2009/01/21
論文紹介（鳥井）

1400 OPTICS LETTERS / Vol. 16, No. 18 / September 15, 1991

Frequency doubling with $KNbO_3$ in an external cavity

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Received May 14, 1991

Potassium niobate is employed in an external resonator to generate single-frequency tunable radiation near 430 nm. For excitation with 1.35 W of power from a cw titanium–sapphire laser, 0.65 W of blue light is produced. A simple model has been developed to account for thermal lensing in the nonlinear crystal.

実験装置

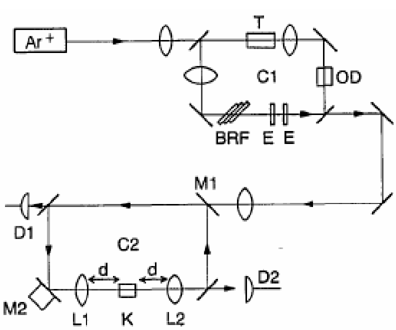


Fig. 1. Diagram of the principal components, with C1 the cavity of the $Ti:Al_2O_3$ laser and C2 the external doubling cavity with the $KNbO_3$ crystal. Elements of C1: BRF, birefringent filter; E's, étalons; OD, optical diode; T, laser crystal. Elements of C2: M1, input coupler; M2, piezoelectric-mounted mirror; L1, L2, lenses; K, $KNbO_3$ crystal. Detector D1 is for $\lambda_1 \simeq 860$ nm, while detector D2 is for $\lambda_2 = 430$ nm.

<Ti;Sapphire laser>
- capable for 2W output
- 50-kHz linewidth

<Doubling cavity>
- 6-mmKNbO3 crystal
- L1, L2: f = 35 mm
- w_0 = 20 μm (f# = 36)
- Z0 =1.4 mm
- Linear Loss: （4.0±0.5）% (calculated from the finesse observed with M1 replaced by a high reflector)

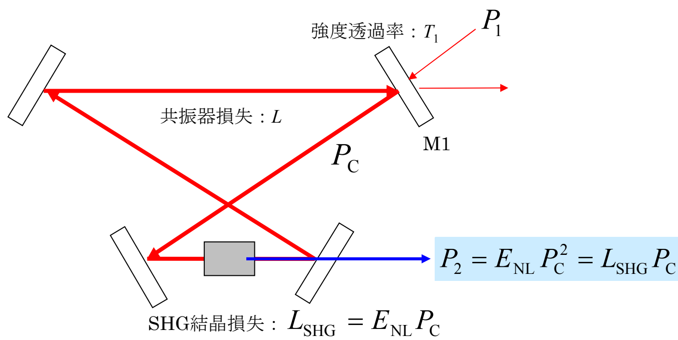
結晶の変換効率

E_{NL}: single-pass nonlinear conversion efficiency

$$P_2 = E_{NL} P_1^2 \ (for\ T_1 = 1)$$

共振器による基本波の
増幅がない場合

E_{NL} = 0.005 W^{-1}(observed with T_1=1)
E_{NL} = 0.016 W^{-1}(optimum focusing outside the cavity)
30% lower than the best reported



最適なインプットカプラー透過率

共振器内パワー

$$P_C == \frac{T_1}{(1-r)^2} P_1 \quad \left(r \equiv \sqrt{(1-T_1)(1-L)(1-L_{SHG})} \right)$$

共振器を1周した際の（実効的）振幅反射率

共振器内パワーが最大のとき（critical coupling）

$$T_1^0 = 1-(1-L)(1-L_{SHG}) \approx L + L_{SHG}$$

$$P_C^0 = \frac{P_1}{T_1^0} = \frac{P_1}{L+L_{SHG}} \qquad L_{SHG} = E_{NL} P_C^0 = \frac{E_{NL} P_1}{L+L_{SHG}}$$

$$T_1^0 = L + L_{SHG} = \frac{L}{2} + \sqrt{L^2/4 + E_{NL} P_1}$$

$$P_2^0 = E_{NL} \left(\frac{P_1}{T_1^0} \right)^2 = \frac{E_{NL} P_1^2}{\left(L/2 + \sqrt{L^2/4 + E_{NL} P_1} \right)^2}$$

SHG変換曲線

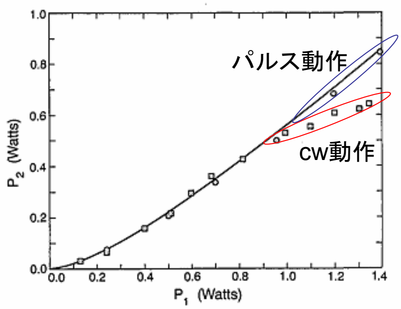


Fig. 2. Second-harmonic output power P_2 at 430 nm versus input fundamental power P_1 at 860 nm. The solid curve is the theoretical prediction based on the independently measured single-pass conversion efficiency and intracavity losses. The experimental points labeled by the squares are for cw operation with the external buildup cavity actively locked to the infrared input. The circles are obtained in a swept mode of operation to avoid thermal effects, with P_2 the peak power. In each case P_2 is referenced to the power level just outside the crystal face. Propagation losses to detector D_2 are (20 ± 5)%.

- P_1を変える毎に最適なT_1^0を選ぶ
- cwモードではP_1=1Wまでは理論と一致
- パルス(sweep)モードではP_1=1.4Wまで理論と一致

＜熱の効果＞
- 結晶における吸収率：0.5%（基本波）、8%（2倍波）
- 共振器内の基本波は10-15W（結晶内で60mW程度吸収）
- P_1=+0.5-1.4Wでは位相整合温度が1－3℃減少（位相整合温度幅は0.5℃）

熱レンズ効果

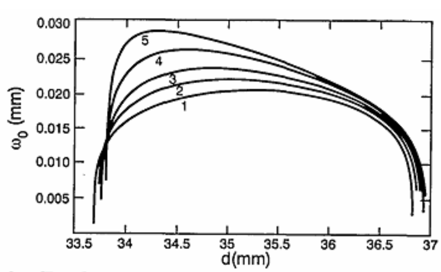


Fig. 3. Fundamental waist size ω_0 versus the spacing d between the lenses and the crystal surfaces to investigate the role of thermal lensing. Curves 1–5 are for increasing values of the axial temperature difference of $\Delta T(0)$ = 0, 0.6, 1.0, 1.4, and 1.6 K, respectively.

$$n(r) = n_0 + \frac{\partial n_b}{\partial T}\Delta T(r) \equiv n_0' + \frac{1}{2}n_2 r^2, \qquad (4)$$

where $n_2 \equiv -2\alpha\partial n_b/\partial T$. Our measured value of the temperature derivative for the b axis of $KNbO_3$ is $\partial n_b/\partial T = -5 \times 10^{-5}$/K. Thus in the approxima-

温度が上がると、屈折率が下がる
→媒質は凹レンズのように振舞う
→ビームウェストが広がる