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Upconversion spectroscopy in rare-earth doped chalcogenide glasses

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

In this work we report on the upconversion spectroscopy of chalcogenide glasses. The chalcogenide glasses utilized in this work are of type GS (Gallium Selenide-Sulfide) and GeS2/SiO2, which in a modified version of GLS glass by the addition of tellurium-oxide, and the samples were pumped at 1.06 µm and 1.54 µm. For 1.06/µm pumped at 1.06 µm, the results present the generation of broad band visible emission in the wavelength region of 590-600 nm. Two-photon absorption mediated by multiphoton decay are responsible for the population of excited-states emitting levels. For GeS2/SiO2 sample pumped with 1.06/µm the results reveal the generation of visible upconversion emission around 525, 530, 670, 810 and 912 nm, for 1.06 and 1.54 µm pumping wavelengths. As depicted in spectrum of the GeS2/SiO2 sample in Fig. 1, the efficiency of the upconversion process with excitation intensity, temperatures and rare-earth concentrations were strongly studied. The low 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 sideband-sources [2].

REFERENCES


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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-Kleinmann 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 fields (em), 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 beams diverge changes in the system is tested away from degeneracy. In our derivation all three beams are assumed to be focused TEM00 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 for the original Boyd-Kleinmann can be given in 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 evaluated 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 charged fields are then used as input to the following segment. This way depletion and growth of all three fields can be handled.