800 nm 영역에서 펌핑된 $Cd_xHg_{1-x}Ga_2S_4$ 펨토초 중적외선 광매개 증폭

Femtosecond mid-IR optical parametric amplification with pumping near 800nm using $Cd_xHg_{1-x}Ga_2S_4$

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Ternary semiconductors of the type $A^{II}B_2^{III}C_4^{VI}$ known as defect chalcopyrites are considered to be very promising for operation in the mid-IR spectral range(1) because of their superior nonlinearity and damage threshold. Representatives are $CdGa_2S_4$ (CGS) and $HgGa_2S_4$ (HGS) from which only HGS possesses sufficient birefringence for phase-matching.

In previous work we demonstrated the practical advantages of $Cd_xHg_{1-x}Ga_2S_4$ relative to HGS resulting from the modified index of refraction (group-velocity mismatch). This first experimental application of $Cd_xHg_{1-x}Ga_2S_4$ in a traveling-wave type optical parametric amplifier with 1.25 μm pumping relied on linear interpolation of the Sellmeier equations for HGS and those for CGS.(2)

Here we present experimental evidence for the advantages of the mixed crystal $Cd_xHg_{1-x}Ga_2S_4$ in the mid-IR spectral range utilizing the possibility to increase the bandgap relatively to HGS in order to avoid TPA in a femtosecond OPA .

The bandgaps of CGS and HGS were measured to be 3.58 eV (346 nm) and 2.79 eV (444 nm), respectively and it has been shown that the bandgap for the mixture can be linearly interpolated.(3) This means that a phase-matchable solid solution of $Cd_xHg_{1-x}Ga_2S_4$ could be pumped near 800 nm without the onset of two-photon absorption (TPA). This possibility could open the way for efficient single step parametric down-conversion of high-power femtosecond/picosecond laser sources on the basis of Ti:sapphire to the mid-IR spectral range above 5 μm up to 11 μm, a property demonstrated so far only with LiInS2 whose nonlinearity is modest.(4)

The effective nonlinearity d_{eff} of $Cd_xHg_{1-x}Ga_2S_4$ for type-I interaction is given by $d_{ooc}=(d_{36}\sin 2\varphi + d_{31}\cos 2\varphi)\sin\theta$, or eliminating the smaller coefficient d_{31} by choosing $\varphi=45^\circ$, simply by $d_{ooc}=d_{36}\sin\theta$ where $d_{36}(Cd_xHg_{1-x}Ga_2S_4)=d_{36}(HGS)=d_{36}(CGS)=22.9$ pm/V can be assumed. Pumping an OPA at wavelengths shorter than 1.25 μm(2) requires larger birefringence and consequently higher Hg-content (1-x). For the single stage OPA experiment described here a Ti:sapphire regenerative amplifier at 1 kHz was used to pump 3-mm thick $Cd_{0.35}Hg_{0.65}Ga_2S_4$ at $\lambda_P=820$ nm with 220 fs long pump pulses. The 220 fs pulse duration was obtained by adjusting the pulse compressor and the actual spectral width of the pump pulses corresponds to a duration of 80 fs with a Fourier product of about 0.6 which gives a FWHM of 7.64 THz or $\Delta\lambda$=17 nm.

The experimental set-up for the single stage OPA is shown in Fig. 1. We used only a part of the available pump energy (230 μJ) which for the beam diameter of 2.3 mm corresponded to a peak on-axis pump intensity of 50 GW/cm^2. At this pump level the transmission of the sample was 55%, about 14% loss in addition to the Fresnel reflections was caused by TPA. The OPA was seeded by continuum generated by 30 μJ of pump radiation in a 2-mm sapphire plate.

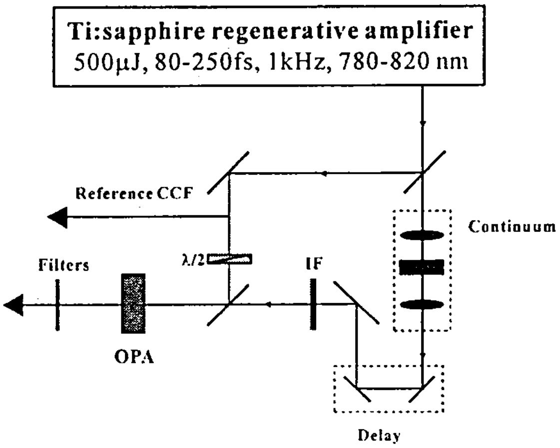

Fig. 1 Experimental set-up of the single stage parametric down-converter

Interference filters were used to select 10 nm wide spectral portions of the continuum near 900 nm for characterization and tuning of the OPA. The continuum seed pulses were measured by sum-frequency generation in a 0.5-mm thick BBO crystal where the GVM (20 fs/mm) with the references pulses at 820 nm was negligible. The estimated seed pulse duration was about 400 fs and the seed pulses at the signal wave were approximately 3-times Fourier limited.

The single stage OPA produced 2-μJ idler pulses near 6.6 μm corresponding to an internal conversion efficiency of 10% when no interference filter was inserted for spectral selection of the seed continuum. The idler pulse duration was measured by sum-frequency generation with reference pulses at λ_P in a 0.3-mm thick AgGaS2 crystal cut at θ=40.5° for type-I interaction. Deconvolving the cross-correlation trace by taking into account the GVM in the $AgGaS_2$ crystal, we arrive at 215 fs (FWHM) for the idler pulse duration assuming Gaussian pulse shapes.

At longer idler wavelengths the generated mid-IR pulses were lengthened as expected from the lower gain. At 8 μm the temporal FWHM of 500 fs and the 500 nm spectral FWHM lead to a time-bandwidth product of 1.2. Similar behaviour to that described above was observed, as the unseeded single stage OPA operated as an optical parametric generator (OPG) when pumped at higher levels (using shorter pulses and/or higher pump energy).

References:

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