Mid-IR optical parametric oscillator based on $LiGaS_2$

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The orthorhombic lithium ternary chalcogenides with the chemical formula $LiBC_2$, where B=In or Ga and C=S or Se, occupy a special position among the non-oxide nonlinear crystals because they are characterized by the widest band-gaps.[1] Thus, in contrast to most of the other chalcogenide mid-IR nonlinear crystals used for down-conversion of near-IR laser sources, they will not suffer two-photon absorption (TPA) at the pump wavelength of 1064 nm (nanosecond or picosecond Nd:YAG based systems) and in some cases even near 800 nm (femtosecond Ti:sapphire lasers/amplifiers).[2] In addition, these compounds exhibit increased damage threshold and relatively low refractive index dispersion in the infrared, which is important for frequency conversion of ultrashort laser pulses, and their thermal conductivity is higher compared to their Ag analogues $AgBC_2$, which is an essential advantage at high average powers. Though exhibiting the lowest nonlinear coefficients, e.g. d_{eff}~5.5 pm/V for down conversion from 1064 nm to an idler wavelength of 6.45 µm, $LiGaS_2$ (LGS) possesses the widest band-gap among the $LiBC_2$ compounds and recently we established that it is also the compound characterized by highest damage threshold at 1064 nm: with 14 ns pulses at 100 Hz (exposure time of 1 min) the damage threshold of such crystals, both uncoated and with a single layer antireflection- (AR-)coating, was between ~3.5 J/cm^2 (turbidity) and ~4 J/cm^2 (full damage) in terms of on-axis fluence. In addition, no aging (no surface degradation after a period of ~7 years) was observed in such polished colourless LGS samples.

Limited by the sample length achievable with sufficient optical quality and the surface damage threshold, previously we demonstrated optical parametric oscillation (OPO) only with $LiInSe_2$, the $LiBC_2$ compound with highest d_{eff}~10.57 pm/V, using crystals lengths between 17 and 24.5 mm.[3] Here we report for the first time mid-IR OPO with LGS. The sample was only 8.2 mm long, with an aperture of 5 mm (along Z-axis) × 7 mm. It was cut at θ=90°, φ=40.6° for eo-e type-II phase-matching in the X-Y plane and AR-coated with a single layer of YF_3 centered at 1250 nm. The 10-mm long linear cavity was formed by a 10-cm radius of curvature (RC) input-output coupler on a 3-mm thick YAG substrate (highly reflecting the signal and highly transmitting the pump and idler waves) and a 5-cm RC Ag total end reflector. The short cavity length permitted pumping with 1-ns pulses from a Nd-laser based system at 1 kHz, which normally results in sub-ns signal and idler pulse durations.[4]

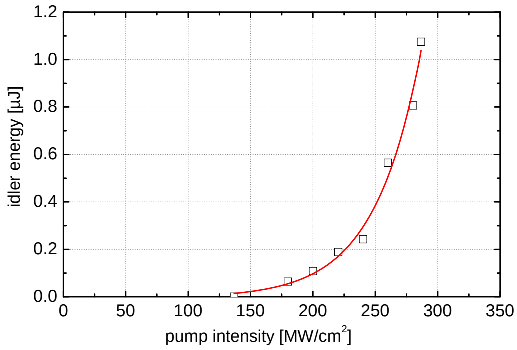

Fig. 1. Idler pulse energy of the OPO at 5.457 µm versus average pump intensity (appr. ½ of the peak on-axis intensity) at 1064 nm. The output coupler transmits about 55% at this wavelength due to the YAG substrate absorption.

The input-output characteristics at normal incidence are shown in Fig. 1. Although the threshold was ~80 times higher compared to the highly nonlinear, but otherwise limited in tunability $CdSiP_2$ crystal,[4] it was possible to operate the LGS OPO at pump levels >2 times above threshold without optical damage. Angle tuning was studied in a slightly lengthened (15 mm) cavity, covering the 4.046 to 6.014 µm spectral range for the idler.

References

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