Nonlinear Optics

Characterization of nonlinear crystals

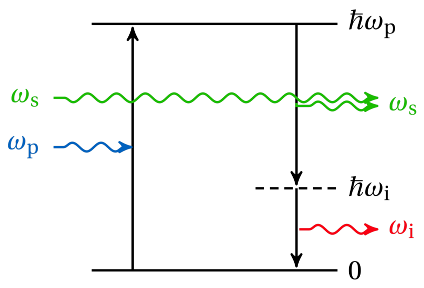

Figure 1: Optical Parametric Amplification

Femtosecond lasers are now usuals tool for basic research in chemistry and physics but also in industry and biomedical applications. These short pulses are interesting because of (i) there extreme peak power ranging from 10^6 to 10^{15} W - in comparison a nuclear plant produces about 10^8 W - which led to ground-breaking breakthroughs in non-linear optics, light-matter interaction and strong field physics, (ii) extremely short pulse duration and hence extreme temporal resolution for time-resolved spectroscopy and more generally for transient phenomena. In order to produce short pulses at a define central wavelength, one technological solution is to use an amplification technique called optical parametric amplification (OPA) (see figure). OPA is a nonlinear process allowing to transfer energy from one frequency to another, via a mechanism that can be understood as photon fission: pump photons (p on Figure 1) are broken in signal photon (s) and idler photons (i). By repeating this process, a signal wave can be amplified as in a laser gain medium but without the constraints of level inversion.

Theory

by Nicolas Forget

In a medium, the dielectric polarization **P** (the right-hand side of the Maxwell propagation equation for the electric field) is defined by:

$$\mathbf{P} = \varepsilon_0[\chi^{(1)}(\mathbf{E}) + \chi^{(2)}(\mathbf{E})^2 + ...] \quad (1)$$

where $\chi^{(n)}$ is the electric susceptibility of the n^{th} order of the medium. If the electric field is intense enough, E^2 starts to be preponderant and we enter the field of nonlinear optics.
Second order nonlinear processes involve the mixing of three electromagnetic waves (see figure 1). In order to optimize the generation or amplification of the desired wavelength, a proper medium with good optical properties has to be selected.
Periodically-poled lithium niobate (PPLN) crystals are engineered nonlinear crystals where the crystallographic orientation of lithium niobate is periodically inverted (poled). Each half-period (equal to what is called the coherence length of the unpoled crystal) produces photons that are dephased by π with respect to the adjacent domains (see figure 2).

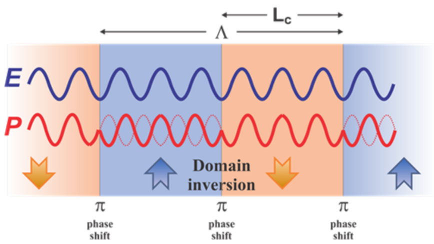

Figure 2: Quasi phase matching in a periodically poled nonlinear crystal. Lc is the coherence length, P is the induced light field, and E the pump field.

By choosing the correct periodicity, the newly generated photons will interfere constructively with previously generated photons, and as a result, the number of generated photons will grow as the light propagates through the PPLN, yielding a high conversion efficiency.

Applications

by Nicolas Thire

PPLN crystals are difficult to manufacture, expensive items and their quality strongly varies spatially and from sample to sample. In order to qualify PPLN crystals and select the best ones, each PPLN crystal must be qualified in situ by measuring, point-by-point, the parametric gain.
During the training the students will build an optical bench to test PPLN crystals. Data analysis will be done via Python scripts to extract the relevant physical data.

See also

Wikipedia: Quasi Phase Matching

www.fastlite.com

Contact

☎ +33 (0)4 8813 1755
✉ nico@fastlite.com