광 파라메트릭 진동자에서의 Walkoff 효과

Walkoff effect in optical parametric oscillators

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To improve the conversion efficiency in optical parametric oscillators (OPO), we need to take into account the effects of a number of parameters that govern the characteristics of OPO, such as walkoff, nonlinear optical coefficients, and pump power. However, previous works on OPO have rarely dealt with the walkoff effect on conversion efficiency throughly. Brosnan and Byer expressed the threshold pump intensity as the following equation, with walkoff represented by Z[1].

$$(I_P)_{th} = \frac{2.25}{kg_s Z^2}\sqrt{\frac{2}{\pi}}\left[\frac{L}{2\tau c}\ln\frac{P_n}{P_0} + 2\alpha l + ln\frac{1}{\sqrt{R}} + ln2\right]^2, \text{ where } Z = l_w erf\left(\frac{l\sqrt{\pi}}{l_w 2}\right).$$

From the above equation, we may derive the relationship between the conversion efficiency and walkoff, and it has been well known that the walkoff effect causes the conversion efficiency to decrease. However, a few experiments showed that the conversion efficiency was relatively insensitive to the walkoff[2-3], and the detailed rationale has not been given yet. In this paper, we verified the effect by theoretical calculations and experiments. Although the walkoff effect of OPO may be classified into several different cases, we, here, limit ourselves to three important cases, which are pump walkoff only, signal and idler walkoff, and idler walkoff only. We calculated the walkoff effects for each case using the Runge-Kuta method and the split step method. In the case of pump walkoff only, we found out that the effective walkoff is not large (Fig. 1), because the signal and idler beams travel along with the pump propagation, which is type I nonlinear interactions in the x-z plane in negative uniaxial crystals. In the case of signal and idler walkoff, the conversion efficiency is much less than the other two cases, because both signal and idler beams are deviated from the pump propagation direction significantly. In the case of idler walkoff only, the conversion efficiency is closely related to the beam size, as shown in Fig. 2.

A Q-switched Nd:YAG laser operating at 1.064 ㎛ and with a repetition rate of 10 Hz was used to pump a singly resonant OPO. A top-hat beam of 6 mm diameter was expanded with a telescope to a diameter of 8 mm. The size of the pump beam was controlled by adjusting the aperture of an iris. The temporal profile of the pump beam was observed to be near Gaussian with a pulse duration of 25 ns (FWHM). The size of a $LiNbO_3$ crystal cut at $\Phi = 0°$ and $\theta = 47°$ was 10 × 10 × 50 mm^3 with the type I phase-matching orientation. Output energy was measured as a function of pump energy for five different sizes of the pump beam diameter, ranging from 1 to 8 mm. The experimental results show an excellent agreement with the calculations (Figs. 3 and 4). It is interesting to notice that the conversion efficiency become independent of the beam size when the beam size is larger than 2 mm.

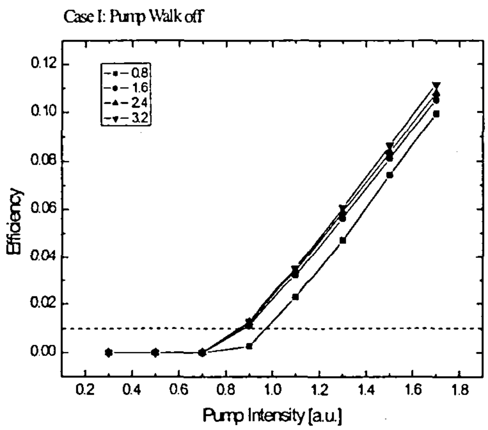

Fig.1 Dependence of conversion efficiency on the pump intensity in the case of pump walkoff only: theoretical results.

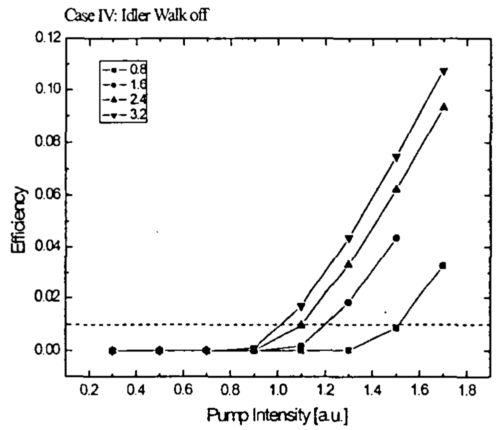

Fig.2 Dependence of conversion efficiency on the pump intensity in the case of idler walkoff only: theoretical results.

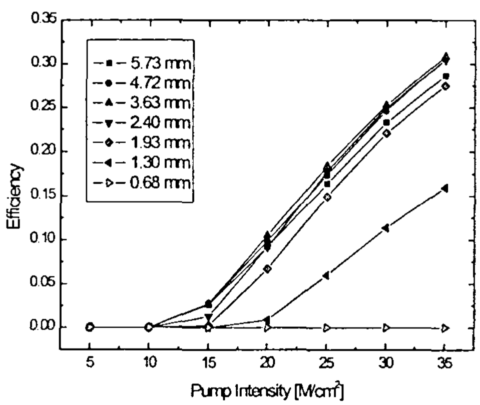

Fig.3 Dependence of conversion efficiency on the pump intensity in the case of pump walkoff only: theoretical results for a $LiNbO_3$ OPO.

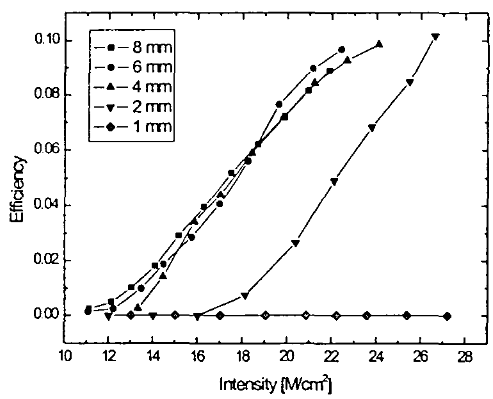

Fig.4 Dependence of conversion efficiency on the pump intensity in the case of pump walkoff only: experimental results for a $LiNbO_3$ OPO.

References

1. Stephen J. Brosnan, Robert L. Byer, IEEE J. Quantum Electron. **QE-15**, 432 (1979).
2. Gordon Robertson, Angus Henderson, and Malcolm Dunn, Opt. Lett. **20**, 1584 (1991).
3. Gordon Robertson, Angus Henderson, and Malcolm Dunn, Appl. Phys. Lett. **60**, 271 (1992).