비선형광학 단결정의 제작 및 광학특성

Nonlinear Optical Crystals : Fabrication and Properties

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Although the theoretical background for frequency conversions such as harmonic generation and optical parametric generation was already established in 1970's, it was not 1980's until the practical applications came into realization. KDP (KH_2PO_4), DKDP (Deuterated KDP), ADP, $LiNbO_3$ were all developed by 1970's. However the relatively small values of their nonlinear coefficients kept the crystals only in the applications of limited area such as second harmonic generation.

The recent development of all solid state laser systems has stimultated an extensive search for the novel nonlinear optical (NLO) crystals of high nonlinear coefficient and wide range of transparency. With the advent of low power diode lasers, nonlinear crystals of high conversion efficiency were much needed so that frequency can be converted with a moderate power.

1980's saw the development of highly efficient new nonlinear crystals, KTP ($KTiOPO_4$), BBO (β-BaB_2O_4), LBO (LiB_3O_5) and $KNbO_3$ due to intensive efforts which were made all over the world, especially in China and USA. In due course the second-, third-, fourth- and fifth- harmonic generations and optical parametric oscillations became routine practice in laboratories by using the newly developed NLO crystals and the crystals were increasingly utilized in the commercial solid state laser systems to provide wider range of spectrum.

The fast growing development of optical communication systems has also stimulated the wider search for materials with even higher nonlinear optical properties capable of forming the basis of devices for the efficient processing of optical signals. Organic materials have drawn much attention because of their excellent nonlinear optical properties. In benzene ring structure the delocalized π-electron system can respond to an external field with great mobility and speed, and attaching an electron donor on one end of the π-electron system and an acceptor on the other end enhances nonlinearity even further. Organic material such as meta-nitroaniline (mNA), 2-methyl-4-nitroaniline (MNA), 4-(N, N'-dimethylamino-3-acetamidonitrobenzene (DAN), (-)2-(α-methylbenzylamino)-5-nitrobenzene (MBANP) and 3-methyl-4-methoxy-4'-nitrostilbene (MMONS) have been developed and their second-order nonlinear coefficients were found to be one to three orders of magnitude larger than those of inorganic counterparts.

In this paper discussed will be the fabrication, optical properties and the issues related with practical applications of the NLO crystals which have been developed not only in author's laboratory but in elsewhere.

Table. Comparisons of NLO Properties

	$KNbO_3$	KTP	LBO	BBO
Transparency (㎛)	0.4~5.5	0.35~4.3	0.16~3.2	0.2~3.5
Laser Damage Threshold	150 MW/cm^2 (25ns, 1.064㎛)	400 MW/cm^2 (10ns, 1.064㎛)	40GW/cm^2 1ns, 1.064㎛)	14GW/cm^2 (1ns, 1.064㎛)
d_{ij} (pm/V)	$d_{15} \cong d_{31} = -11.9$ $d_{24} \cong d_{32} = -13.7$ $d_{33} = -20.6$	$d_{15} \cong d_{31} = 2.5$ $d_{24} \cong d_{32} = 4.4$ $d_{33} = 16.9$	$d_{15} \cong d_{31} = 1.05$ $d_{24} \cong d_{32} = -0.98$ $d_{33} = 0.05$	$d_{11} = 2.1$
Effective d-coeff. Type I Type II	$d_{eff} = 9.64$ (1.30) $d_{eff} = 0.06$ (1.30)	$d_{eff} = 0.44$ (1.064) $d_{eff} = 3.30$ (1.064)	$d_{eff} = 1.03$ (1.064) $d_{eff} = 0.92$ (1.064)	$d_{eff} = 0.47$ (1.064) $d_{eff} = 0.98$ (1.064)
Walk-off Angle	3.36° (Type I) 2.25° (Type II)	2.8° (Type I) 0.27° (Type II)	0.40° (Type I) 0.35° (Type II)	3.2° (Type I) 2.74° (Type II)
OPG Spectrum (㎛)	$\lambda_s = 0.59 \sim 1.06$ $\lambda_i = 1.06 \sim 5.5$ (0.532㎛ pump)	$\lambda_s = 0.59 \sim 0.96$ $\lambda_i = 1.19 \sim 4.3$ (0.532㎛ pump)	$\lambda_s = 0.4 \sim 0.55$ $\lambda_i = 1.0 \sim 3.2$ (0.355㎛ pump)	$\lambda_s = 0.4 \sim 0.6$ $\lambda_i = 0.6 \sim 3.5$ (0.355㎛ pump)