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Published in:
Proceedings of the European Quantum Electronics Conference

Publication date:
1998

Document Version
Publisher's PDF, also known as Version of record

QThG32

Upconversion spectroscopy in rare-earth doped chalcogenide glasses

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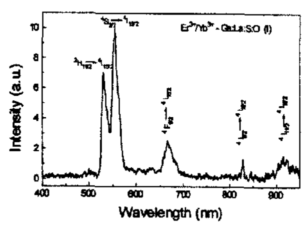
In recent years, there has been a widespread in the develoment of new host materials to for rare-earth doped solid-state optical devices. Amongt many alternatives, chalcogenide glasses [1] have emerged as serious competitors for applications as in 1.3 μm optical fiber amplifiers, mid-infrared lasers, upconversion lasers and satturable absorbers [2].

In this work we report, on the infrared-to-visible upconversion fluorescence spectroscopy of chalcogenide glasses doped with rare-earth ions (Pr^{3+}, Er^{3+} and Er^{3+}/Yb^{3+}). The chalcogenide glasses utilized in this work are of types GLS (Gallium-Lanthanum-Sulphide) and $Ga_2S_3:La_2O_3$ which is a modified version of GLS glass by the addition of lanthanum-oxide, and the samples were pumped at 1.06 μm and 1.54 μm. For $GLS:Pr^{3+}$ pumped at 1.06 μm, the results present the generation of broad band visible emission in the wavelength region of 590-900 nm. Two-photon absorption mediated by multiphonon decays are responsible for the population of excited-states emitting levels. For $Ga_2S_3:La_2O_3$ samples doped with Er^{3+} and Er^{3+}/Yb^{3+} the results reveal the generation of visible upconversion emission around 525, 550, 670, 813 and 925 nm, for 1.06 and 1.54 μm pumping wavelengths. As depicted in spectrum of fig. 1. Energy transfer involving Er-Er and Er-Yb ions and multiphonon assisted nonradiative decays account for the excitation mechanism. The dependence of the upconversion processes with excitation intensity, temperature and rare-earth concentrations were also studied. The high efficiency of the upconversion process in these chalcogenide glasses suggest new applications for the material such as upconversion lasers and upconversion based optical temperature sensors, and saturable absorbers.



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QThG33

Generalised Boyd-Kleinmann coefficients for OPO modelling

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SUMMARY
The fundamental process of the optical parametric oscillator is a parametric coupling of three monochromatic waves. Three wave interaction of focused Gaussian fields was first considered by Boyd and Kleinmann in the late sixties. In their work the interaction of the three beams was computed as an overlap integral throughout the crystal resulting in the so-called Boyd-Kleinman reduction factor. Their analysis also takes into account walk-off associated with an extraordinarily polarised beam propagating in a birefringent crystal. Their description was, however, limited to either ordinary polarised pump and extraordinary polarised signal and idler (oee) or extraordinary polarised pump and ordinary polarised signal and idler fields (eoo), usually denoted Type I phase matched interaction. In the following a generalised theory including arbitrary confocal parameters for the three beams and independent walk-off of any two beam pairs as it occurs in Type II phase matching will be derived.

The derivation of the generalised expressions follows the same procedure as used by Boyd and Kleinmann [1]. However, in the case of Type II phase matching, walk-off leads to expressions that are different from those of Type I phase matching. Firstly, walk-off can occur for both the pump field and the signal or idler fields, and the walk-off angles of the two beams are in general not identical although in the same plane. Secondly, the generalised Boyd-Kleinmann factor becomes wavelength dependent in case of critical Type II phase matching, as the walk-off angles vary and the beam divergence changes as the system is tuned away from degeneracy.

In our derivation all three beams are assumed to be focused TEM_{00}-mode beams with a Gaussian intensity profile and are allowed to have independent beam parameters. However, in practice the beams are often confined by a confocal optical cavity, which means that all beams are focused at the same location, and all beam focal parameters are equal. In that case the overlap integrals are somewhat simpler, and the results that include the original Boyd-Kleinman can be given as rather simple one-dimensional integrals.

The derivation of the overlap integrals assumes non-depleted fields. To go further one must consider the explicit resonance behaviour (single resonant, double resonant, pump enhanced etc.). In some of these cases the integrals can be carried out analytically; in others they must be evaluated numerically. We have used the reduction factors instead in a model, where the crystal is sliced up into small segments normal to the general propagation direction (z-axis) and the changes in the fields computed in each segment. The changed fields are then used as input to the following segment. This way depletion and growth of all three fields can be handled.