus as the defect temperature is increased.

The laser beam is focused further inside the laser at a certain distance from the hot spot, which decreases as the temperature rises.



Laser cavity eigenmodes in the presence of a degraded region on the QW.

The laser cavity mode concentrates approximately 3 - 4 µm from the degraded region (black square).

Consecutively, new local COD events are triggered, and the damaged region is extended.

Conclusions

Local hot spots produce a thermal lensing effect that focuses the travelling wave on a point situated ~ 3 - 5 µm behind the heated region.

If the heated region is fully degraded, the laser cavity modes present maxima which are located ~ 3 - 5 µm in front of the degraded region.

The simulations suggest that a new COD process would be triggered at about 3 µm from the previously heated/degraded region, in good agreement with the experimental CL results.

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