$LiYF_4$ ceramic

On the Host Lattice $LiYF_4$ Doped by Trivalent Praseodymium as a Transparent Ceramic Laser Material

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Background

Laser projection is regarded as one of the potential future technologies for digital projection. To realise a full colour laser projection according to the RGB concept three laser types are required. Red and blue efficient laser diodes are already available. Since green emitting laser diodes exhibit a much lower efficiency as the red and blue ones so far, the colour conversion of blue laser diodes by a luminescent material is of interest.

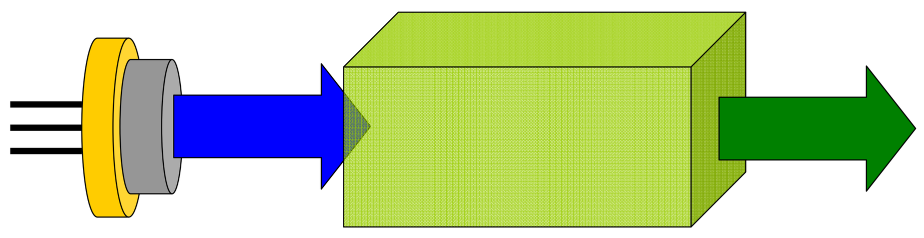

Fig. 1 Principle of light conversion

Converter materials for such a luminescence conversion mostly rely on single crystals. An alternative material class are transparent ceramics, which are presently attracting more and more interest. They are less time consuming in preparation and offer a more homogeneous dopant distribution than single crystals. Moreover, size and geometry can be almost arbitrarily designed. Therefore, they are cheaper in production compared to single crystals. A severe problem of transparent ceramics is scattering at grain boundaries and cavities. Consequently, a laser ceramic must have a low pore density, i.e. a density, which is close to the theoretical limit.

Synthesis

In this study, the host lattice $LiYF_4$ was investigated. It exhibits a tetragonal crystal system ($I4_1/a$), low phonon frequencies (ca. 460 cm^{-1}), a wide band gap (10.6 eV), and a low melting point of 819 °C, which are some of the most important requirements for a transparent laser material. The host lattice was doped by trivalent Praseodymium as the active medium onto the Y^{3+} position.

In order to obtain particles with variable morphology and size, two different powder preparation routes, the so-called “Mix and Fire” and the micro emulsion method, were performed. As starting materials for the “Mix and Fire” route high purity fluorides of the metals were used, viz. LiF, YF_3, and PrF_3. Stoichiometric blends were sintered at 650 °C for 6 h in an Nitrogen stream to obtain single phase material. The micro emulsion method was performed by dissolving cetyltrimethylammonium bromide (CTAB) in n-Octanol. In the resulting micelles a mixture of high purity LiCl, YCl_3 diluted in water was introduced. After that a second solution of NH_4HF_2 was introduced in the micelles and the precipitation of the fluorides took place. The resulting powder was sintered at 300 °C for 4 h to increase the crystallinity of the particles.

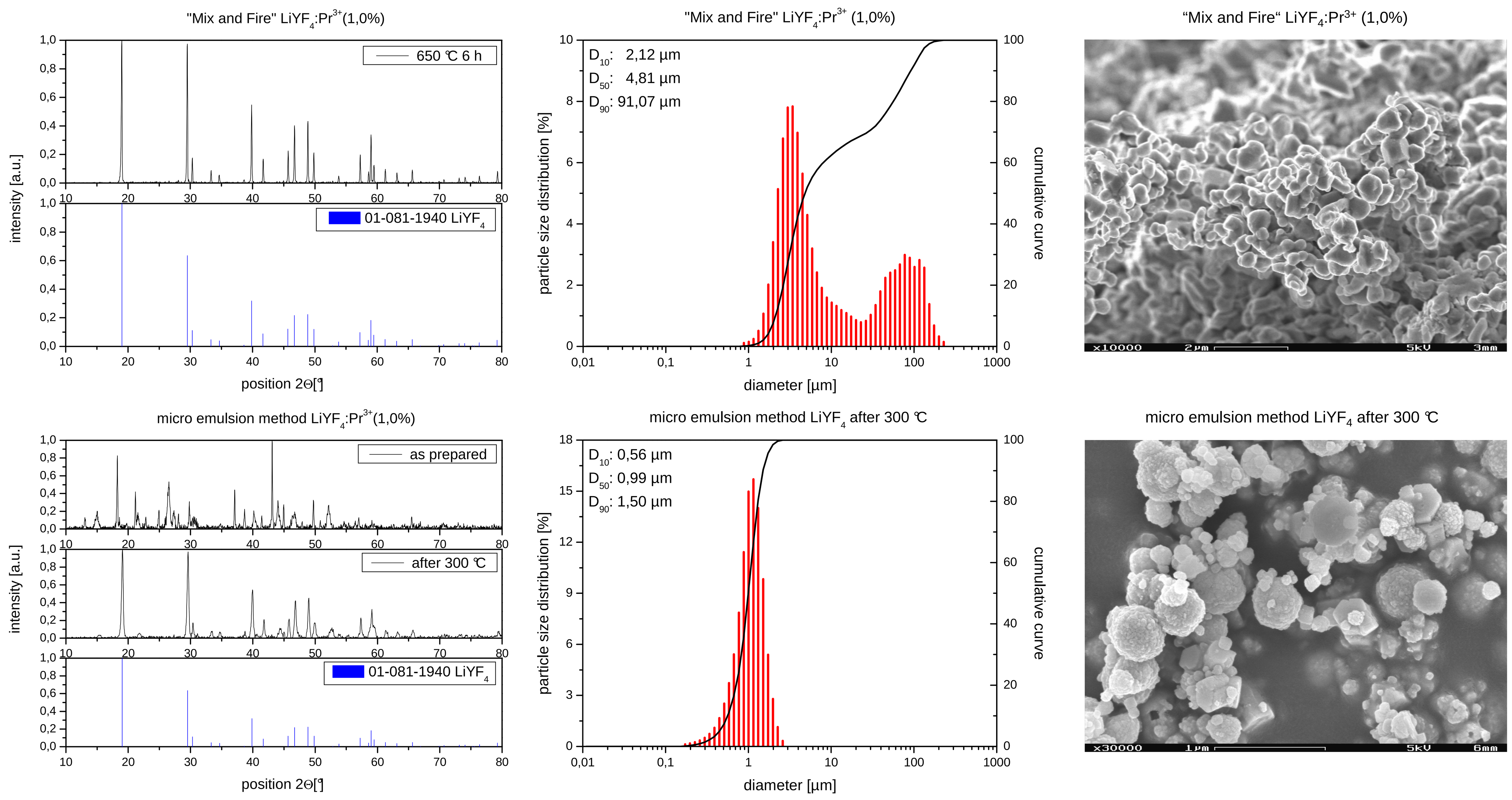

Fig. 2 Powder diffraction pattern, particle size distribution, and SEM images of the two different powder preparation routes

Ceramic preparation

Resulting powders were homogeneously mixed on a rolling bench and afterwards pressed uniaxially and subsequently isostatic for one hour to achieve pellets with a high green body density. These green bodies were subsequently sintered for several hours at temperatures around 700 °C in a Nitrogen stream. Achieved translucent ceramics were characterised by powder diffraction, secondary electron microscopy, and optical spectroscopy.

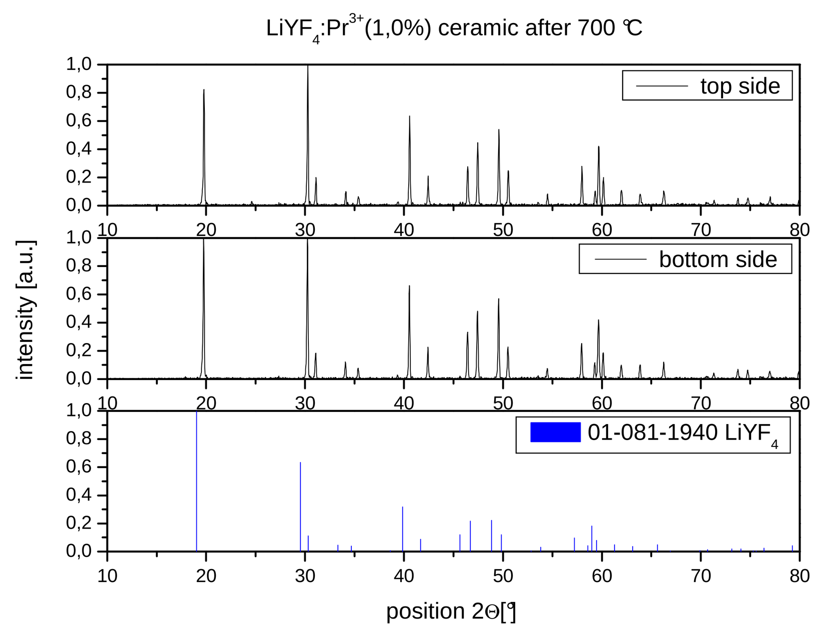

Fig. 3 Powder diffraction pattern of an as-prepared $LiYF_4$ ceramic

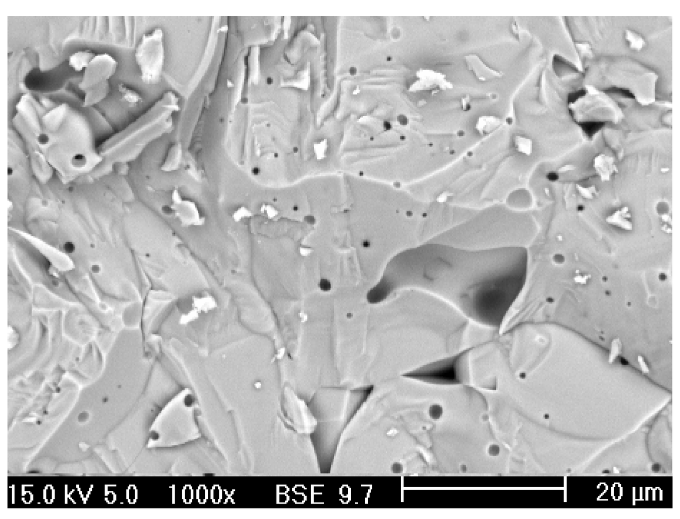

Fig. 4 SEM image of a as-prepared $LiYF_4$ ceramic

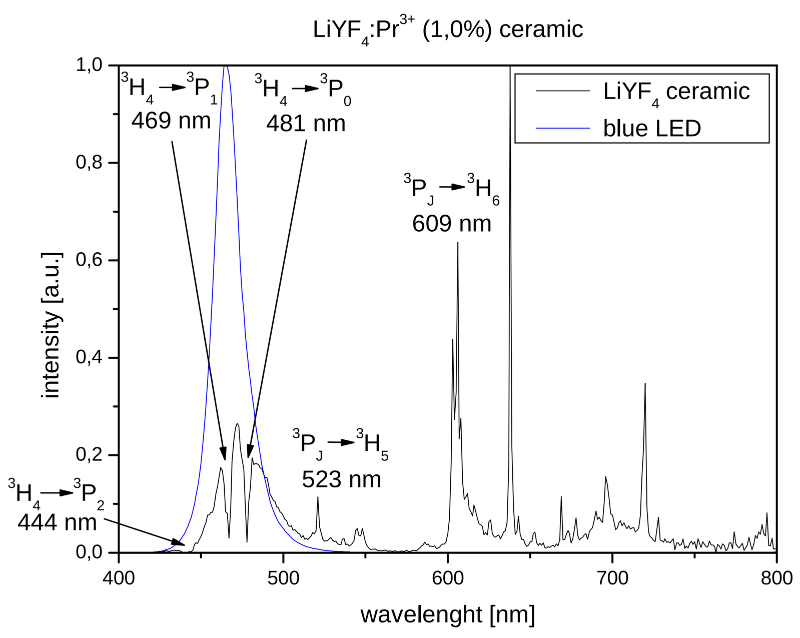

Fig. 5 Blue LED and resulting spectrum upon passing a $LiYF_4:Pr^{3+}$ ceramic

Fig. 6 Example of a typical translucent $LiYF_4:Pr^{3+}$ ceramic

Conclusions

By pressing the obtained mixed $LiYF_4:Pr^{3+}$ powders uniaxially and isostatically, it is possible to obtain green bodies with a density around 70 – 75% of the theoretical density. Sintering these green bodies yields densities up to 95%, which leads to translucent ceramics. The spectrum of a 465 nm LED measured in transmission through such a ceramic body consists of the blue LED spectrum modified by the absorption lines of Pr^{3+} and of the respective emission lines of Pr^{3+}.

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