Optical parametric generator and amplifier

Min Heasik's Ph.D. thesis topic: Construction of sum-frequency generation spectroscopic setup and the second-harmonic phase measurements on quartz crystal and ordered organic samples

Zaure

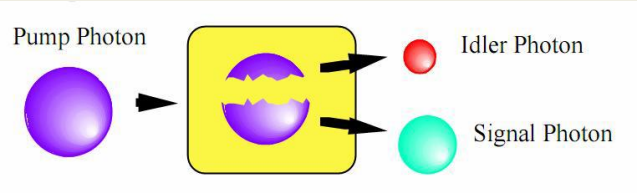
2013.06.01

Optical parametric generator and amplifier

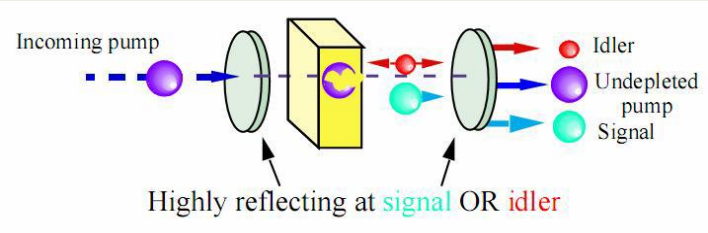
- Introduction
- Phase matching
- Properties of nonlinear optical crystals
- Construction
- Summary

Introduction OPA and OPG

The frequency of the all beams is given as
$\omega_i < \omega_s < \omega_p$



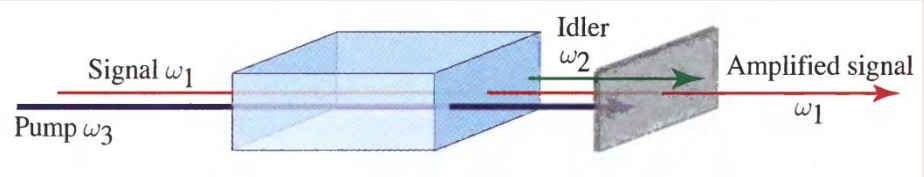
A suitable OPG nonlinear crystal (BBO) enclosed in cavity



The energy conservation is satisfied

$$\hbar\omega_p = \hbar\omega_s + \hbar\omega_i$$
$$\hbar k_p = \hbar k_s + \hbar k_i$$

OPA

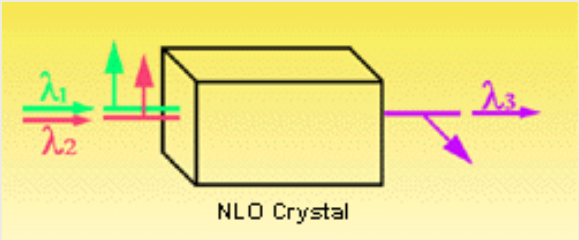


Phase matching

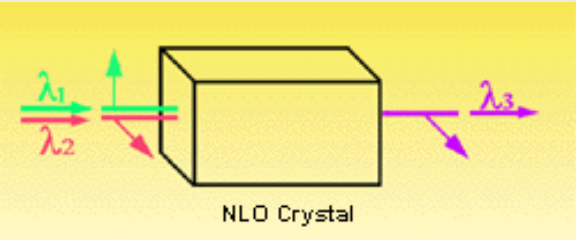
Two types of phase-matching are classified in consideration of polarization of lasers.

If the polarizations of two input beams (for sum frequency) are parallel to each other, it is called type I phase-matching. If the polarizations are perpendicular to each other, it is called type II phase-matching

type I phase-matching



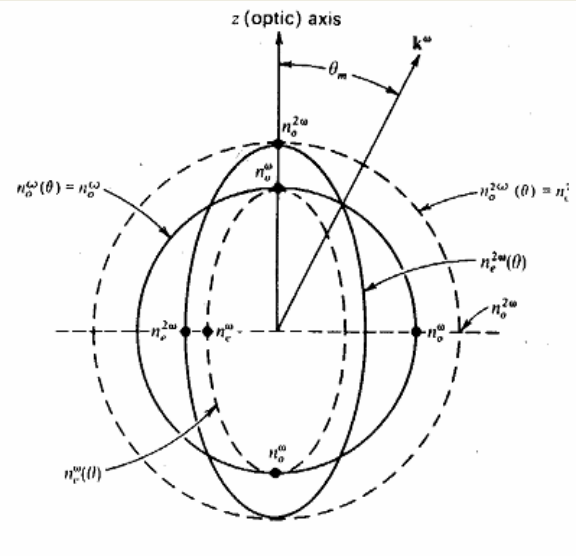
type II phase-matching



Phase matching

Phase-matching condition (Δk=0) is very essential to be fulfilled in order to achieve maximum gain, in term of indexes of refraction, the phase matching is given as

$$n_p = \frac{n_i \omega_i}{\omega_p} + \frac{n_s \omega_s}{\omega_p}$$



Negative uniaxial nonlinear crystal (n_e<n_o) of KDP.

Negative uniaxial crystal which the type I phase-matching

$$n_{ep}(\theta_m)\omega_p = n_{os}\omega_s + n_{oi}\omega_i$$

$$\frac{1}{n_{ep}^2(\theta_m)} = \frac{\sin^2(\theta_m)}{n_{ep}^2} + \frac{\cos^2(\theta_m)}{n_{op}^2}$$

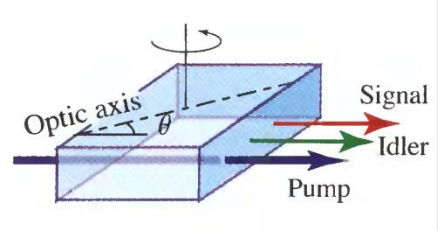
The phase matching angle

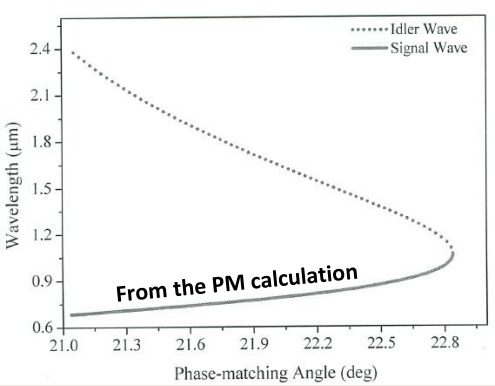
$$\theta_m = \sin^{-1}\left[\frac{n_{ep}}{n_{ep}(\theta_m)}\sqrt{\frac{n_{op}^2 - n_{ep}^2(\theta_m)}{n_{op}^2 - n_{ep}^2}}\right]$$

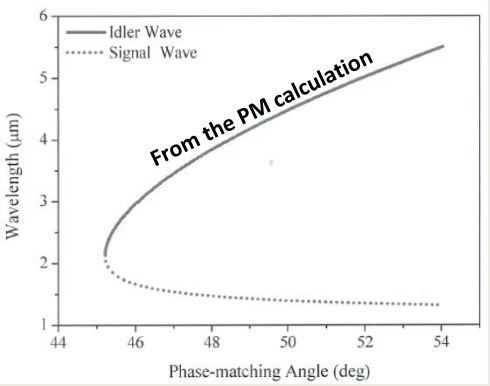
Properties of nonlinear optical crystals

	$LiNbO_3$	BBO
Optical symmetry	negative uniaxial crystal ($n_o > n_e$)	negative uniaxial crystal ($n_o > n_e$)
Reflective index at 1064 nm at 532 nm	 $n_o = 2.23, n_e = 2.14$ $n_o = 2.23, n_e = 2.14$	 $n_o = 1.65, n_e = 1.54$ $n_o = 1.68, n_e = 1.56$

Angle-tuning curve



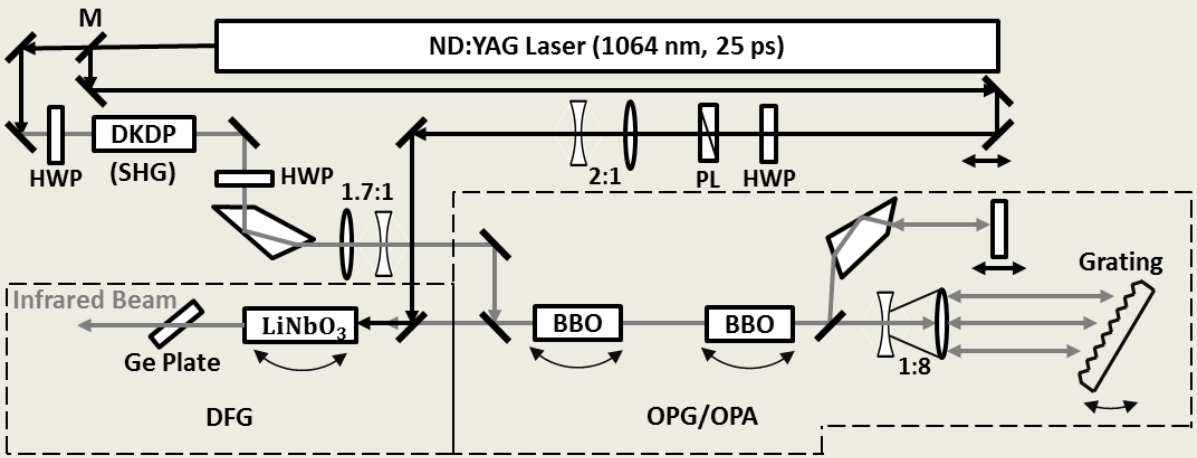




Angle-tuning curve to change the output wavelength in the optical parametric process with type-I PM of the BBO. The pump beam is at 532 nm. From the PM calculation

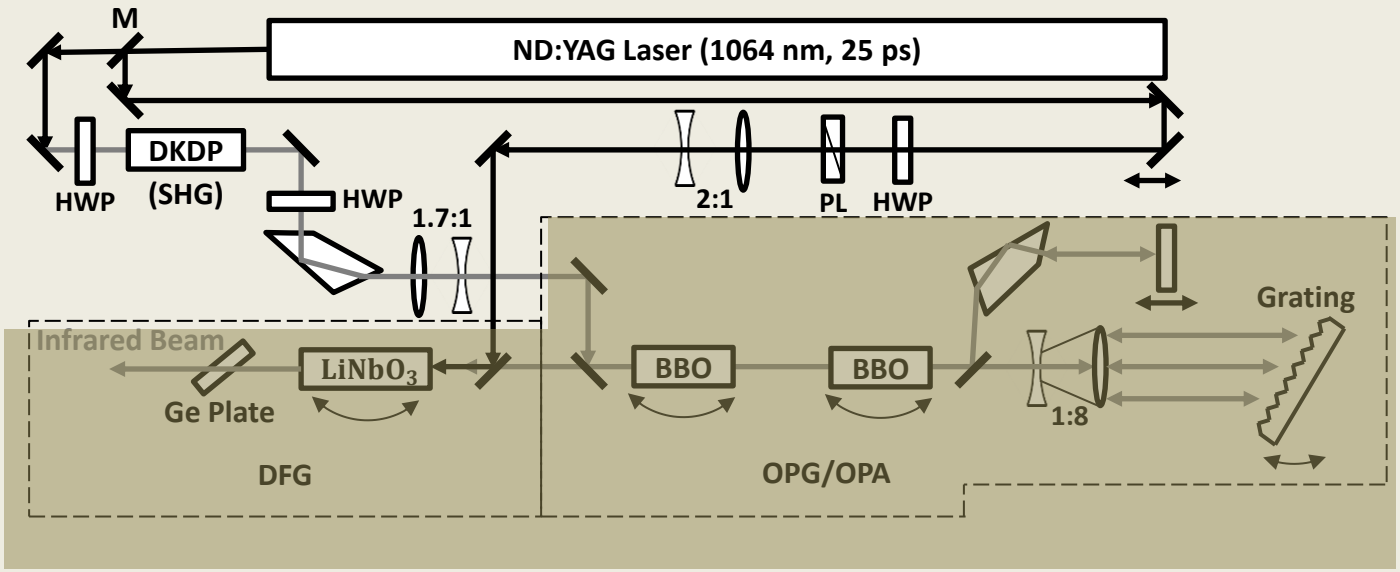
Angle-tuning curve to change the output wavelength in the optical parametric process with type-I PM of the $LiNbO_3$. The pump beam is at 1064 nm. From the PM calculation

Construction

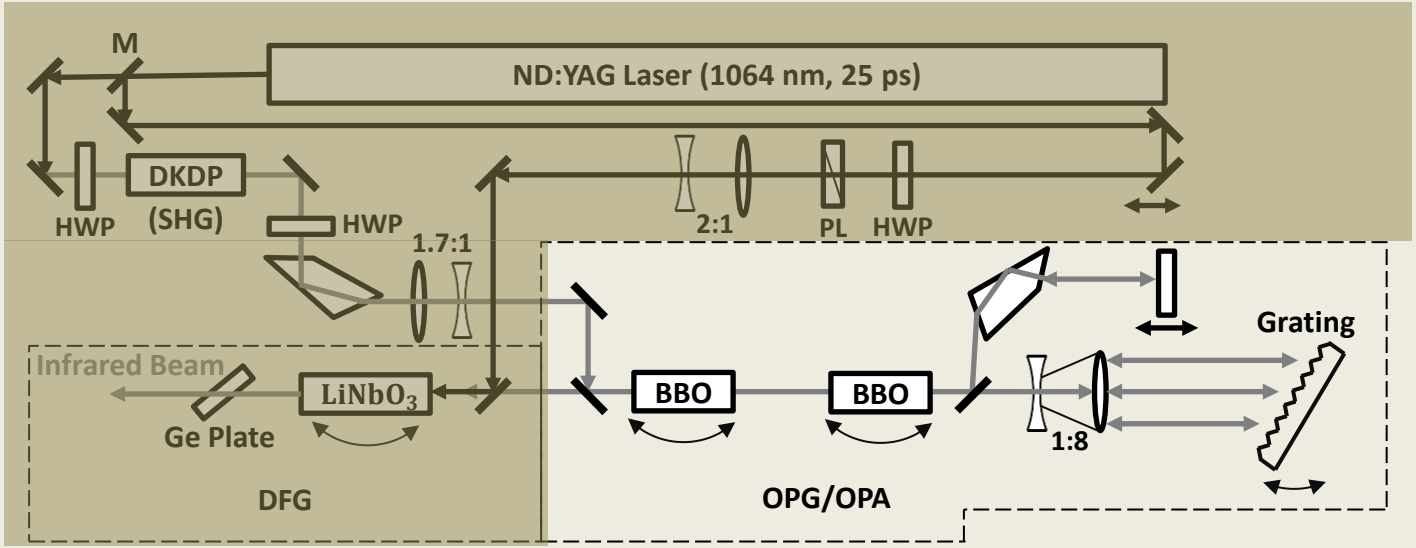


- **DKDP:** θ=53.5°, 12x12x15mm, type-II phase matching
- **BBO:** θ=31.3°, 6x6x8 mm
- **Grating:** 1200 grooves/mm
- **$LiNbO_3$:** θ=47°, 12x10x40mm, type−I phase matching
- **Ge plate:** θ=76° {Brewster angle}

Construction



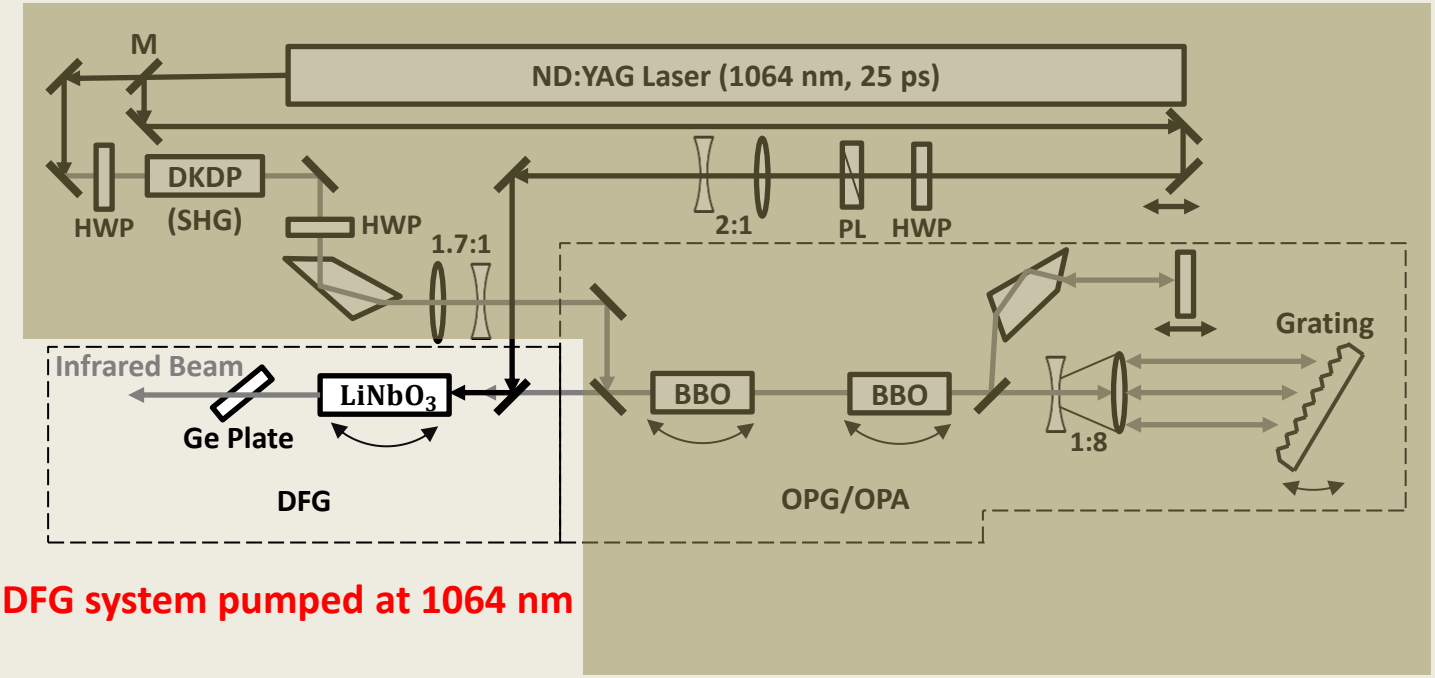
Construction



OPG/OPA system pumped at 532 nm with a grating

The OPG/OPA output beam is tunable near-IR from 0.74 to 1.88 µm

Construction



DFG system pumped at 1064 nm

The spectral bandwidth

- The spectral bandwidth :

$$\boldsymbol{\Delta\lambda = \Delta\beta \times \frac{d \times cos\beta}{m \times M}}$$

β – the average diffraction angle of the dispersed seed beam

$\Delta\beta$ – the angular spread of the seed beam

d – the groove spacing

m – the order of diffraction

M – the magnification of the telescope

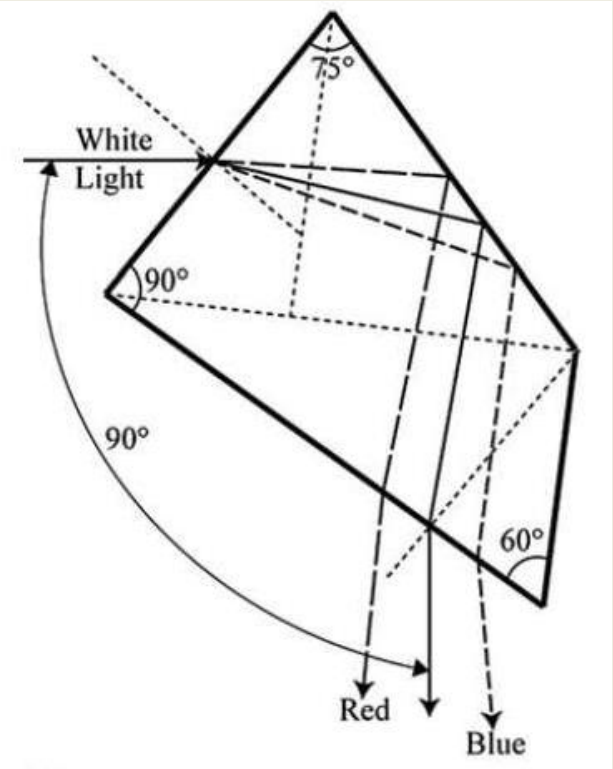
For λ=800nm, β=28.7°

$\Delta\beta = 0.24/85.5 = 2.8$mrad

m=1, M=8 => $\Delta\lambda = 0.26$nm

Pellin–Broca prism

- Pellin–Broca prism - produces a deviation of 90°c as well as an angular spectrum; as outlined in dashed lines, can be thought of as being made up of two 30°–60°–90° prisms and a 45°–90°–45° prism.
- One color is refracted through exactly 90°.
- Rotating the prism selects different colors.
- Ideal for selecting a particular wavelength with minimal change to an optical system.



Summary

1. OPG and OPA
2. Phase matching
3. Nonlinear crystals
4. OPG/OPA setup

The end