Yb³⁺-doped optimized laser crystals: Crystal growths, optical spectroscopy and combinatorial approach to study concentration quenching mechanisms.

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1. Presentation of our approach.

Our scientific program is involving different crystal growth, optical spectroscopy analysis, criteria of evaluation and a new combinatorial approach to study concentration quenching mechanisms in Yb³⁺-doped oxide or fluoride laser crystals which are diode-pumped [1]. Among crystalline families which provide the best expected performances, we have choose to grow crystalline fibres as sesquioxides, oxypates, niobates and garnets pulled either from the Laser Heated Pedestal Growth (LHPG) or the Micro-Pulling Down (µ-PD) technique. Bulky samples have been also grown either by the top nucleated floating crystal (TNFC)as tunstasates and by the Czochralski (CZ) technique as garnets, and molydates.

Optical spectroscopy of all Yb³⁺-doped crystals have been analyzed by researching electronic transitions among vibronic transitions. In addition, a new combinatorial chemistry approach has been pointed out to study the Yb³⁺ radiative lifetimes and concentration quenching processes in these laser crystals.

2. Samples of Yb³⁺-doped laser crystals which have been grown and analyzed:

- Yf³⁺, Sc³⁺, Lu³⁺, Lu₂O₃, lutecia sesquioxides, LiNbO₃ (LNb) lithium niobate, and Y₃Al₅O₁₂ yttrium aluminium garnet (YAG), grown by the Laser Heated Pedestal Growth (LHPG) method,
- oxypate Ca₃La₃(PO₄)₃O₂ (CLYPA), Y₃Al₅O₁₂ yttrium aluminium garnet (YAG) and Ba₂Na Nb₅O₁₅ (BNN) niobate grown by the Micro-Pulling Down Method,
- KY(WO₄)₂ potassium yttrium (KYW) tungstate and KNd(WO₄)₂ (KGW) potassium gadolinium tungstate grown by the top nucleated floating crystal (TNFC).
- Gd₂Ga₂O₁₂ (GGG) grown by the Czochralski technique.

3. Evaluation of Yb³⁺-doped oxide crystals

Taking into account of the great number of Yb³⁺-doped crystals, a need of a new evaluation of Yb³⁺-doped crystals was necessary in order to predict the laser efficiency in a more realistic manner in different kinds of regimes. According to a new evaluation based on a quasi-three level laser model, [2], several Yb³⁺-doped laser crystals have been evaluated for either oscillators or amplifiers.

The results of calculations is visualized in a two-dimensional diagram considering the laser extracted power and the slope efficiency. KY(WO₄)₂ (KYW) and KNd(WO₄)₂ (KGW), Yf³⁺, Sc³⁺, Lu³⁺, lutecia sesquioxides and YAB [YAl₅(BO₃)₃] have the highest laser potentialities in the CW regime, whereas C-FAP (Ca₅(PO₄)₂F) and S-FAP (Sr₅(PO₄)₂F) of apatite structure, oxypate Ca₃La₃(PO₄)₃O₂ (CLYPA), Y₃Al₅O₁₂ yttrium aluminium garnet (YAG), and tungstates are the most efficient when considering the small-signal gain in amplifier regime.

3. Combinatorial approach based on gradient concentration fibres

A new and original method has been pointed out to grow activator ion concentration gradient crystal fibres by using the LHPG (Laser Heated Pedestal Growth) technique [3]. In this technique a floating zone is created at the top of a vertical feed rod by a focused laser beam. Because of the lack of crucible and of the use of 200 watt power CO₂ laser, the LHPG technique is well adapted to high refractory crystals such as Yf³⁺, Sc³⁺, Lu³⁺, lutecia sesquioxides and also garnets. This new approach is an efficient tool for measuring optical, spectroscopic or thermal properties in any type of inorganic optical materials in which either activator ion or nominal composition concentrations can be changed. First of all, we have used the technique to study concentration dependences of the spectroscopic properties both in rare earth-doped and co-doped refractory sesquioxide crystals [4] and recently in Yb³⁺-doped YAG. Radiative (self-trapping) and non-radiative energy transfers have been observed from the Yb³⁺ ²F⁵/₂ → ²F⁷/₂ IR transitions. The radiative lifetimes and the competition between radiative, non-radiative processes to unexpected ions and pair effects shown by green anti-Stokes emission will be described.

References

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