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Neodymium-doped gallium lanthanum sulphide glass laser

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Summary

Chalcogenide glasses are compound glasses containing one or more of the chalcogen elements S, Se, and Te and metals such as Ga, As, and Ge[1]. The main applications of these glasses are their use as infrared transmitting windows and as "light pipes" for infrared radiation when pulled into fibre form. The infrared transparency is caused by the low phonon energies of the glass structure. The low phonon energies also reduce the non-radiative decay rates in rare-earth doped chalcogenide glasses making them interesting for applications such as lasers and fibre amplifiers[2,3,4].

Our work focusses on the chalcogenide glass gallium lanthanum sulphide (Ga:La:S) which has been proposed as a material for lasers and praseodymium-doped fibre amplifiers[3,4,5]. These early laser experiments with a neodymium-doped Ga:La:S glass failed due to the destruction of the sample in the pumping beam[5].

A high quality neodymium-doped sample with the molar ratio $70Ga_2S_3$:$28.5La_2S_3$:$1.5Nd_2S_3$ was prepared by melt quenching. The absorption spectrum of a 1.42 mm thick sample (fig. 1) shows the wide transmission of Ga:La:S glass (max. phonon energy of 425 cm^{-1}) extending from the UV absorption edge at 0.5 µm to beyond 8 µm. The absorption bands of the $^2H_{9/2}$ and $^4F_{5/2}$ levels at 0.815 µm and of the upper laser level $^4F_{3/2}$ at 0.890 µm were used to excite the samples for fluorescence, lifetime and laser experiments. Three fluorescing transitions from the $^4F_{3/2}$ level to the $^4I_{9/2}$, the $^4I_{11/2}$, and the $^4I_{13/2}$ levels at 0.915 µm, 1.08 µm, and 1.36 µm, respectively, were measured when excited with a Ti:sapphire at 0.815 µm. The measured lifetime of the $^4F_{3/2}$ level is 70 µs.

Laser action could be achieved on the strongest transition at 1.08 µm (see fig. 1). This is, to our knowledge, the first demonstration of laser action in a chalcogenide glass and in Ga:La:S glass in particular.

We used a simple hemispherical resonator formed by a flat input coupler and an output coupler with 50 mm radius of curvature. The 1.42 mm thick sample doped with 1.5mol% neodymium was placed close to the input mirror. Continuous wave laser action at room temperature was obtained by pumping with a Ti:sapphire laser at either 0.815 µm or 0.890 µm. The longer pump wavelength yielded better results due to the lower thermal loading of the glass. The input-output curves for two different output couplings (oc) in figure 2 show the thermal problems of the glass laser. Strong thermal lensing was observed by superimposing a red He/Ne laser beam on the Ti:sapphire beam. The output power reached values of 2.7 mW and the slope efficiency η values of 11% when fitted to the first linear part of each curve as indicated by the lines. The thresholds are reasonably low indicating acceptable glass losses. Based on these laser experiments we will melt Ga:La:S glasses with different neodymium concentrations for further experiments, the results of which will be reported at the conference.

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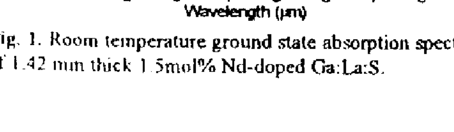

Fig. 1. Room temperature ground state absorption spectrum of 1.42 mm thick 1.5mol% Nd-doped Ga:La:S.

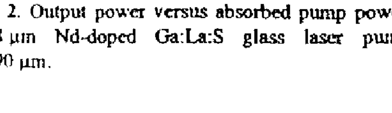

Fig. 2. Output power versus absorbed pump power of the 1.08 µm Nd-doped Ga:La:S glass laser pumped at 0.890 µm.