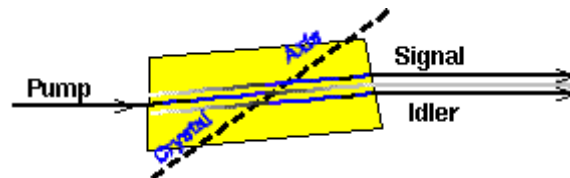


## An Introduction to Optical Parametric Oscillators

Unlike a tunable laser, which employs various energy strategies to deliver relatively broad coverage, an optical parametric oscillator (OPO), in a process similar to harmonic generation, relies on the nonlinear response of a medium to a driving field (the pump laser beam) to convert photons of one wavelength to photons of other, longer wavelengths.

Specifically, in the parametric process, a nonlinear medium (usually a crystal) converts the high energy photon (the pump wave) into two lower energy photons (the signal and idler waves).



*Signal and Idler Beam Generated in a Non-Linear Crystal*

Energy conversion requires that the three photons be related as follows:

$$\frac{1}{\text{pump wavelength}} = \frac{1}{\text{signal wavelength}} + \frac{1}{\text{idler wavelength}}$$

or in terms of photon energy,

$$\text{pump energy} = \text{signal energy} + \text{idler energy}$$

The exact wavelengths of the signal and idler are determined by the angle the pump wave vector makes with respect to the crystal axis. Energy can be transferred efficiently to the parametric waves if all three waves are traveling at the same velocity. Under most circumstances, the variation of index of refraction with crystal angle and wavelength allows this "phase matching" condition to be met only for a single set of wavelengths for a given crystal angle and pump wavelength. Thus as the crystal rotates, different wavelengths of light are produced.

When the crystal is contained in a resonant cavity, feedback causes gain in the parametric waves in a process similar to buildup in a laser cavity. Thus, light output at the resonated wavelength (and the simultaneously produced other parametric wavelength) occurs. The cavity can either be singly resonant at either the signal or idler wavelength, or it can be doubly resonant at both wavelengths.

A simple OPO will exhibit a relatively broad bandwidth (about 15 cm<sup>-1</sup>) determined by the bandwidth acceptance of the nonlinear crystal. Introducing frequency selective elements into the cavity helps reduce bandwidth.

Additional parametric stages may amplify the beam further. These stages may be resonant or nonresonant. An advantage of optical parametric amplifiers (OPA) over ordinary amplifiers is OPA can also provide additional conversion. Seeding an OPA with either the signal or idler wavelength results not only in amplification at that wavelength, but also at the accompanying wavelength. And pumping the OPA with a frequency different from the OPO pump extends the wavelength range of an oscillator. When amplifying low energy pulses from a narrowband oscillator, an OPA produces higher energy while maintaining the fidelity of the oscillator's narrow bandwidth. Varying OPA configurations produce outputs which span the wavelength range of interest.

**For further reading, please see the following:**

Solid State Laser Engineering, 3rd edition, Walter Koechner, ed., Springer Verlag, Berlin, 1992  
Improving High Power

OPO Performance, M. B. Radunsky, Laser Focus World, p.107, October 1995 Spectroscopic  
Applications of Pulsed

Tunable Parametric Oscillators, B. J. Orr et. al., in Tunable Laser Applications, F. J. Duarte, ed.,  
Marcel Dekker, 1995