Fabrication of Composite Structures in Transparent Optical Ceramics

HERIOT WATT UNIVERSITY

Figure 1 : RED DEVIL Vacuum Furnace.


Figure 2 : Sintered semi-transparent ceramic.

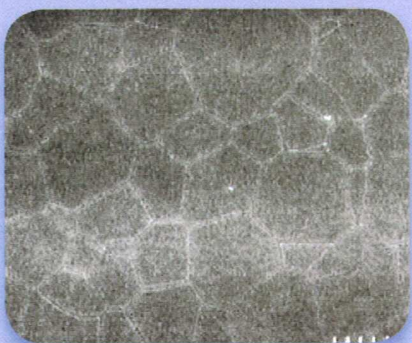
Figure 3 : Polycrystalline structure of highly transparent YAG ceramic after vacuum sintering.


Figure 4 : Powder suspension dispensing system.

Rationale

High performance diode and solid state lasers are currently based on crystalline and glass active materials (e.g. Nd:YAG, Nd:Glass). New organic polymer active materials are increasingly being used in low-cost optics, but their poor thermal conductivity limits their use to low-power applications.

A new topic in optical materials has emerged in the last 10 years, based on innovations in ceramics technology. Transparent ceramics now offer a third route to high performance optics, providing a combination of the stability, durability and power dissipation characteristics of traditional inorganic materials with compatibility with many of the low cost manufacturing processes enjoyed by organic polymer materials. Transparent ceramic production technology can produce very uniform doped or mixed oxide compositions for use in lasers, with, for example, ytterbium or neodymium substitution for yttrium in the YAG ceramic host. Optical ceramics also offer the prospect of creating active-passive structures that cannot currently be fabricated in glass or crystalline materials.

Research Aims

In this project, we aim to address the functional aspects of optical ceramics through development of methods for creating composite and microstructured optical components in these materials. Optical ceramic composite structures will be produced by precision dispensing of ultra-fine powders in liquid suspension, combined with on-line drying to compact the structure. Layer-by layer build-up allows the production of internal structures such as buried channel waveguides.

Research Objectives

The particular objectives are to:

- Develop techniques for producing composite low-optical-scatter homogeneous ceramic structures using a liquid suspension of ultra-fine ceramic powder and 'switched' dispensing of several powder compositions.
- Develop a layered deposition method using a liquid suspension of ultra-fine ceramic powder, and demonstrate sintering to produce a low-optical-scatter, homogeneous transparent ceramic in a planar configuration.
- Introduce dispenser switching within the deposition of a layer to produce microstructured planar layers, enabling the fabrication of difficult components such as buried optical waveguides with lensed ends, or compositionally graded microstructures for high performance solid-state lasers.
- Evaluate the material, mechanical and optical characteristics of these structures, and explore their use high power planar waveguide laser fabrication.

Research Tasks

- Production of characterised samples of sintered ceramic YAG with low optical losses.
- Development of precision dispensing equipment and software control.
- Fabrication of flat layered samples of several cm^2 in area and several mm thickness.
- Achievement of low scatter, low attenuation fully characterised optical ceramic.
- Demonstration of layered composites.
- Demonstration of graded composition within a waveguide.
- Measurement of gain and demonstration of laser operation.

Collaborators

Institute for Materials Research,
University of Leeds