$ZnGeP_2$ / $AgGaSe_2$ / $AgGaS_2$ / GaSe – INFRARED NONLINEAR CRYSTALS

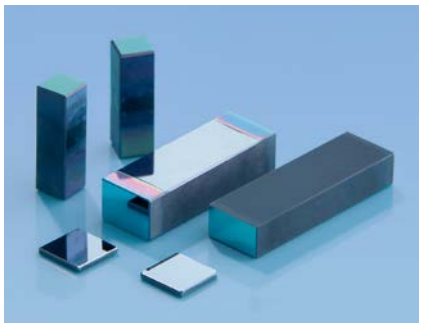
$ZnGeP_2$

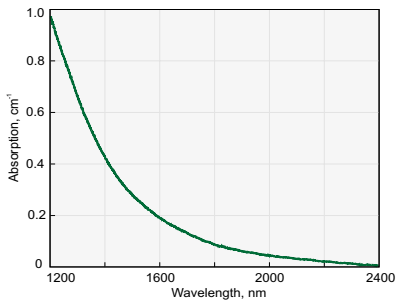
$ZnGeP_2$ (ZGP) crystal has transmission band edges at 0.74 and 12 µm. However it's useful transmission range is from 1.9 to 8.6 µm and from 9.6 to 10.2 µm. ZGP crystal has the largest nonlinear optical coefficient and relatively high laser damage threshold. The crystal is successfully used in diverse applications:

- up-conversion of CO_2 and CO laser radiation to near IR range via harmonics generation and mixing processes;
- efficient SHG of pulsed CO, CO_2 and chemical DF-laser;
- efficient down conversion of Holmium, Thulium and Erbium and laser wavelengths to mid infrared wavelength ranges by OPO process.

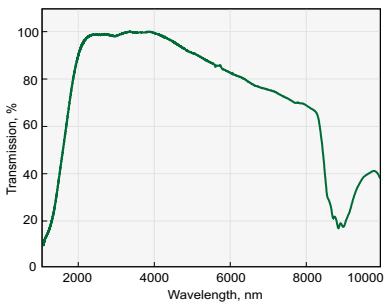
Crystals with high damage threshold BBAR coatings and the lowest absorption coefficient $\alpha < 0.05$ cm^{-1} at pump wavelengths 2.05 – 2.1 µm „o"- polarisation are available for OPO applications.

Typical absorption coefficient is <0.03 cm^{-1} at 2.5 – 8.2 µm range.

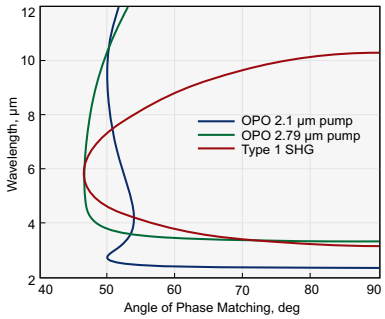




Absorption spectra of $ZnGeP_2$ crystal near 2 µm



Transmission spectra of 15 mm long AR coated $ZnGeP_2$ crystal for OPO @ 2.1 µm



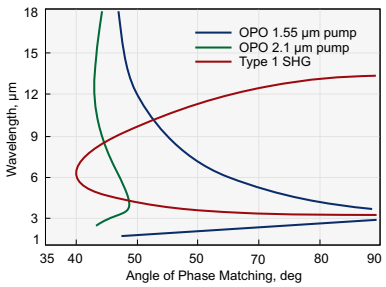
Type 1 OPO and SHG tuning curves in $ZnGeP_2$

Type 1 $ZnGeP_2$ crystalS for OPO at 3.5-5 µm range pumped at ~2.1 µm

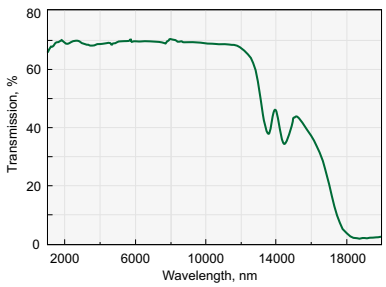
Size, mm	θ, deg	φ, deg	Coating	Application	Catalogue number
7×5×15	54	0	AR @ 2.1 µm + BBAR @ 3.5-5 µm	OPO@2.1 → 3.5-5 µm	ZGP-401
7×5×20	54	0	AR @ 2.1 µm + BBAR @ 3.5-5 µm	OPO@2.1 → 3.5-5 µm	ZGP-402
7×5×25	54	0	AR @ 2.1 µm + BBAR @ 3.5-5 µm	OPO@2.1 → 3.5-5 µm	ZGP-403

$AgGaSe_2$

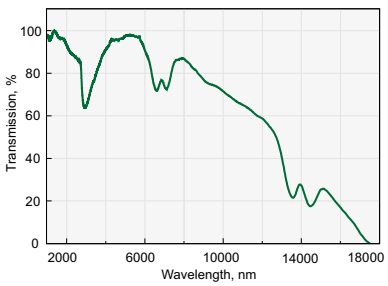
$AgGaSe_2$ has band edges at 0.73 and 18 µm. Its useful transmission range of 0.9–16 µm and wide phase matching capability provide excellent potential for OPO applications when pumped by a variety of currently available lasers. Tuning from 2.5–12 µm has been obtained when pumping by Ho:YLF laser at 2.05 µm; as well as NCPM operation from 1.9–5.5 µm when pumping at 1.4–1.55 µm. Efficient SHG of pulsed CO_2 laser has been demonstrated.



Type 1 OPO and SHG tuning curves in $AgGaSe_2$



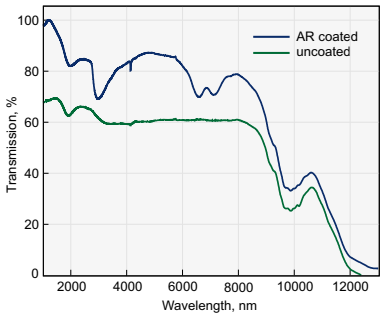
Transmission spectra of 18 mm long uncoated $AgGaSe_2$ crystal



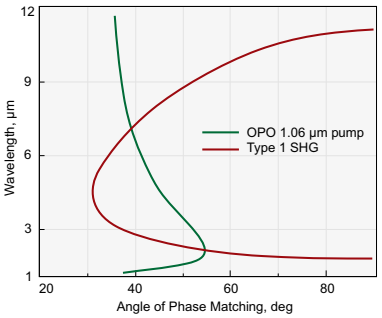
Transmission spectra of 25 mm long AR coated $AgGaSe_2$ crystal

$AgGaS_2$

$AgGaS_2$ is transparent from 0.53 to 12 µm. Although nonlinear optical coefficient is the lowest among the above mentioned infrared crystals, its high short wavelength transparency edging at 550 nm is used in OPOs pumped by Nd:YAG laser; in numerous difference frequency mixing experiments using diode, Ti:Sapphire, Nd:YAG and IR dye lasers covering 3–12 µm range; direct infrared countermeasure systems, and SHG of CO_2 laser.



Transmission spectra of 14 mm long AR coated and uncoated $AgGaS_2$ crystal used for OPO pumped by Nd:YAG laser



Type 1 OPO and SHG tuning curves in $AgGaS_2$

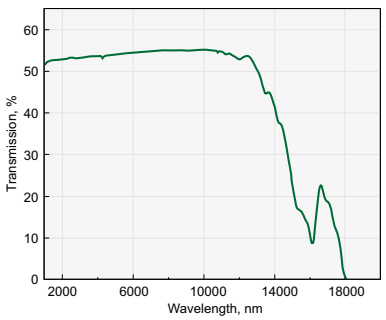
List of Standard $AgGaS_2$ Crystals

Size, mm	θ, deg	φ, deg	Coating	Application	Catalogue number	Price, EUR
5×5×1	39	45	BBAR/BBAR @ 1.1-2.6 / 2.6-11 µm	DFG @ 1.2-2.4 µm -> 2.4-11 µm	AGS-401H	1770
6×6×2	50	0	BBAR/BBAR @ 1.1-2.6 / 2.6-11 µm	DFG @ 1.2-2.4 µm -> 2.4-11 µm	AGS-402H	2375
5×5×0.4	34	45	BBAR/BBAR @ 3-6 / 1.5-3 µm	SHG @ 3-6 µm, Type 1	AGS-403H	2040
5×5×0.4	39	45	BBAR/BBAR @ 1.1-2.6 / 2.6-11 µm	DFG @ 1.2-2.4 µm -> 2.4-11 µm	AGS-404H	2040
8×8×0.4	39	45	BBAR/BBAR @ 1.1-2.6 / 2.6-11 µm	DFG @ 1.2-2.4 µm, Type 1	AGS-801H	4080
8×8×1	39	45	BBAR/BBAR @ 1.1-2.6 / 2.6-11 µm	DFG @ 1.2-2.4 µm, Type 1	AGS-802H	3670

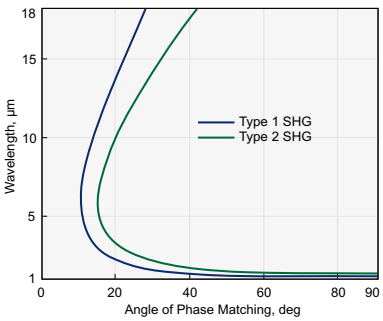
Crystals are mounted into open ring holders (see page 2.26).

GaSe

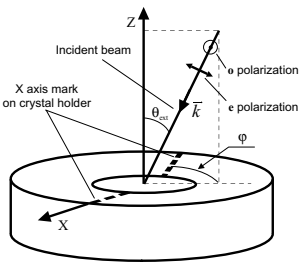
GaSe has band edges at 0.65 and 18 µm. GaSe has been successfully used for efficient SHG of CO_2 laser, for SHG of pulsed CO, CO_2 and chemical DF-laser (λ = 2.36 µm) radiation; up conversion of CO and CO_2 laser radiation into the visible range; infrared pulses generation via difference frequency mixing of Neodymium and infrared dye laser or (F-)-centre laser pulses; OPG light generation within 3.5–18 µm; efficient TeraHertz generation in 100–1600 µm range. It is impossible to cut crystals for certain phase matching angles because of material structure (cleave along (001) plane) limiting areas of applications.



Transmission spectra of 17 mm long uncoated GaSe crystal



Type 1 and Type 2 SHG tuning curves in GaSe



GaSe, Z-Cut

Clear aperture, mm	Thickness, µm	Holder, mm	Catalogue number	Price, EUR
Ø7	10	Ø25.4	GaSe-10H1	1950
Ø7	30	Ø25.4	GaSe-30H1	1625
Ø7	100	Ø25.4	GaSe-100H1	1475
Ø7	500	Ø25.4	GaSe-500H1	1460
Ø7	1000	Ø25.4	GaSe-1000H1	1635
Ø7	2000	Ø25.4	GaSe-2000H1	1810

Please note that from now all standard GaSe crystals are provided mounted into Ø25.4 mm ring holders.
Crystals could be mounted into Ø40 mm holders under your request.

Related Products

Ring Holders for Nonlinear Crystals

See page 2.26

Optical nonlinear crystals $ZnGeP_2$, $AgGaSe_2$, $AgGaS_2$, GaSe have gained tremendous interest for middle and deep infrared applications due to their unique features. The crystals have large effective optical nonlinearity, wide spectral and angular acceptances, broad transparency range, non-critical requirements for temperature stabilization and vibration control, are well mechanically processed (except GaSe).

Physical Properties

Crystal		$ZnGeP_2$	$AgGaSe_2$	$AgGaS_2$	GaSe
Crystal Symmetry		Tetragonal	Tetragonal	Tetragonal	Hexagonal
Point Group		42m	42m	42m	62m
Lattice Constants, Å	a	5.465	5.9901	5.757	3.742
	c	10.771	10.8823	10.305	15.918
Density, g/cm3		4.175	5.71	4.56	5.03

Optical Properties

Crystal		$ZnGeP_2$	$AgGaSe_2$	$AgGaS_2$	GaSe
Optical transmission, μm		0.74–12	0.73–18	0.53–12	0.65–18
Indices of Refraction at					
1.06 μm	n_o	3.2324	2.7005	2.4508	2.9082
	n_e	3.2786	2.6759	2.3966	2.5676
5.3 μm	n_o	3.1141	2.6140	2.3954	2.8340
	n_e	3.1524	2.5823	2.3421	2.4599
10.6 μm	n_o	3.0725	2.5915	2.3466	2.8158
	n_e	3.1119	2.5585	2.2924	2.4392
Absorption Coefficient, cm^{-1} at					
1.06 μm		3.0	<0.02	<0.09	0.25
2.5 μm		0.03	<0.01	0.01	0.05
5.0 μm		0.02	<0.01	0.01	0.05
7.5 μm		0.02	—	0.02	0.05
10.0 μm		0.4	–	<0.6	0.05
11.0 μm		0.8	–	0.6	0.05

Nonlinear Optical Properties

Crystal	$ZnGeP_2$	$AgGaSe_2$	$AgGaS_2$	GaSe
Laser damage threshold, MW/cm^2	60	25	10	28
at pulse duration, ns	100	50	20	150
at wavelength, μm	2.05	10.6	1.06	9.3
Nonlinearity, pm/V	111	43	31	63
Phase matching angle for Type 1 SHG at 10.6 μm, deg	76	55	67	14
Walk-off angle at 5.3 μm, deg	0.57	0.67	0.85	3.4

Thermal Properties

Crystal		$ZnGeP_2$	$AgGaSe_2$	$AgGaS_2$	GaSe
Melting point, °C		1298	851	998	1233
Thermal Expansion Coefficient, 10^{-6}/°K	⊥	17.5[a]	23.4[c]	12.5	9.0
	⊥	9.1[b]	18.0[d]		
	||	1.59[a]	-6.4[c]	-13.2	8.25
	||	8.08[b]	-16.0[d]		

a) at 293–573 K, b) at 573–873 K, c) at 298–423 K, d) at 423–873 K

Sellmeier equations for calculation of indices of refraction

Crystal		A	B	C	D	E	F	Expression
$ZnGeP_2$	n_o	8.0409	1.68625	0.40824	1.2880	611.05	–	$n^2 = A + B\lambda^2/(\lambda^2 - C) + D\lambda^2/(\lambda^2 - E)$
	n_e	8.0929	1.8649	0.41468	0.84052	452.05	–	
$AgGaSe_2$	n_o	6.8507	0.4297	0.15840	0.00125	–	–	$n^2 = A + B/(\lambda^2 - C) - D\lambda^2$
	n_e	6.6792	0.4598	0.21220	0.00126	–	–	
$AgGaS_2$	n_o	3.3970	2.3982	0.09311	2.1640	950.0	–	$n^2 = A + B/(1 - C/\lambda^2) + D/(1 - E/\lambda^2)$
	n_e	3.5873	1.9533	0.11066	2.3391	1030.7	–	
GaSe	n_o	7.443	0.405	0.0186	0.0061	3.1485	2194	$n^2 = A + B/\lambda^2 + C/\lambda^4 + D/\lambda^6 + E/(1 - F/\lambda^2)$
	n_e	5.76	0.3879	-0.2288	0.1223	1.855	1780	