Engineered crystal layers grown by pulsed laser deposition - making bespoke planar gain-media devices

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Pulsed laser deposition (PLD) is a non-thermal-equilibrium epitaxial crystal growth technique that enables the fabrication of thin optically active materials suitable for waveguide or thin-disk laser media. In recent years, a dramatic improvement in PLD-grown crystal-film quality has been reported, defined by the improving optical-optical efficiencies in a planar waveguide laser setup (Figure 1-left). These results cover a range of novel host materials for rare-earth ions, such as garnets, sesquioxides, and more recently sapphire. High-quality crystal materials are paramount for efficient laser sources. Moreover, in power-scaling laser architectures, the thermal loading density is tending to extreme levels and materials with excellent thermomechanical and thermo-optical properties are essential. Through PLD, we are exploring novel materials and composite designs that have the potential to be bespoke gain elements, engineered for enhanced spectroscopic and physical properties.

We report a number of active planar waveguide lasers, doped with Tm^{3+}, Nd^{3+} and Yb^{3+}, in sesquioxide and garnet hosts, such as Y_2O_3 and Lu_2O_3, and GGG and YAG. For the latter, doped with Yb^{3+} at 7.5at.% and homo-epitaxial growth on a YAG substrate, we have realised 70% slope efficiency with a 12-micron thick waveguide laser end-pumped with a single diode-laser bar giving 16W of output. This slope is comparable to the best values reported for crystals grown by the conventional Czochralski process. In terms of a passive crystalline composites, we have fabricated a 145 layer YAG/GGG Bragg mirror with >99.5% reflectivity [1], illustrated below (middle) with spectral response (right), produced by multi-beam PLD enabling mixing of similar crystals to obtain enhanced functionality. Damage thresholds of >30Jcm^{-2} were obtained from first experiments with a similar stack containing 45 layers. Also of note is their robustness with performance maintained at temperatures up to 750°C.

In this presentation, I will review our progress and recent results with sesquioxide and garnet waveguide devices, and discuss the potential for new tailored structures such as graded-doping structures and all crystalline Bragg mirrors.

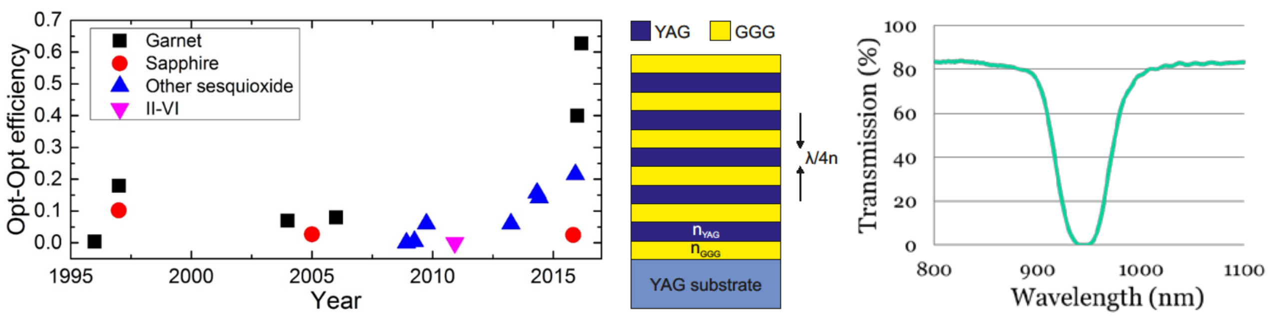

Figure 1. Left: optical efficiency of PLD grown PWL's in recent years. Middle: schematic diagram of Bragg mirror device. Right: spectral response of 145 layer YAG/GGG Bragg mirror.

[1] K. A. Sloyan, T. C. May-Smith, M. N. Zervas, and R. W. Eason, Appl. Phys. Lett, **101**, 081117 (2012)